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Mechanical and physical properties of apricot pruning (biomass) for energy purpose in Tajikistan

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Declaration

I hereby declare that I have done this thesis entitled "Mechanical and physical properties of apricot pruning (biomass) for energy purpose in Tajikistan" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 24th of April 2019

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Abdulloeva Surayyo

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Abstract

One of Tajikistan's current problem is the lack of energy access in rural areas during the winter season. The negative environmental impact associated with burning of fossil fuel has launched the expansion of solid biofuels made of different biomass as an alternative to conventional fuels in many countries. The advantages of renewable biofuels are the potential of briquettes and pellets produced from various agricultural waste or combination of raw materials. The objective of Tajikistan is to achieve energy independence. Tajikistan is an agricultural country, which farming provides food and employment to rural communities, the main source of income for a majority of the population, especially in rural areas.

According to the TAJSTAT in 2017 61,617 hectares of apricot has been cultivated, which yearly are accumulated a huge quantity pruning wastes. The pruning of the apricot tree is one of the main agro-technical treatments which provides at least once a year. By the Institute of Horticulture in Tajikistan about 156 trees are growing in one hectare and every year approximately 15–20 kg of branches after pruning each tree are available for utilization as biomass, which is usually improperly wasted. The main focus of the present thesis is evaluating the possibility of using the raw materials from apricot branches for production of briquettes and pellets analyse of its properties, through the laboratory measurements and calculation of the energy yield and potential from this material.

Key words: apricot, briquettes, pellets, agriculture, biomass, Tajikistan, renewable energy

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List of the abbreviations used in the thesis

ADB	Asian Development Bank
ASSR	Autonomous Soviet Socialist Republic
CAPS	Central Asia Power System
CIS	Commonwealth of Independent States
CULS	Czech University of Life Sciences in Prague
CV	Calorific Value
DU	Mechanical Durability
FAO	Food and Agriculture Organisation
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Ktoe	Thousand tonnes of oil equivalent
MC	Moisture content
NCV	Net Calorific Value
RES	Renewable Energy Sources
TAJSTAT	The Statistical Agency under the President of the Republic of Tajikistan
TJS	Tajik somoni, Tajikistan National Currency
TJ	Terajoule
UN	United Nation
UNDP	United Nation Development Program
UNECE	United Nations Economic Commission for Europe
USSR	The Union of Soviet Socialist Republics
SSR	Soviet Socialist Republic
%	Percent

cm	Centimetre
g	Gramm
h	Hour
kg	Kilogram
mm	Millimetre
t	Ton
j	Joule
MJ	Megajoule
C	Carbon
N	Nitrogen
H	Hydrogen
Atm	Atmosphere

1. Introduction

The most important issues in Central Asia is energy, particularly in Tajikistan. It is one of the poorest countries in Central Asia. Tajikistan became independent in 1991, the breakup of the Soviet Union, and there was a civil war between political, regional, and religious factions, that last from 1992 to 1997 and influenced to its developments (UNDP 2019). In winter electricity is available just for up to 3 hours daily for rural population. In the meantime, the people living in rural areas is accounting 70% and consumes just 9% out of total energy use (UNDP Sustainable Energy For All 2013). Therefore, during winter time in regions and villages face power outages. Another researcher refers that the average of electricity available in rural areas of Northern part of Tajikistan is 4 hours every day, and it is lasting for 5 months of winter. And each rural/farming family consist of 7 household members. During winter time such kind of families using approximately 4 tons of coal to heat their house, which is really expensive to afford it (Energypedia 2019). Fossil fuels are expensive, and it is difficult to transport them to rural areas.

Tajikistan is highly agrarian country. Agriculture has big influences in work labor, more than 53% population works in agriculture sectors. Also, agriculture has potential role in the economy of the country (FAO 2018). Many types of fruits and nut trees can grow in Tajikistan. In a period when there was a Soviet Union in Tajikistan was created a big plantation of apricot. Because of these plantations and development independent Tajikistan grows big amount of dried fruits, especially apricot (Microfinance centre 2011). Tajikistan mainly exports apricots to Russia, which is counting 80% of Tajikistan's dried apricots (Mirsaidov 2018). The main problem in agriculture is the yearly accumulation of wastes obtained from the cultivation of crops, trees, and processing of agricultural products.

The solution to energy deficit and waste utilization is the application of pruning wastes that represents wood biomass, from apricot trees for energy purposes.

Biomass has main important role in rural area especially in energy sector. Besides that, it can give to economy the possibility to create new job places and source of income to the rural population. It also helps to the environment thanks to lower the CO_2 emission and deforestation (Alam et al. 2011). Also, biomass consist lower Sulphur and ashes than coal, thus produce less emissions of SO_x and particles (Bilandzija et al. 2012). Some reports show that Tajikistan has possibilities to produce 2 billion kWh/year of electricity from biomass sources. Nowadays, approximately three quarters of population use biomass in cooking and heating in their houses (REEEP 2012). Biomass pruned from fruit trees can be permanent harvested, being a completely renewable resource of energy (Ivanova et al. 2018). Besides, we are able to convert tree residues into briquettes (Ajit 2017) and pellets by a utilization method (Miranda et al. 2015). Biomass briquettes and pellets are easy to transport and store.

Based on the fact that apricot pruning wastes are one of the most accessible types of biomass in Tajikistan it is necessary to provide deeper research of the possibility of using them for biofuel production especially in the form of pellets and briquettes. These types of solid biofuel can be an accessible alternative for Tajikistan in comparison with fossil fuels.

2. Literature review

2.1. Country review

Tajikistan is a country with an amazing landscape and with the highest mountains in the world (Asian Development Bank 2014). Tajikistan, officially name of the country Republic of Tajikistan, is a mountainous, landlocked country which is situated just in the middle of Central Asia with an elevation varying from 330 to 7,495 m. above the sea level (Muminjonov 2008). The country is surrounded by land on all sides. The country area is 143,100 km^2 and an estimated population of 9.1 million people as of 2018. It is presidential republic, which means that the president acts as both the head of the state and the head of government ("Tajikistan country profile - BBC News" 2018).

It is bordering with Afghanistan from the south, with Uzbekistan from the west, with Kyrgyzstan from the north, and with China from the east (see below in Figure 1). The capital of the country is Dushanbe and it is one of the largest cities in Tajikistan. The four-fifths of the population is ethically Tajik and the rest of them are Uzbeks, Kyrgyzs, Russians and others. The state system of Tajikistan is determined by the Constitution, which is adopted on November 6, 1994 (Encyclopedia Britannica 2019).

Tajikistan has strongly continental climate and changes according to elevation. During summer time in the north-south parts of the country can get hot and dry, the temperature is about 35°C to 38°C and winter is cold as well, the temperature can reach about -5°C to -10°C. In the mountain areas get more colder (The Agency for Hydrometeorology Committee of environmental protection under the Government of the Republic of Tajikistan 2019). There are many rivers in Tajikistan, and they are the main source of replenishment of the Aral Sea, which is also helping for other neighborhood countries for the cotton growing and hydropower. The largest rivers of Tajikistan are: Panj, Vakhsh, Syr Darya, Zeravshan, Kafirnigan, Bartang. In general, there are 947 rivers stretching over 10 km. the Total length of the rivers are 28,500 km (UN 2002).

People on the territory of modern Tajikistan, according to archaeologists, lived in the stone age. In ancient times the central, southern and eastern parts of modern Tajikistan were part of the slave-owning state of Bactria, and the northern areas of the Hissar range belonged to the slave-owning state of Sogd. Later Alexander the great and his Greeks conquered these lands, then they became part of the Seleucid state. And this is only a small part of the States, which included modern Tajikistan. After all, Tajikistan still conquered the Kushan Kingdom, the Turkic Khaganate, the state of the Karakhanids, the Tatar-Mongolian Empire, the state of the Sheibanids. In 1868 Tajikistan was joined to the Russian Empire. After revolution of 1917 in Russia, in the territory of Tajikistan, the Tajik ASSR as a part of the Uzbek SSR was formed. In 1929, the Tajik ASSR was transformed into one of the republics of the Soviet Union. Only in 1991 Tajikistan declared its independence (Tajik Development Gateway 2019a).

Figure 1. Map of the Republic of Tajikistan

Source: (Encyclopedia Britannica 2019)

Once Tajikistan became independent, it led to civil war between political, regional, and religious factions, which last for 7 years. During civil war more than 50,000 people were dead and around 1,2 million people were moved and it brought to economic collapse, food and fuel shortages. After signing by president of Tajikistan Emomali Rahmon the agreement about peace in 1997, the economy of the country has increased (USAID 2010).

2.1.1. Economy of the country

Tajikistan is still very poor country, one of the poorest countries in Central Asia (World Bank 2013). In 2015, 31.3% of population of Tajikistan lives below the national poverty line (Asian Development Bank 2018).

Unemployment was one of the important issues in Tajikistan in Soviet period. Since then, the situation has certainly stabilized at a more acceptable level, even though the absolute number of unemployed and the unemployment rate have increased over the past decade. According to UNDP report, only 55 thousand were registered people as unemployed in 2013, which means that the unemployment rate was only 2.3%. Most of unemployed people is young people, it is 16.7%. And also in district area where there are many unemployed people, it is 16.8%. Almost every third young people were unemployed in 2009 (UNDP 2015). For the reason that there is a huge problem with unemployment in the country, most of the people migrate to other countries. In the second half of twentieth century another worldwide problem was migration of labor force from one country to another. Tajikistan like all other former Soviet countries faced a huge labor migration flows after the breakup of the Union of Soviet Socialist Republics (USSR) in 1991. Mostly labor migration grew in 1994 to 1995 because of civil war (Saodat & Igor 2003). According to another researcher that the population of Tajikistan lost their job after the collapse of USSR and for the reason of earnings they start to travel abroad, and this became one of the essential parts of their lives (Kurbonov 2011).

And the money transferring from migration play a central role in Tajikistan's economic life. Tajikistan is one of the most remittance-dependent country in the world where the income from money transfer was $3,8 billion in 2014, accounting for 41.7% of the country's gross domestic product (GDP) (Zotova & Cohen 2016).

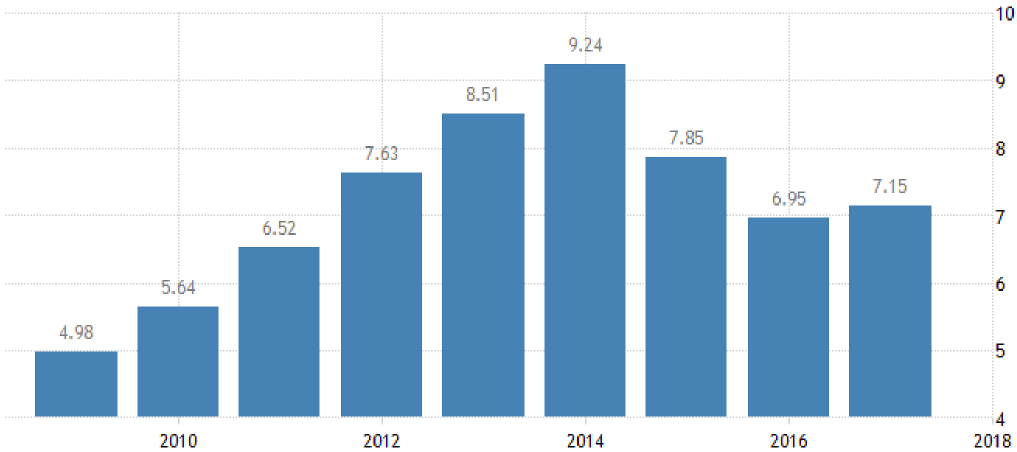


Figure 2. GDP of Republic of Tajikistan

Source: (Trading Economics 2018)

In the following table is presented most microeconomics sector of Republic Tajikistan

Table 1. Macroeconomic Indicators of the Republic of Tajikistan

	2009	2010	2011	2012	2013	2014	2015	2016
GDP in nominal price, billion TJS	20,6	24,7	30,1	36,2	40,5	45,6	48,4	54,5
Growth rate %	103.9	106.5	107.4	107.5	107.4	106.7	106.0	106.9
Industrial output, billion TJS	6,5	8,2	7,9	9,5	9,9	10,5	12,2	15,1
Growth rate (%)	93.6	109.2	105.7	110.8	103.8	105.0	111.3	116.0
Agricultural output, billion TJS	8,8	9,4	14,9	16,5	16,8	21,0	21,6	22,2

Growth rate (%)	110.5	106.8	107.9	110.4	107.6	104.5	103.2	105.2
Fixed Capital Investment, billion TJS	3,9	4,7	5,0	4,5	5,8	7,5	9,7	11,1
Inflation Rate, periodic, %	5.0	9.8	9.3	6.4	3.7	7.4	5.1	6.1
Unemployment rate, %	2.2	2.1	2.3	2.4	2.3	2.4	2.3	2.4
Public Budget Expenditures, billion TJS	5,7	6,7	8,5	9,1	11,6	13,2	15,7	18,4

Source: (Press service of President of Republic of Tajikistan 2016)

According to the data published on the official website of TAJSTAT, the main sectors of the economic in the country are as follows. One of the most significant sectors of Tajikistan's economy is agriculture, which accounted for more than a quarter of GDP in 2015. Next (in descending order of contribution to GDP) are: industry, trade, transport, communications, services, construction and other sources (Legislation of Tajikistan 2019).

Table 2. Tajikistan’s GDP Growth, %

Sectors	2015	2016	2017	9 month of 2018
Real GDP growth	6	6.9	7.1	7
Agriculture	0.9	1.3	1.6	0.8
Construction	2.5	2.7	0.5	1.7
Industry	1.6	2.3	3.6	2.6
Services	1.1	0.5	1.4	1.8

Source: (World Bank 2018)

Tajikistan is very much dependent on agriculture, and this sector accounts for about 21% of its GDP and about half of its labor force. Nevertheless, arable land in the country is limited and most of it is used for production of cotton, which increases dependence on food imports (about 60%). About a third of the country's population is food insecure and 70% rely on agriculture, both directly and indirectly. Tajikistan is especially vulnerable to the unfavorable effects of climate change and has a very low capacity for adaptation. Agricultural production is particularly vulnerable to changing weather conditions, natural disasters and water scarcity (Asian Development Bank 2016).

The industry of Tajikistan exists of more than 90 industries and types of production. Many companies are private or joint-stock forms of ownership and were established with foreign capital. Tajikistan are rich in raw materials for the metallurgical, chemical, construction and other industries. Most of metallurgical, mining, chemical, machine-building, textile enterprises with high export potential in short time can meet the growing interest of consumers in high quality raw materials and products both inside and outside of the country. The products of mining companies are mostly intended for export and have a stable demand in the world market (Tajik Development Gateway 2019b).

Another sector which is also important to the country is light industry. Light industry of Tajikistan is a large national economic sector of the country, providing, together with the production of consumer goods, the production of industrial and technical products for other industries on the basis of processing of local raw materials and the provision of household services to the population. It consists of main industries: textile, silk and clothing. In addition, the light industry includes wool, carpet, knitted, leather and footwear and furniture industries. The share of light industry in the total production of commercial products in 2010 was 13.7% (Tajik Development Gateway 2019c).

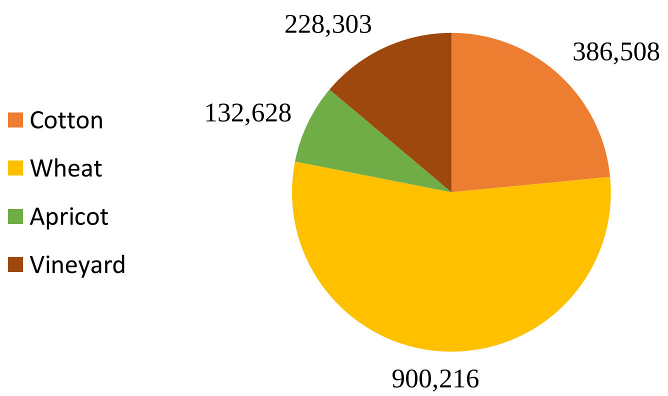
2.1.2. Agriculture of Tajikistan

Nowadays, in terms of developing the agricultural complex, the world continues to actively differentiate countries. Nearly every developed country in the world use advanced equipment and technology, but it is not always available for the countries in transition, especially to the Tajikistan, due to economic, scientific and technical backwardness. The importance of agriculture is demonstrated by the fact that this sector is one of the main sources of citizens ' income and employment in Tajikistan's economy. Thanks to agriculture people could stay the political and economic crisis that engulfed Tajikistan's economy in 1992 – 1997 (Kurbonov & Pulatova 2011).

Tajikistan is one of Central Asia's least urbanized countries. With 73% living in rural areas of the country involved in agricultural activities, the population is unevenly distributed (FAO 2018). Today, in contrast to the Soviet era, where collective managements (collective farms) were developed, the country's agricultural complex consists mainly of dehkan farms (small family farms). In 2009, there were 32,631 dehkan farms registered (Kurbonov & Pulatova 2011). The president of Tajikistan in his annual speech paid a great attention on agro - industrial complex which serves as a determining link in the Republic's real economy (Ministry of Finance of the Republic of Tajikistan 2009).

Agriculture, with 19% of GDP and almost one third of exportations, is one of the major economic sectors of the Republic of Tajikistan. Mountains cover a large part of Tajikistan, and only 7% of Tajikistan is occupied by irrigation and arable land. Furthermore, the favorable climate helps to produce a number of crops, fruit and vegetable species. The production of livestock is only a tiny part of the farm production. In the last decade there have been changes in the structure of production of different crop types: cotton and fruit have decreased in physical output since 2000 and grain, vegetables and food maize have been increasing. In the last ten years the livestock structure has remained almost unchanged, with the number of horses and sheep slightly decreasing and the proportion of goats increasing.

Major cultivated crops in Tajikistan is presented in graph 1.



Graph 1. The average quantity of the main agricultural products obtained yearly in Tajikistan, tons

Source: (TAJSTAT 2017)

The cotton is the main farming product. Its production in 2012 accounted for approximately 20% of the Republic's agriculture. Cotton has recently shown a significant dynamic in the harvest, reaching 560,000 tons in 2004 and dropping to 300,000 tons in 2009 - 2010, caused by a considerable decrease in the area used to cultivate. Farms are the main source of cotton production. In 2012, cotton was the second most important export product after aluminum and accounted for 12% of the Republic of Tajikistan exports. During 2006 - 09, exports of cotton and their share of the Republic of Tajikistan's total exports decreased almost equally in 2010. A large proportion of cotton exports makes Tajikistan dependent on world cotton prices, which, especially in recent years, are not very stable. Generally speaking, cotton is gradually becoming less important in Tajikistan's economy. The food industry of the Republic of Tajikistan is primarily represented by companies producing meat and dairy products as well as canned food. Other industries include bread - baking, flour - milling, wine - making and brewing. Domestic consumption is a significant part of production. Russia and Kazakhstan are the main directions for exporting food products (Webeconomy 2019).

Bread is one of the most important food products of the population in Tajikistan like in other Asian countries, and wheat cultivation is considered to be one of Tajik main agricultural areas. However, the current historical circumstances and socio - political changes have greatly affected the production of wheat and cereal in general. When the country became independent, was designed to achieve food safety in general, and especially grain independence. At the same time, the main focus is on wheat cultivation, as it supplies about 60% of the country's food requirements. Tajikistan's total demand for grain is between 1,5 million and 2 million tons. To increase grain production a program was developed and adopted, and according to this program, grain production in Tajikistan by 2010 was to reach 1 million tons. Nevertheless, there is still a deficit of grain. (Sultanova 2012). Horticulture and wine growing are another agricultural sector of the Republic of Tajikistan that is able to supply food to the domestic market, enhance the Republic's export potential and provide permanent employment for the public (The government of the Republic of Tajikistan 2015). Even there was a Government's projects on the development of the country's horticulture and viticulture, in particular the creation of 46,901 hectares of new orchards and vineyards for the 2010 - 2014 period, provide for 16,000 hectares of apricot gardens, which once again confirms the importance of this culture in Tajikistan's economy (Kamolov 2012).

Tajikistan is a favorable gardening region, and in early 2016 about 180,000 hectares of land was occupied under that direction, representing over 25% of the country's total area of arable land. Horticulture in Tajikistan is mainly targeted to the cultivation of apples, pears, apricots, plums, peaches, persimmons and other fruits that are most frequently concentrated in Sogd, Khatlon regions and the district of Republican subordination. Tajikistan cultivates more than 1 million tons of fruit annually, of which approximately 10 to 20% are exported. The country is known in many countries of the world including Russia, Kazakhstan, China, Afghanistan, Pakistan and other for its branded fruit, such as apricots, grapes, pears, persimmons, lemons, plums, cherries, and Greek nuts (Ansor 2019).

2.1.2.1. Apricot cultivation in Tajikistan

Apricot (*Prunus Armeniaca*), stone fruit of the Rosacea family, closely linked to peaches, almond and cherries. Apricots are grown in temperate parts of the world, particularly in the Mediterranean. Apricots are a good source of vitamin A. Dried apricots provide an excellent source of iron (Encyclopedia Britannica 2018). The importance of apricot fruits with therapeutic and dietary properties has been given special attention by Avicenna in the eleventh century in his work "Canon of medical science" along with other fruits. The nutritional value of apricot fruits is based on the high sugar content, which is more than 26% fresh in certain varieties, and more than 65% in dried products. The fruits of the apricots contribute to the recovery of blood hemoglobin (Boymatov 2009). The apricot flowers and fruits that are important for the reproduction of plants, also provide greater values for the ecosystem and for humans. Flowers and fruits provide a source of food for fruit-consuming pollinating insects and animals. The apricot is considered to be Chinese and has been grown in China for over 4,000 years and spread across Europe and Caucasus (New Word Encyclopedia 2008).

As I mentioned above that horticulture is another important sector of Tajikistan's agriculture and a widespread fruit cultivation is apricot. According to the (FAO 2016)

Tajikistan was between the top 25 apricot producing countries in the world and 11,788 ha of apricot has been cultivated. However, (TAJSTAT 2017) reported in total 61,617 ha including small-scale orchards. There is little data on horticultural history in Northern Tajikistan, although the apricots culture here is very ancient, leaving in the prehistoric era for many years. The literary and archeological excavations that were founded on the territory of Modern Tajikistan show that in the III and V centuries before century, the peoples of the States of Bactria and Sogdiana, with great success engaged in the cultivation of apricots, until 1930 for the people the main source of sugar was apricots (Boymatov 2009).

Figure 3. Picture of apricot

Source: (Britannica Kids 2019)

The apricot is growing almost in all places of the country from 330 meters to 3,000 meters above sea level. Tajikistan's main apricot orchards are mostly located in the area of the Sughd, Zeravshan, Hissar and mountainous areas. In these regions of the Republic with favorable natural condition, it is possible to produce a very high yield even with the most conventional methods of care for plantations. In some cases, the apricots are producing 10 - 12 tons per 1 hectare under these conditions. The country currently provides very different apricot ranges, the suitability of the species is based on the following indicators for high - quality drying and commercial sales: chemical and mechanical ingredients of fresh fruit, the proportion of the dried product output, the duration of the drying in days, the assessment in appearance and taste of the finished product (Toshmatov 1996). Dried fruit exports to the Russian Federation are one of the main exports of agricultural produce from Tajikistan. We can see the volume of exports is increasing annually. The other dried fruits like apples, pears, plums and peaches also exported but still most of the exported dried fruits accounting was apricots (Microfinance centre 2011).

Table 3. Export of dry fruits from Tajikistan in 2003-2010, in tons

	2003	2004	2005	2006	2007	2008	2009	2010
Total dry fruits	500,70	42,661	44,339	52,310	57,825	69,488	78,492	76,316
Belorussia	282	382	561	767	1,175	1,618	1,539	1,596
Georgia							3	
Turkmenistan							63	36
Kazakhstan	36	19	62	163	204	231	471	6770
Russia	49,485	42,066	43,489	51,067	55,878	66,381	73,943	63,101
Ukraine	195	150	227	292	466	1,115	1,335	845
Uzbekistan							30	
Afghanistan	18			21		120		28
Iraq					46		810	
Iran		44			43	20	269	332
USA					13		11	11
China								17
Syria								12
Japan								3

Pakistan	18	43

Source: (Microfinance centre 2011)

Apricot cultivation and dried apricots production in Sughd region are now nearly a national idea. The majority of the rural population of the region works in this sector. The farmers of this region have been working in cotton fields for many years, often suffering loss, because growing this crop requires large investments and labor costs, and to establish its export is difficult. Then market brought a new trend. It is far easier to grow and sell apricot than cotton under modern conditions, and the Sogdians started turning their cotton fields into apricot garden. The local authorities supported this trend and now appreciate their farmer and try to encourage their citizens. For example, they assigned 630 hectares of land to a huge orchard a few years ago in the suburbs of Khujand city. Today it employs people from dehkan farms and private entrepreneurs who are engaged in the cultivation and processing of fruit. A total of 18 towns and districts of the Sughd region are involved here in gardening. The Deputy Director of the gardens "Wahdat" Abdukahor Vohidov explained that from 630 hectares 350 occupy apricot trees. Our farmers produce dried fruit apricots, canned apricot and even making wine from this fruit (Open Asia online 2016).

Apricot is part of the category of trees which cannot efficient regulate the formation of fruit, and therefore, the branches below the crop break and the crown is deformed. To avoid this, the timely pruning throughout the season should be carried out periodically, helping not only to maintain the integrity of the apricot, but also to improve the fruit's quality (Official Gardening Website 2017).

Pruning can begin in late winter and early spring before bud break. In the winter, when it is below zero, it is better not to cut it. Pruning does not damage the tree after bud or flowering period but should be done accurately. Late pruning slows down the growth of shoots. Trees are pruned in two ways: thinning and shortening of the branches. Thinning is the removal of the branches which greatly densifies the crown to the soil. This improves the fruiting period. Shortening means removing a certain part of the branches annually. The degree of pruning is based on the species, tree growth strength, garden plantation density, crown shape and other factors (Boymatov 2009).

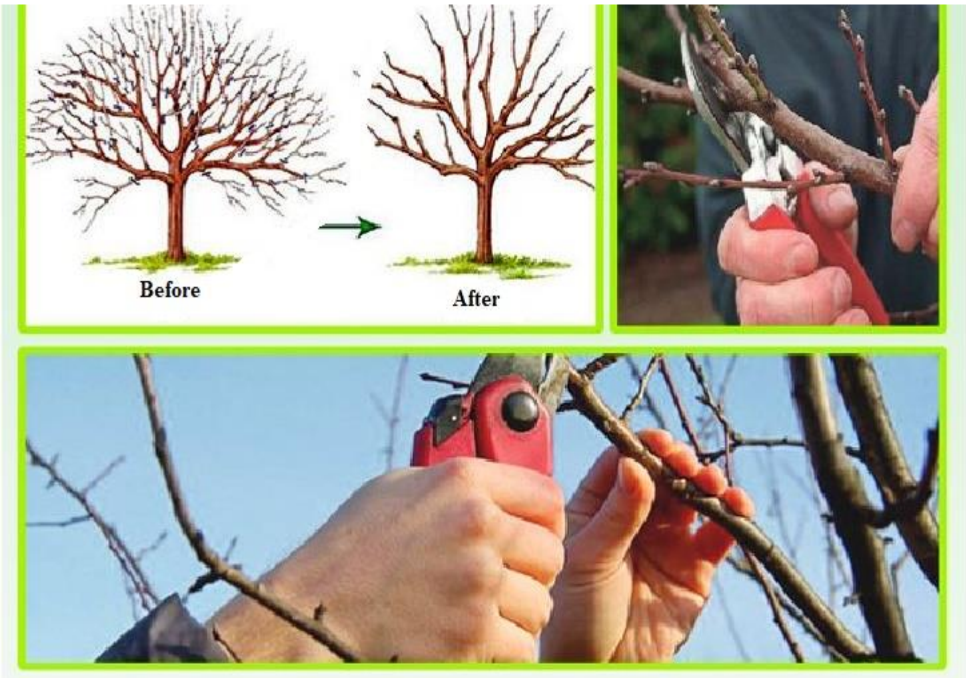


Figure 4. Tree pruning

Source: (Official Gardening Website 2018)

After these operations in the gardens are formed agricultural waste, which is suitable for further use as a biomass. Their minimal environmental impact in the combustion period is a positive aspect of using wood briquettes as fuel compared to conventional solid fuel with the same calorific quality, as for example coal but with the ash content being 15 times lower. Fruit wood briquettes have a high heat value, are ecologically safe and have a pleasant smell when burned. It is therefore recommended that a technology for fruit wood biomass production to be developed and proposed, considering of all these benefits (Syasin 2017).

2.1.3. Energy situation in the Republic of Tajikistan

During last decades, the energy sector of Tajikistan has been suffered by remarkable changes. The regional energy cooperation has been stopped and gas supplies have been cut off due to the collapse of the Soviet Union. And to invest required amounts in maintaining the national energy infrastructure the country has been incapable (World Bank 2014). All five countries in Central Asia in Soviet period was part of the Central Asia Power System (CAPS). This system was constructed to meet the requirement of the region. It had capable generation and transmission ability. In the period of CAPS, 60% of electricity demands of Tajikistan partially covered by imports from other Soviet Republics. Unfortunately, after the breakdown of USSR, the operation and maintenance of CAPS gradually deteriorated and every participating country became independent and in the terms of production and fuel supply (Energy Charter Secretariat 2013).

The primary natural energy resources in Tajikistan are water and the sun, but as the result of deficiency of new technologies, the solar energy is not well developed in the country. Compare Tajikistan with other former Soviet countries except Russian Federation, Tajikistan has the highest potential for hydropower generation (Energy Charter Secretariat 2010). And also due to the lack of technology solid fossil fuel and due to the limitation of imports natural gas is not used in the energy system of the country for electric energy generation (Olimbekov 2013). The country does not have much crude oil. In the mountain valleys of Northern part of the Republic were found six coal deposits with confirmed reserves of 110 million tons. One more is known Shurab Deposit of brown coal with reserves of 69 million tons were identified in the North part of the country. Also, in the North part of the country are concentrated oil and natural gas reserves. The largest deposits of Ferghana oil and gas region are Ayritan, Kanibadam, Ravat, Kim and others the most significant gas field is Niyazbek – North Karakchikum. The confirmed oil reserves are estimated at 1,6 million tons, gas-5,7 billion m3 (Amburcev et al. 2010).

The proportion of energy costs in total GDP is 60%. Meanwhile, due to the lack of its own sources, Tajikistan covers about 70% of its needs for fuel resources through expensive imports (UNDP Sustainable Energy For All 2013).

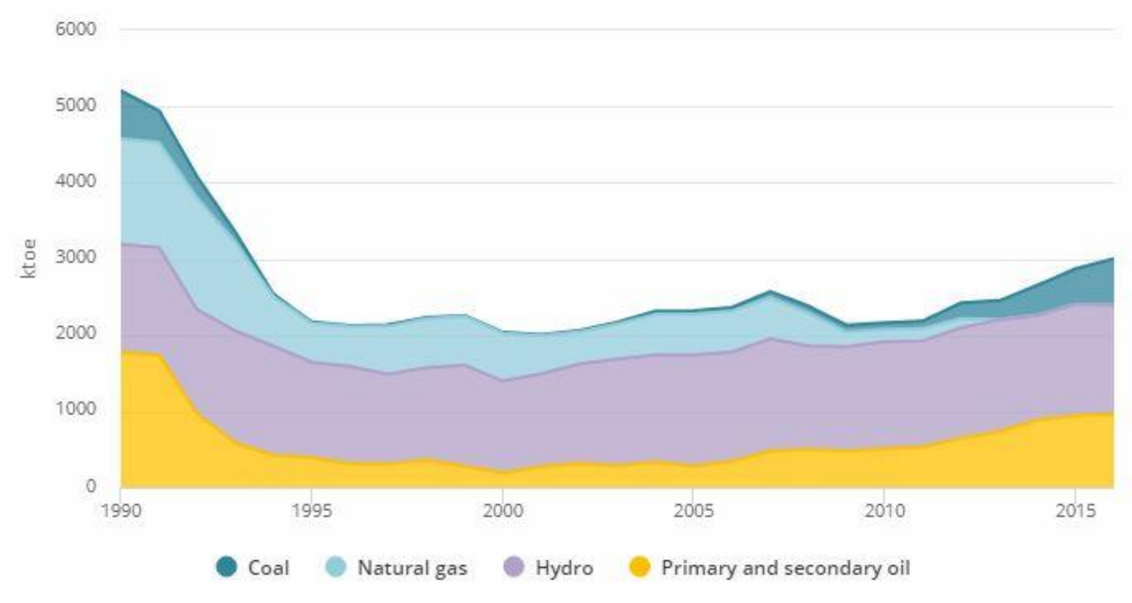


Figure 5. Total primary energy supply of Tajikistan

Source: (International Energy Agency 2018)

In the winter time as the result of restriction of access to other types of energy, the demand for electricity increases strongly. Almost every household using electricity for food preparation and heating purposes. Since the generation of electricity at hydropower plant is seasonal and in this period the power system is not capable to meet the growing demand of the population for electricity. Due to this problem, in the country there is a shortage of power from October to March every year. For example, in 2009-2010 the electricity was limited from 7 to 12 hours a day. In some regions even more. In was almost in everywhere of the country except the capital of the country Dushanbe, the city of Sohgd and the aluminum plant in Tursunzoda city (Halimjanova 2017).

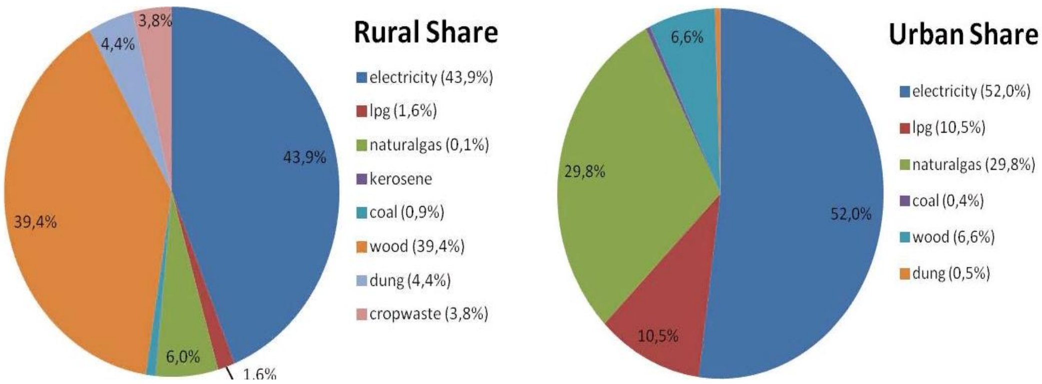


Figure 6. Share of energy types in urban and rural areas of Tajikistan

Source: (Energypedia 2019)

Stable energy supply is necessary for food security and economic development of the country. In rural areas every year because of this limitation of electricity in the country, the loss of agricultural productivity is about 30% and about 850 medium and small enterprises had to stop their production (UNDP Sustainable Energy For All 2013). Tajikistan has great renewable energy resources. According to this estimation, the potential of renewable energy resources such as waterpower, solar radiation, biomass energy, wind energy, and geothermal energy amounts to 527 billion kWh/year, 25 billion kWh/year (calculated values), 2 billion kWh/year, 25–150 billion kWh/year (calculated values), and 45 billion kWh/year (calculated values), respectively. Although if we use them partly will have a positive effect on the energy balance of Tajikistan and improve the ecological situation in the country and in the region (Kabutov 2007).

As I mentioned earlier that Tajikistan is agricultural country and it has a good number of solid biomass such as wood, sawdust, household waste, agricultural waste, charcoal, dry manure, grass hay and cotton stalks. The country even introduced the National Development Program in 2016 for the period up to 2030. One of the first aims is energy security and efficient use of electricity and to increase energy production from Renewable Energy Sources (RES) up to 20% against the baseline (Zuhurov et al. 2016). The share of RES in 2012, within the total energy production in Tajikistan was about 0.01% (Olimbekov 2013). For this reason, the use of biofuel and biomass in agricultural areas for obtaining thermal and electrical energy is considered not only economically effective, but also necessary. As reported by expert analysis, the use of biofuels and biomass has the main role in the household for 75% of the population. If we start to use biomass residues and bioenergy plants at the large livestock farms and poultry farms, it would be not only additional energy but also will contribute to the improvement the living standard of the population and will be a good solution for waste management (Shvedov et al. 2018).

2.2. Renewable Energy Sources

2.2.1. General information and position of RES in the World

Renewable Energy sources are such kind of sources that are collected yearly due to their ability to replenish themselves naturally. There are many types of renewable sources, such as: solar, wind, biomass, geothermal and hydropower energy (DOE's Energy Efficiency and Renewable Energy & (EREC) 2001).

Another definition of renewable energy according to some researchers can be defined as "energy obtained from continuous or repetitive currents recurring in the natural environment" (Donovan 2015).

The last 150 years, modern civilization became extremely dependent on fossil fuels such as coal, oil and natural gas. But these resources are limited in nature by their availability and their combustion releases carbon dioxide into the atmosphere which is one of the main global problem. The different types of renewable energy usually have lower environmental impacts rather than fossil fuel and can be renewed providing the opportunity to provide energy unlimitedly. These renewable sources will help to provide primary energy demand globally in three main sectors: electricity production, heat and cooling, and transport (Donovan 2015).

The adoption of the Paris agreement on climate change on 12 December 2015 by the United Nations (UN) and the partner countries at the United Nations Framework Convention on Climate Change was one of the major achievements. A major challenge is the transition to a carbon-neutral world, and it will take many years. The goal is by 2050 to reduce greenhouse gas (GHG) emissions by 80%. The California State is aiming to reduce its GHG emissions by 40% by 2030 compared to 1990. And by 2020, the German government has set the goal of reducing by 40% compared to 1990. The greenhouse gas emissions and increasing their concentrations in the environment are having many effects. Global average temperatures have increased and in 2016 a new record was set. The average global temperature across land and ocean was 0,94 degrees Celsius higher than the 20th century's average temperature, which is now the 3rd year in a row (Erickson 2017).

According to UN that the renewable energy is the least costly ways to increase access to electricity, reduce air pollution, and reduce carbon dioxide emissions around the world (United Nations 2018). The potential of renewable energy is enormous to provide energy services worldwide (Turkenburg 2012).

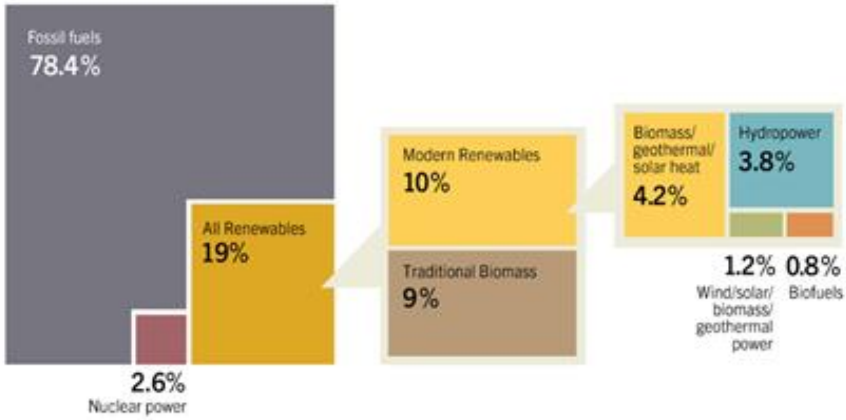


Figure 7. Estimated renewable energy share of global final energy consumption, 2012

Source: (REN21 2014)

During last two decades the generation of renewable energy changed slightly, we cannot see a big difference in numbers, because in 1990 the share of energy produced by RES was 19.5% but due to low growth of energy sector and stagnations the numbers fell to 19.3% in 2009 (Vacek 2015).

Every country is different in production and consumption of RES due to its resources and energy demand (Kramov et al. 2005). Especially in developing countries in Africa, Asia and Latin America the supply is dominated by traditional biomass, mostly fuel wood used for cooking and heating. A significant contribution is also derived from the use of large hydropower and this source supplies almost 20% of the worldwide electricity supply. Many studies examined the potential contribution of renewables to the global energy sources, suggesting that the contribution of RES could range from nearly 20% to more than 50% in the second half of the 21st century with the right policies in place (Herzog et al. 2016).

2.2.2. Biomass as a renewable energy

Biomass or bioenergy is the organic material of recent living plants from trees, grasses and agricultural crops. Biomass feedstocks are highly heterogeneous, and the chemical composition depends on the plant species (IRENA 2012). Biomass is one of the oldest energy sources used for heating purposes. It accounts for 10% of the world of primary energy supply higher than all other forms of renewable energy sources, and it grows at a rate of 1.4% every year. But its contribution to the generation of electricity is relatively less developed. Biomass is currently one of the most complex sources of renewable energy sources available, and some forms, such as ethanol, biodiesel, pellets or briquette, have been traded on international markets (Houri 2013).

These biomass resources come primarily from traditional planting, natural forest, forest planting, home gardens and other farmlands. Oil - rich algae, animal waste and organic waste components of municipal and industrial waste are also important forms of biomass resources. Below on the Table 4, you can see the classification of biomass according to origin (Malik et al. 2015).

Table 4. Classification of biomass according to origin

Biomass group	Biomass subgroup, varieties and species
Wood and woody biomass	Coniferous or deciduous; soft or hard; stems, branches, foliage, bark, chips, lumps, pellets, briquettes, sawdust, sawmill and others from various wood species
Herbaceous and agricultural waste	Annual or perennial and field based or processed based such as: grasses and flowers (alfalfa, Arundo, bamboo, bana, Brassica, cane, Miscanthus switchgrass, timothy, etc.); straws (barley, rice, wheat, sunflower, oat, rape, rye, bean, etc.); other residues (fruits, shells, husks, hulls, pits, grains, seeds, coir, stalks, cobs, kernels, bagasse, food, fodder, pulps, etc.)
Aquatic biomass	Marine or freshwater algae; macroalgae or microalgae; blue, green, blue-green, brown, red, seaweed, kelp, lake weed, water hyacinth

Animal and human biomass wastes	Various manures, bones, meat-bone meal, chicken litter, etc.
Contaminated biomass and industrial biomass wastes (semi-biomass)	Municipal solid waste, demolition wood, refuse-derived fuel (RDF), sewage sludge, hospital waste, paper-pulp sludge and liquors, waste paper, paperboard waste, tannery waste, etc.
Biomass mixture	Blends from the above varieties

Source: (Malik et al. 2015)

Wood is frequently the main household fuel and makes a major contribution to the consumption of industrial energy. It is estimated that around 55% of the world's wood harvest is burned as fuel and the rest 45% is used as industrial raw material which is a substantial part of primary or minor process residues that are suitable for energy production (Malik et al. 2015). Briquetting means densifying or compacting residues into a higher density product than raw materials. It can be used in households and small household industries for heat generation and also in large industries for power production (Ajit 2017). The briquetting technology of sawdust and other agricultural residues has been used in many countries for many years. In Japan screw extrusion briquetting technology was invented and developed in 1945. The density of briquettes of 1.2 g/cm^3 can be generated from loose biomass of bulk density 0.1 to 0.2 g/cm^3, as you can see in the Figure 8. The advantages of using biomass also in the briquettes are environmentally friendly and clean (Grover & Mishra 1996). Another type of biomass are pellets. The transformation of biomass into pellets allows organic matter to be converted into a standard form of fuel that can be easily obtained, carried and used. There are quite different types of biomass used in pellet production that affect the final product's physicochemical characteristics (Foltynowicz & Golinski 2012).

Figure 8. Picture of pellets and briquettes

Source: ("Guide to Pelleting Plant and Wood Pellet Business|Pelletization" 2019)

3. Objective

3.1. Main objective

The main purpose of the presented thesis is evaluating the possibility of using the raw materials from apricot branches for production of briquettes and pellets. And to analyze the quality of the made the solid biofuels from the apricot branches in the Republic of Tajikistan.

Presented main objectives achievements was fulfilled by specific objectives described below.

3.2. Specific objectives

To fulfill the main objective was set specific objectives and to determine the energetic potential of apricot branches after pruning residues in Tajikistan. The specific objectives are:

- Calculation the potential yield of raw material (apricot branches after pruning)
- Determination of the chemical, physical and mechanical properties of the briquettes and pellets made from apricot branches in order to compare with other materials and standards.
- Calculation of the energy potential, based on the yield of apricot branches biomass, and net calorific value for Tajikistan.

4. Materials and methods

4.1. Material

The raw material (apricot branches) was obtained after pruning in February 2017 from North part of Tajikistan in Sogd region, B. Gafurov distract, Histevarz area. Big area of apricot orchards located in North part of Tajikistan because the climate is suitable for apricot production. The biomass was pruned manually, and samples was delivered to Czech University of Life Sciences.

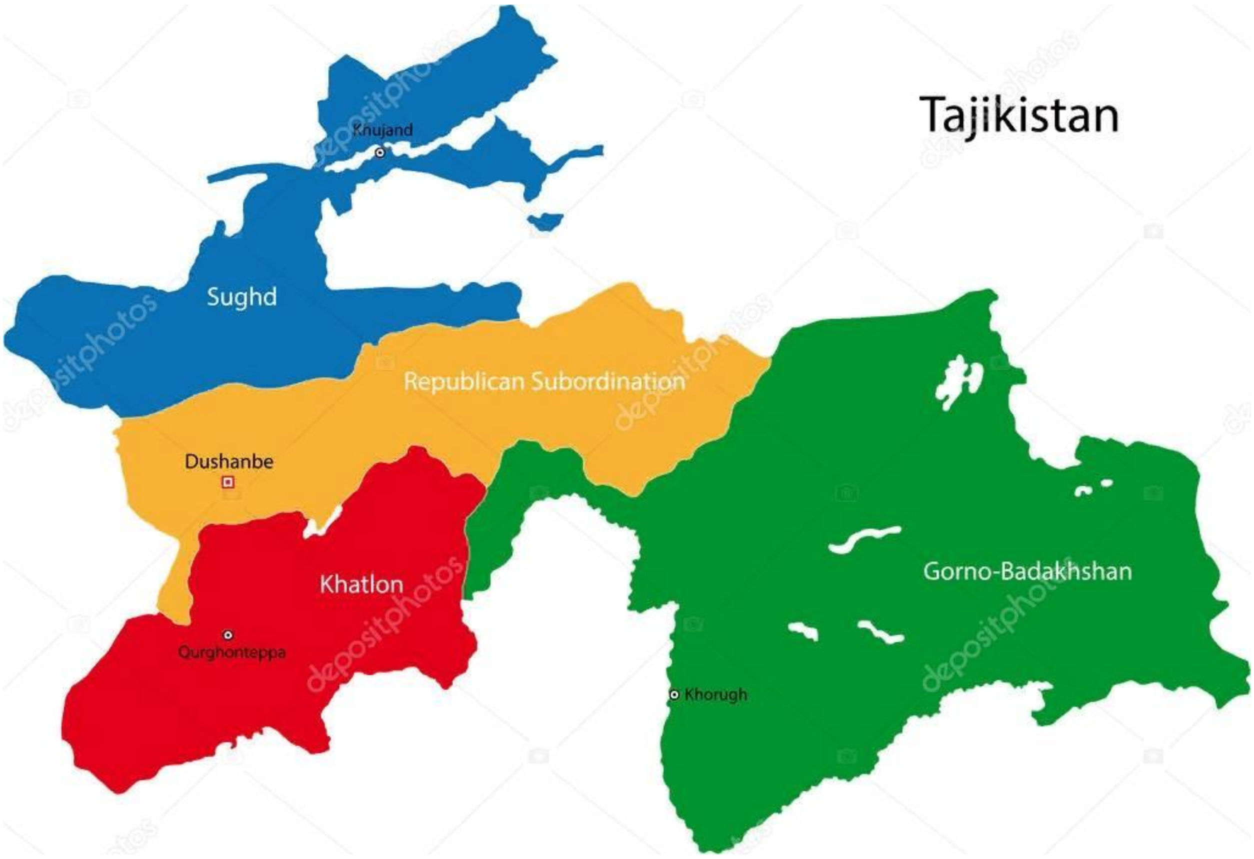


Figure 9. Map of Republic of Tajikistan

Source: (Asia-Plus 2017)

4.2. Methodology

Methodology of this thesis is consisting of theoretical, scientific and practical parts. Data for theoretical part were obtained from scientific articles by searching in Web of Science, Scopus, ScienceDirect databases, searching by keywords: Apricot branches, agriculture, biomass, renewable energies and energy potential. Most articles were in English and Russian languages. Another part of the thesis is practical part. Methodology for theoretical part is described below.

4.3. Preparation of biomass for briquettes and pellets production

Due to easier transportation, apricot branches were carried with small modification, using a simple cut. For further experiments and production of briquettes and pellets it was adjusted by using the hammer mill crusher.

4.3.1. Material crushing

For the reducing the size of raw material it was used Hummer mill 9FQ – 40°C. Biomass was grinded through the 12-8 mm screen. The grinding machine energy consumption is 5.5 kW/h. The Hammer mill machine is available in the Technical Faculty of Czech University of Life Sciences.

4.3.2. Production of briquettes and pellets

Production of biofuels was done in Bioenergy Center of Research Institute at Agricultural Engineering. For producing the briquettes, it was used Briklis Brikstar 50 press equipment. The briquettes have a cylinder shape of 65 mm in diameter, length 30 to 50 mm, heating value is 15 to 18 MJ/kg. Installed capacity of the bunker into press machine is 0.7 m^3. The production capacity of the machine is 40-60 kg/hour. The installed electric input of the briquette press is 5.4 kW and the maximum of working pressure is 180 bars (18 MPa).

Figure 10. Briquetting press CS 22 50

Source: (Briklis 2015)

Production of pellet was carried out in Bioenergy Center of Research Institute of Agricultural Engineering on pelletizing line Kova Novak MGL 200, size of matrix holes is 6 mm. Grinded apricot branches were put in to container of the pelleting machine, by the compression through the horizontal matrix pellets were produced. The electric input of the pelletizing line is 8.85 kW. The capacity of the pelletizing equipment is up to 150 kg/hour.

Figure 11. Pelletizer Kova Novak MGL 200

Source: (KOVONOVAK 2014)

4.4. Preparation of analytical sample

Analytical sample preparation was done at the Laboratory of Biofuels in the Faculty of Tropical AgriSciences (FTA). The raw material was pruned by scissors into 1-3 cm. And it was shrouded into smaller size by IKA MF 10 and eventually grounded to lesser part 1 mm in the laboratory of Biofuel at FTA by Grinder knife mill GRINDOMIX GM 100. Final part was storing the analytical sample to the glass bowl with a cover and kept into desiccator.

Figure 12. Grinder IKA MF 10

Source: (Author 2018)

Figure 13.: GRINDOMIX GM 100

Source: (Author 2018)

4.5. Experimental methods

For experimental research on this thesis a comprehensive set of chemical, physical and mechanical tests has been used. All the experiments were accomplished in the laboratory of Biofuel Center at Research Institute of Agricultural Engineering, laboratory of Biofuel in Faculty of Tropical AgriScience. Quality testing methods are described in the following paragraphs:

4.5.1. Moisture content (w)

Determination and calculation the moisture content of the raw material was made according the European Standard EN ISO 18134 - 2 (2016): Solid biofuel - Determination of moisture content - Oven dry method. Experiment was done at Laboratory of Biofuels in FTA. For identification of moisture content was used oven Memmert (model 100 - 800). For the weighting the samples were used the digital laboratory weighing scale Kern (model EW 3000 - 2M) with accuracy 0.1mg.

The oven was heated up to 105°C together with empty containers. After constant temperature was achieved in oven, containers were removed out, cooled in the desiccator with desiccant about 15 minutes to room temperature and weighed. Samples were placed in the weighted containers, weighed together and dried in the oven for 5 hours at 105°C until the weight is constant in mass. After the drying process, the filled containers were removed, cooled in the desiccator and reweighed. For the calculation of the moisture content was used following formula.

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

Where:

w – moisture content (%)

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 result shall be calculated for two decimal places and rounded to 0,1%.

Figure 14. Memmert (model 100 - 800) oven laboratory device

Source: (Author 2018)

4.5.2. Ash content (AC)

Determination of ash content was made according the European Standard EN 14775 (2009). Solid - Biofuels Determination of ash content. Ash content is determined after combustion of sample at controlled temperature by calculating the weight of the inorganic residue. Analytical samples were grinded into smaller piece than 1mm, after dried in oven before determination. Empty containers were put into muffle furnace for 60 min for 550°C. After removing the containers were cooled in room temperature for 5-10 minutes. Approximately 1g weighted samples were putted into muffle furnace, then furnace temperature smoothly raised to 250°C for 30 minutes. Samples were kept into muffle furnace for the same temperature for 60 minutes to reduce the volatile materials before combustion. The furnace temperature continued to increase steadily for another 30 minutes at an additional 550°C. It lasted 120 minutes to achieve the absolute ignition.

The crucible with ash content were removed from muffle furnace and kept for 5-10 minutes into desiccator for cool down. Then containers were weighted, and data were recorder. For the calculation of ash content was use following formula:

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

Where:

AC – ash content (%)

m_1 – weight of empty crucible (g)

m_2 – weight of crucible with sample (g)

m_3 – weight of crucible with ash (g)

M_{ad} – water content in a sample expressed as a mass fraction (%)

The result of ash content was stated an average of three measurements and rounded to nearest 0.1%.

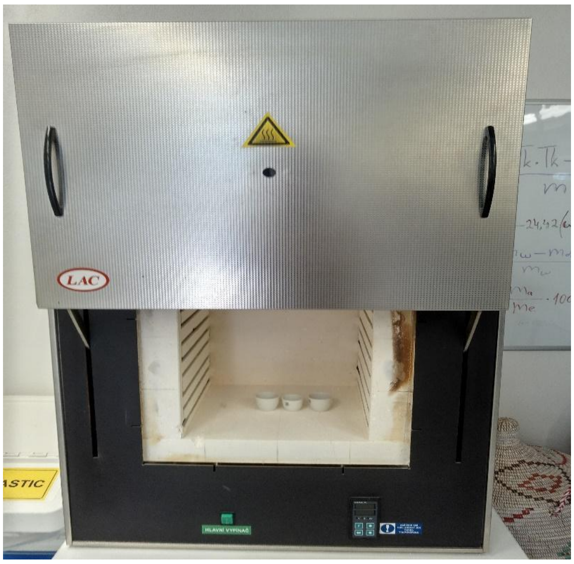


Figure 15. Muffle furnace

Source: (Author 2019)

4.5.3. Gross calorific value (GCV)

Identification of gross calorific value were made in laboratory of Biofuels in FTA. All the experiments were made according the European Standard EN 14918 (2009): Solid biofuels - Determination of gross calorific value and net calorific value.

For determination of gross calorific value was used calorimeter MS-10A. This standard describes a method to calculate solid biofuels calorific value at a constant volume and the reference temperature of 25°C in an under-pressure vessel calibrated with benzoic acid combustion. Dried and weighed sample was placed into combustion dish and then into calorimeter pressure vessel. The wire was used to help the burning. The pressure bowl was locked with matrix and it was filled with oxygen of 28 atmosphere pressure. Then it was putted at the defined position on calorimeter. The process of combustion took 8 minutes to show the dTk value for further calculations.

The resulting combustion heat is measured from the precise measurement of the increase the water temperature of calorimeter and the vessel itself.

Following formula was used for calculation of gross calorific value (GCV):

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

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

Figure 16. Calorimeter MS-10A

Source: (Author)

4.5.4. Net calorific value (NCV)

The net calorific value was calculated based on gross calorific value. And calculation was made according the standard EN 14918 (2009): Solid biofuel – Determination of calorific value Difference between gross calorific value (GCV) and net calorific value (NCV) is NCV is fully dry. Net calorific value is not applicable measure in laboratory, but its possible to calculated by the following formula:

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

Where:

NCV – net calorific value (J/g)

GCV – gross calorific value (J/g)

24.42 – coefficient of 1% water in the sample at 25°C (J/g)

w – water content in the sample (%)

8.94 – coefficient for the conversion of hydrogen to water

H_a – hydrogen content in the sample (%)

4.5.5. Nitrogen, Carbon and Hydrogen content test (CNH)

Measurement of nitrogen, carbon and hydrogen was made in Research Institute of Agricultural Engineering at Bioenergy center. And experiment was done based on International Standard EN ISO 16948 (2015): Determination of total carbon, hydrogen and nitrogen content in solid biofuel. Laboratory equipment LECO CNH628 were used for determination of (CNH). All the samples were prepared respect to the standards, weighted and packed in aluminum foil. Materials were dried and weighted to 0.1g before placing into machine. The samples were inserted to autoloader into purge inner tube in order to remove the atmospheric gas. Then the materials were moved into dual furnace and operational system temperature was up to 1050ºC with clean oxygen to make sure all the samples were burned. The result of the experiment was calculated automatically and given by computer.

Figure 17. Laboratory equipment LECO CNH628

Source: (Author 2019)

4.5.6. Mechanical Durability test (DU)

Determination of mechanical durability of pellets and briquettes was conducted by EN ISO 17831 – 1 (2015) using the pellet tester and mechanical durability of briquettes was done by EN ISO 17831 – 2 (2015) in rotation drum.

Experiment for identification of mechanical durability of pellets was made in Bioenergy Center in Research Institute of Agricultural Engineering in Prague. And for the test was used the Pellet tester with rotation steel drum and speed of turning 50 per minute. The pellet samples were prepared and weighted with total mass 2.5 kg. Then considerable portion of samples were divided into four parts and two of them were sieved through the sieve with size of 40 cm and holes of 3.15 mm. After there were weighted two times 500 ± 10 g of sieved pellets and were placed into pellet tester for 10 minutes. After the experiment finished the pellets were weighted one more time.

Figure 18. Rotation steel drum

Source: (Author 2018)

Determination of mechanical durability of briquettes carried out in Czech University of Life Sciences (CULS) at the Technical Faculty (TF). For the test of mechanical durability of briquettes was used the steel cylinder - shape abrasion with volume 160 liter (depth 598±8 mm, inner diameter 598±8 mm) and rotation speed of the equipment is 21±0.1 per minute. The machine equipped with rectangular steel barrier (length 598±8 mm, height 200±2 mm).

Before the determination briquet samples arranged and weighted to rich the required amount mass of 2 kg (±0.1 kg). Then samples were added into machine for 5 minutes. Inside the running drum the briquettes hit the steel partition which cause the scrape.

Figure 19. Steel cylinder - shape abrasion

Source: (Author 2018)

For the calculation the result of mechanical durability of pellets and briquettes was used the formula:

$$DU = \frac{m_A}{m_E} \times 100, \% \quad (5)$$

Where:

DU – mechanical durability (%)

m_A – sample weight after crumbling (g)

m_E – sample weight before crumbling (g)

4.5.7. Calculation of raw biomass (apricot branches)

Determination of yearly amount of wastes obtained after pruning of apricot orchard, for one hectare with the following formula

$$W_{ha} = Q_{Tha} \times Q_{TW}, \text{ t ha}^{-1} \quad (6)$$

Where:

W_{ha} – yearly amount of wastes obtained after pruning of apricot orchard, for one hectare, t;

Q_{Tha} – the number of trees per one hectare of apricot orchard;

Q_{TW} – the quantity of wastes obtained from pruning of one tree, kg.

Determination of yearly total amount of wastes obtained after pruning of apricot orchards calculated by the following formula

$$W_T = W_{ha} \times Q_{TT}, \text{ t} \quad (7)$$

Where:

W_T – total amount of wastes obtained after pruning of apricot orchards (t);

Q_{TT} – total area of apricot orchards in Tajikistan, hectares (ha);

4.5.8. Calculation of total energy yield (E_{YA})

Calculation was considered for the Republic of Tajikistan. For achieving the maximum theoretical energy yield it is necessary to multiply the NCV in unit MJ kg^{-1} to the total amount of waste obtained after pruning of apricot orchards in unit ton (t).

Determination of the total energy yield was calculated by following formula

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

Where:

W_T – total yearly quantity of apricot waste, t;

NCV – net calorific value of apricot waste biomass, J g^{-1}.

5. Results and discussion

This chapter gives practical results based on objectives and compares them to other authors relevant results. The input results for apricot branches after pruning in the first place. Most results were identified as arithmetic means with the repeatability limit of existing solid bio fuels standards. It is important to keep in mind that briquette and pellet values obtained from other crops can be made under different conditions and production but are still comparable.

5.1. Properties of apricot branches (after pruning)

Chemical, physical and mechanical properties of the apricot branches were obtained based on BSI EN ISO 17225 – 2 (2014) and BSI EN ISO 17225 – 3 (2014): Solid biofuels – Fuel specification and classes, Part 2: Graded woody pellets and Part 3: Graded woody briquettes.

5.2. Moisture content of raw material

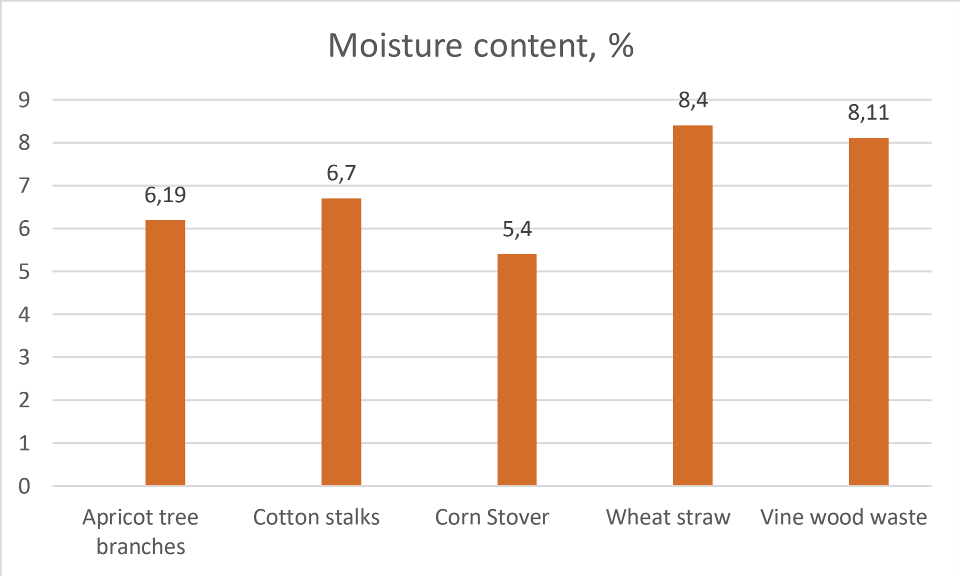
Moisture content calculation is considered one of the most significant tests in the briquette and pellet quality assessment, as moisture content of feedstock influences the final qualities of densified products. Evaluation of moisture content was done according the standard BS EN ISO 18134–3 (2015): Solid biofuels – Determination of moisture content – Oven dry method – Part 3: Moisture in general analysis sample

Table 5. Moisture content of apricot branches

Material	Moisture content, %
Apricot branches (after pruning)	6.19

Source: (Author 2018)

From the table 5 is visible that moisture content of apricot branches corresponds to the required moisture content of produced graded wood pellets. It should be 10% (BS EN ISO 17225–2, 2014), and maximum 12% or up to15% moisture content for different quality classes of graded wood briquettes (BS EN ISO 17225–3, 2014). High moisture content of raw material can have a negative impact on the final properties of solid biofuels such as calorific value as well as strength. According to Ivanova et al. (2014), moisture content of biomass for production of densified biofuels should not exceed 20%. Compare the moisture content of apricot tree branches with other agriculture raw materials shown in following graph 2.



Graph 2. Comparison of moisture content with different raw materials

Sources: (Author 2018; Kaliyan & Morey 2010; Muzikant & Havrland 2010; Lunguleasa & Spirchez 2015; Akhmedov et al. 2017)

Overall moisture content of apricot tree branches corresponds to technical requirement of wooden solid biofuels.

5.3. Ash content

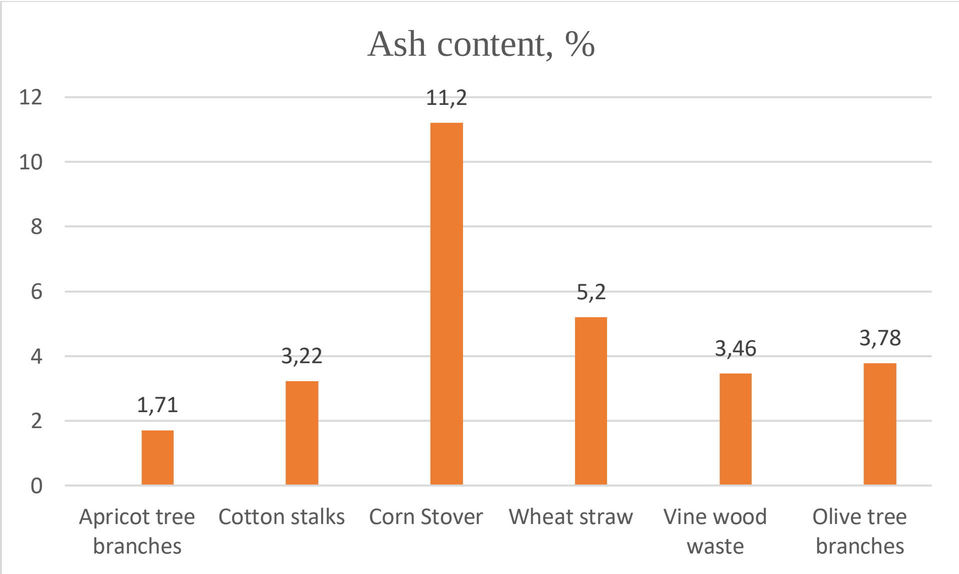
Ash content as well one of the important parameters for solid biofuels. Determination of ash content was made based on BS EN ISO 18122 (2015). Data from the table is visible that corresponds to compulsory technical standards. The results values were noted with two decimal places to better express results differences between specifically tested samples. The result of the determination of ash content is presented in the following table 6.

Table 6. Ash content of the apricot tree branches

Material	Ash content, %
Apricot tree branches	1.71

Source: (Author 2019)

The amount of ash can affect the operation of a combustion devise as well as time spent for the ash removal as it has an influence on the deposits' formation in the boilers (Kamperidou et al., 2017). That is why the content of ash should be known and it is regulated by the modern standards on biofuels quality (Lunguleasa & Spirches, 2015).



Graph 3. Comparison of average ash content with other selected materials

Sources: (Author 2019; Kaliyan & Morey 2010; Muzikant & Havrland 2010; García-Maraver et al. 2014; Lunguleasa & Spirchez 2015; Akhmedov et al. 2017)

Graph 3 shows that ash content of apricot waste is significantly lower in contrast to other materials. However, in comparison to the standard requirement for graded wood briquettes and pellets, the measured ash content in apricot biomass exceed the limits for A class biofuels, but fully fulfilled the requirement for the B class (AC $\leq$ 2% for pellets and AC $\leq$ 3% for wood briquettes).

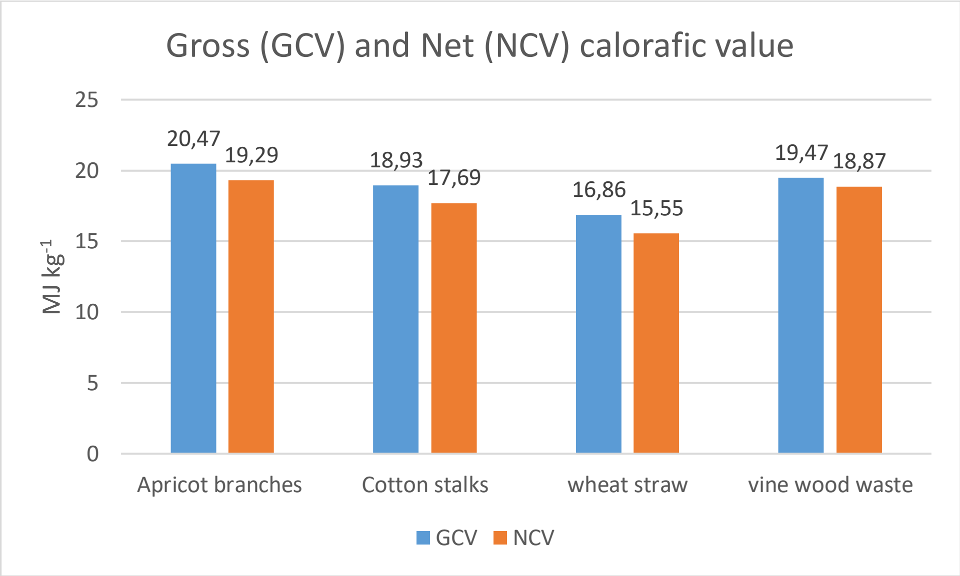
5.4. Gross and net calorific value

The calorific value is the decisive factor of the biofuels, that determines the usefulness of biomass for energy applications. The results of GCV and NCV of apricot branches after pruning as well as calorific values of other materials studied by different authors as presented in the Table 7.

Table 7. Comparing the GCV and NCV of apricot branches with selected biomass

Materials	GCV, (MJ kg^{-1})	NCV, (MJ kg^{-1})	Source
Apricot branches	20.47	19.29	(Author 2019)
Cotton stalks	18.93	17.69	(Akhmedov et al. 2017)
Wheat straw	16.86	15.55	(Bradna et al. 2016)
Vine wood waste	19.47	18.87	(Spinelli et al. 2012; Cosereanu et al. 2015)

In consequence with many studies performed by different researches, e.g. (Cosereanu et al. 2015; Kamperidou et al. 2017), it was found that herbaceous biomass has typically lower calorific value than wood biomass. From the Table 3 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, which could be generated in Tajikistan in large quantities as well. According to the standard requirement (BS EN ISO 17225–2, 2014; BS EN ISO 17225–3, 2014), NCV of the best quality A1 class graded wood pellets should be $\geq$ 16.5 MJ kg^{-1} and $\geq$ 15.5 MJ kg^{-1} for briquettes, which was fulfilled in case of tested apricot material.



Graph 4. Visualizing and comparing the GCV and NCV of apricot branches with other selected materials

Source: (see tab. 7)

5.5. Carbon Hydrogen Nitrogen content (CHN)

Determination of CHN content of apricot branches was done based on BS EN ISO 16948 (2015). Solid biofuels – Determination of the content of carbon, hydrogen and nitrogen. The result of the experimental data is displayed in the following table 8.

Table 8. Chemical constituent of the apricot biomass, %

Chemical components	**Content, %**
Carbon	47.28
Hydrogen	6.27
Nitrogen	0.36

Source: (Author 2018)

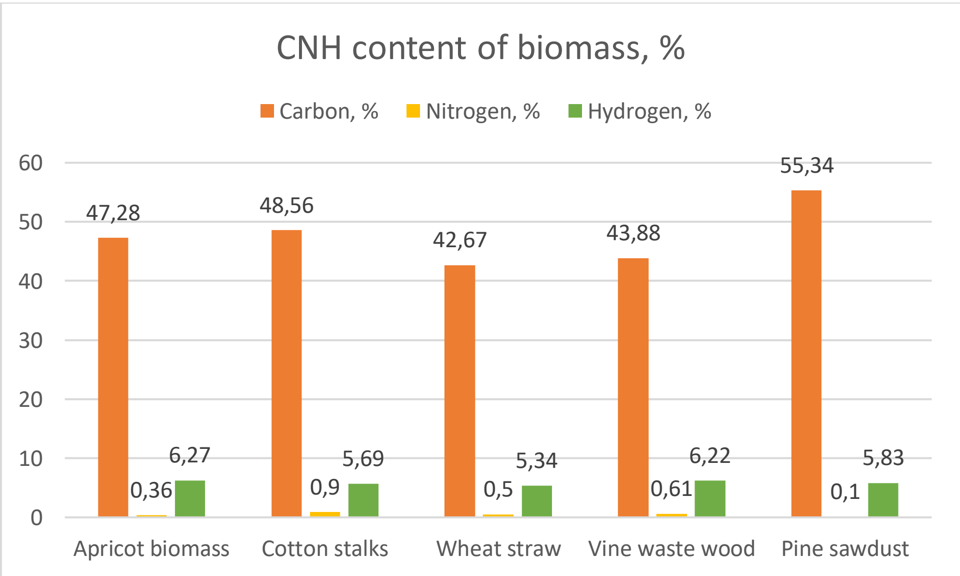
The research also indicated the basic element content in apricot pruning waste (see Table 8). According to (Ivanova et al. 2014) hydrogen content in wood biomass is usually around 6%. Nitrogen content in the biofuels is listed among the necessary stated parameters as nitrogen has a direct impact on formation of harmful nitrogen oxides (NO_x) during fuel combustion (Erisman et al. 2010; Ivanova et al. 2014).

Table 9. Comparison CNH content of apricot tree branches with others biomass, %

Materials	Carbon, %	Nitrogen, %	Hydrogen, %
Apricot biomass	47.28	0.36	6.27
Cotton stalks	48.56	0.90	5.69
Wheat straw	42.67	0.50	5.34
Vine waste wood	43.88	0.61	6.22
Pine sawdust	55.34	0.1	5.83

Source: (Author 2018), (Akhmedov et al. 2017), (Bradna et al. 2016), (Muzikant & Havrland 2010; Zabava et al. 2018), (Stolarski et al. 2013b)

Table 9 shows that, from viewpoint of N content, the apricot waste biomass is the cleanest in comparison with the other materials. In accordance with strict limits for graded wood briquettes as well as pellets, N content is ≤ 0.3% for A1 class solid biofuels, ≤ 0.5% for A2 class and ≤ 1% for B class. Thus, apricot wood waste exceeds A1 class requirements, but fulfils the A2 limits.



Graph 5. Presenting the result of experiments with other agricultural biomass

Source: (see tab. 9)

5.6. Mechanical durability

Mechanical durability is the main indicator of the mechanical quality of manufactured briquettes and pellets. Mechanical durability simply demonstrates how dense and densified fuels form. It measures shock resistance and/or abrasion resistance during transportation and handling (Alakangas 2011; Ivanova et al. 2014). The results of the durability tests are presented in the Table 10

Table 10. The results of mechanical durability for tested briquettes and pellets made from apricot wastes in comparison with durability of solid biofuel from other materials

Materials	Mechanical durability of pellets, %	Mechanical durability of briquettes, %
Apricot biomass	94.37	96.15
Cotton stalks	97.82	97.63
Wheat straw	94.40	95.65
Vine wood waste	-	91.6
Wood poplar chips	-	94.3

Source: (Author 2018; Brožek et al. 2012; Vacek 2015; Guo et al. 2016; Akhmedov et al. 2017; Zabava et al. 2018)

Table 10 indicates that cotton-based biofuels have the highest mechanical durability, followed up by apricot-based biofuels, and then by wheat straw biofuels and the least long-lasting biofuels for vineyard-based pruning biomass briquettes. The mechanical resistance of apricot briquettes produced is similar or even higher than that for wooden briquettes measured by (Brožek et al. 2012), i.e. DU of wood poplar chips briquettes 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 A class and ≥ 96.5% for B class.

5.7. Calculation of yearly availability of raw material (apricot branches after pruning)

Determination of biomass yield was calculated based on data reported and showing the common of apricot growing scheme 156 trees (8x8m) in one hectare and after pruning approximately 15 – 20 kg of branches available as raw material (Kamolov et al. 2010). According (TAJSTAT 2017) in Tajikistan 61,617 ha of apricot has been harvested. The result of the calculation of raw material (apricot branches) is displayed in the following table 11

Table 11. The result of calculation of waste material

Biomass	Amount of waste per hectare, (t)	Total amount of waste, (t year^{-1})
Residual wood obtained after pruning of apricot orchards	2.73	168,241.14

Source: (Author 2019)

From the table is visible that total amount of raw material after pruning represents sufficient quantity that will be possible to apply for efficient production of solid biofuel, that can play big role and improvement in energy sector of the country especially in rural area. Also, calculation of raw material after pruning orchards was reported by another researcher and shown in the table 12

Table 12. Compare of availability of biomass after pruning.

Trees	**Availability of biomass after pruning, kg/tree**
Pear	15.2
Apple	34.6
Plum	9.2
Apricot	13.3
Cherry	26.0

Peach	10.5

Source: (Unal & Alibas 2007)

Data from table is shown that the availability of apricot biomass after pruning in 13.3 kg per tree. And compare to our data it is bit lower because different sort of apricot and scheme of growing apricot tree, due to density of tree per hectare, tree performance are different.

The comparison of other woody crops, which mainly connected for energy purpose are poplars and willows. The poplar yield can vary from 1.57 to 47.7 t ha^{-1} of dry biomass, as (Carmona et al. 2015) have pointed out. (Stolarski et al. 2013a) shows that a willow tree can produce 14.1 t ha^{-1} on average of dry wood.

5.8. Calculation of the energy yield potential

Calculation of energy yield is major purpose of this diploma thesis. By knowing the net calorific value (NCV) of biomass (19.29 MJ kg^{-1}), availability of raw material per hectare (2.73 t ha^{-1}) and number of apricot orchards hectare has been harvested in Tajikistan (61,617 ha) it is possible to calculate the energy yield. The result of the calculation is presented in table 13

Table 13. 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	3,244.86

Source: (Author 2019)

In Tajikistan the annual yield of apricot wastes is approx. 170 thousand tonnes, with a total energy output of about 3,245 TJ, taking account of the average waste per tree (17.5 kg). According to (Stavjarska 2016), a maximum theoretical yield per ha (residual biomass per ha multiplied by GCV) of cotton residues was found to be 93.59 GJ ha-1, in case of apricot waste it would be less (55.90 GJ ha^{-1}) due to lower amount of waste generated. Energy potential is 1,554.8 TJ $year^{-1}$ for Republic Moldova using the vine yard wood (Chardonnay) after pruning was reported by (Vacek 2015). Comparison is difficult with other research because of dissimilar of target areas in most cases or is examined by different type of agricultural raw material.

6. Conclusions

Although Tajikistan today has access to certain of its own energy resources such as coal or hydropower, it still has great difficulties in ensuring accessible and affordable energy for population in rural area of the country. On the other hand, the country has many well-developed agriculture regions which not only play an essential economic role and are the main source of income for the rural population, but also generates waste collected in large quantities each year. The application of abundant agricultural wastes for energy purposes, for example, in the production of pellets and briquettes from apricot-wood trimming seems to be one of the most appropriate solutions of energy and environmental problems.

Although apricot trees are only in fourth place after wheat, cotton and vineyards in Tajikistan by cultivated area, the estimated energy potential output data have indicated the perspective of using of the tested biomass for energy purpose. Furthermore, testing of residual apricot biomass and biofuels produced from it (pellets, briquettes) have demonstrated high physical, chemical and mechanical properties in comparison with the quality of the solid biofuel produced from other agricultural biomass that has potential for the country. The above data shows that apricot wood waste is one of Tajikistan's most prospective, optimal type of biomass for the production of solid biofuel.

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