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ASPECTS OF USING POTENTIAL ENERGY PRODUCTS OF BIOMASS AFTER PRUNING FRUIT AND GRAPE PLANTATIONS IN THE REPUBLIC OF SERBIA

SUMMARY

Contemporary technologies of fruit and vine production imply conducting intensive plantation pruning, and so significant amount of biomass appear with ecological and energetic importance. Thermal energy use of biomass residues as pruning is important from the point of view of environmental protection, the closed cycle of production and emission and consumption of emission CO_2. Remains of pruning the orchards are burden that hinders the implementation of agricultural practices so that their removal is necessary. Limited reserves of fossil fuels and pollution of the environment imposes the necessity of finding alternative and renewable sources of energy while reducing environmental pollution. Very current problem is to define the optimal technical solutions and technologies for utilization of machine pruning fruit trees and vines, you know increases the energy efficiency of production. Outdated technology, extensive production and disposal of inefficient energy in our country collecting, preparing and using plants remains is not enough application.

A prerequisite for the study of the economic feasibility of using pruning remains present data on the quantity, energy potential, workmanship, transport ability, price, convenience for storage, preservation and combustion. The most important starting point for this research is defining energy potential pruning residues annually. The Republic of Serbia has approximately 600,000 t wood biomass from fruit and grape plantations.

Modern burning methods of wood biomass, like different types of wood pellets or classic firewood, enable highly efficient usage of energy; have minimum emissions CO_2 of harmful substances and comfortable heating in domestic. High investment expenses, making subventions from public and government sources indispensable, hinder their introduction.

Key words: Orchards, vineyards, pruning residues, biomass, energy.

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INTRODUCTION

Through photosynthesis, sunlight, CO_2 from the atmosphere and water are transformed into a complex of plant polymers. According to the European Renewable Energy Council (Renewable Energy House 2007), biomass is a result of sunlight stored as chemical energy in plants. Exploitation of those resources for energy enables circulation of CO_2, as well as its storage in durable products (Biomass-Fired District Energy Santa Fe – Fuel Study 2004).

Biomass is a renewable resource, and in addition to its possible usage for bio fuel, bio energy, chemical and other products, it does not increase the CO_2 content in the atmosphere. Production and use of biomass provides significant benefits for the environment, economy and safety.

Plant material used directly as fuel, or transformed into some other form before combustion, is defined as biomass. It uses biodegradable product fractions like residues and litter from agriculture, forestry and supporting industries, plant and animal substances, as well as biodegradable fractions of industry and city waste (Oka and Jovanović 1997).

In many undeveloped countries in the world, using biomass as an energy source still provides basic fuel to households. The fact is that in last few years, biomass usage outside of households has started to be organised, and it presents an important energy resource. Although usage of biomass as an energy source dates back to the ancient times, recently it has begun to be treated as a new renewable energy source. Amongst the various renewable energy sources, biomass has the highest energy potential. The characteristic chemical structure and physical shape of biomass is significantly different to fossil fuels, and this emphasises its ecological value. Numerous studies (Di Blasi, Tanzi and Lanzetta 1997, Đaić 2002, Grubor and Repić 1998, Ilić 2003, UNEP 2007) have shown that biomass in its structure either does not contain, or contains less, sulphur compared to fossil fuels, which gives it ecological importance. Other important features of biomass are: heterogeneity, small volume density, high humidity, variability of content and it makes the processes of shrinking, transport and storage more complex (Mardikis et al. 2004, Radojević et al. 2005). Another advantageous effect of using biomass within combustion systems is that it can be a substitute for coal; that is, by mutual combustion of biomass and coal in the combustion process (Todorović, Marija and Kosi 1998).

When considering the possibility of producing biomass for fuel, two aspects must be considered. The first is the production of a specially selected highly fertile type of plant (energy forests), which has to be organised by the State. The other approach to this problem, which is far more real in current circumstances, is that every agricultural farm produces energy for its needs (Ilić, Gruber and Tešić 2004).

According to research (Oka and Jovanović 1997, Rakin 2002), the energy potential of biomass in the Republic of Serbia is estimated to be 115,000 TJ/year. From that, the total energy potential of the remaining agricultural biomass is about 65,000 TJ/year, where 200,000 t/year comes from fruit trees, vine pruning and other sources related to fruit processing.

In accordance with the level of technical development, it can be stated that in the near future renewable energy sources derived from the remnants of fruit and vine pruning could be used for low-temperature energy needs in the Republic of Serbia (Živković et al. 2008).

Where fruit and vine production is developed, biomass, as an economical fuel, could be successfully used for the heating needs of relatively small consumers – initially in households.

MATERIAL AND METHODS

A mandatory agro-technical measure used in the exploitation of fruit trees and vines is pruning, which is adjusted to biological as features of every sort and type. Pruning can increase fruit fertility by decreasing of vegetative biomass of tree. This measure is usually applied during stillness of vegetation (so-called ripe pruning) but pruning during vegetation (so-called green pruning) is less common. Contemporary intensive technologies of plantations are characterised by pruning, which produces significant quantities of biomass – which can have multiple uses.

Biomass, which is obtained during the pruning of fruit and vines growing in Serbia, is not sufficiently researched, so there are no relevant data on its energy potential. Therefore, this type of biomass is not significantly present in the energy balance of the country. Bearing in mind the importance of estimation of energy balance and increased demand for renewable energy sources, this research topic deserves more attention.

Work data from the statistical annuals is used (Republic Office for Statistic and Informatics 2012), and this data related to orchards and vine plantations as well as the number of trees and vine.

The statistical data used to conduct this research demanded the application of statistical-mathematical methods of data processing, to determine variation in total number of trees and canes and thereby determine energetic potential for the period from 2000–2011.

Quantity of biomass obtained by pruning mature fruit and vines during the stillness period of plant vegetation define its`energetic value. Products of green pruning are characterised by a small amount of cellulose, the significant presence of moisture and so on, and are not important as energy sources for combustion. The application of appropriate technology, as well as engagement of other technical means used for collecting, primary processing (balling, logs, pressing – briqueting), transport, stocking and direct use, are defined by quality and quantity of biomass.

In Table 1, the total number of fruit trees and vine canes in R.Serbia is given for the time period 2000–2011.

The amount of biomass obtained from fruit trees and vines is the basis for projecting proposals and ways of mechanically collecting biomass for production of heating energy in households, in accordance to the experiences of the EU.

Table 1. Number of fruit trees and vines in the Republic of Serbia (Republic Statistical Institute, Republic of Serbia 2006–2010).

Year	Apple	Pear	Quince	Plum	Apricot	Peach	Cherry	Grapes
	trees in thous.	trees in thous.	trees in thous.	trees in thous.	trees in thous.	trees in thous.	trees in thous.	vines in millions
2000	14265	5872	945	43103	1544	3563	8336	396
2001	14176	5384	920	42597	1550	3569	8428	382
2002	14445	5278	950	42383	1609	3946	8397	378
2003	14689	5242	932	42454	1612	3853	8812	367
2004	14890	5120	896	42513	1600	3948	8890	348
2005	14805	4958	926	42583	1583	3993	8938	337
2006	14658	4788	892	41796	1566	4035	8562	322
2007	15037	4723	858	41885	1571	4063	8651	309
2008	15224	4403	864	41885	1637	4093	8637	301
2009	15600	4471	845	41601	1694	4685	8683	290
2010	15880	4414	820	41171	1696	4516	8377	292
2011	16042	4528	836	40822	1781	4800	8377	274
Average	14976	4932	890	42066	1620	4089	8591	333

The research results of the rest of pruning in fruit yards and grapevines with a moisture content of 10–15%, (Babić et al. 2011, Martinov et al. 2006, Tešić, Igić and Adamović 2006), have upper heating power at: apples 17,4 MJ/kg, pears 17,5 MJkg, peaches 17,7 MJ/kg, plums 17,8 MJ/kg and grapes 18 KJ/kg.

RESULTS AND DISCUSSION

The structure of total primary energy use in the world is shown in Figure 1 (International Energy Agency, OECD/IEA 2006), and it can be noticed that renewable energy (OE) constitutes 13.1% of the total. The potential for bio energy is huge and widespread all over the world.

Nowadays, biomass is the main source of total world energy needs amongst all available renewing sources of energy, and it reaches 12% (50 EJ/year) of the world's total needs (406 EJ/year.) (International Energy Agency, OECD/IEA2007). Biomass use mainly exploits residues of forestry and agriculture.

In the Republic of Serbia, according to statistical data from 2000–2011, there are 42.066 million plum trees, constituting 54,51% of the total number of yielding trees, making plums the leading fruit type. After plums come apples, with 14.76 million (19,41%), cherries with 8.591 million (11,13%), pears with 4.932 million (6,39%), peaches with 4.089 million (5,32%), apricots with 1.620 (2,10%) and quince with 0.89 million (1,15%). For the given period, the highest increase in the number of yielding trees recorded belongs to peach trees (14,76%), then apple trees (4,98%), followed by apricot trees (4,92%), and cherry trees (3,6%). Significant falls in the number of yielding trees were recorded for pear trees (16%), quince trees (5,82%) and plum trees (2,41%).

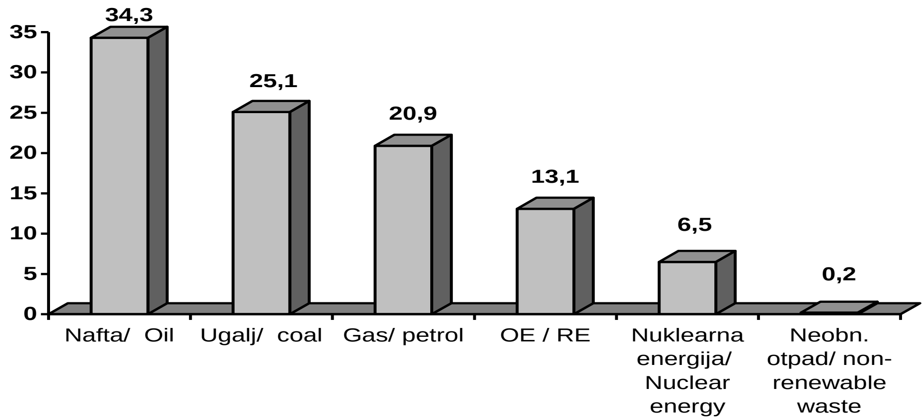

Figure 1. Total primary energy in the world (Int. Energy Agency, OECD/IEA 2006).

The number of vine canes for the period 2000–2011 was approximately 333 million canes. By analysing data, we can notice that there was a decrease in the number of canes from 396 to 274 million, which in terms of cultivated surface is a decrease of 57540 to 56434 hectares. Field data show that in the last year this decrease slowed.

Plant biomass yield of orchards and vineyards depends on many factors, such as biological features, plantation age, agro-technical measures, cultivation system and so on. A crucial influence comes from the amount and type of fruit, agro-technique and pruning system used.

The results of research on the amount of remnants produced from one year of pruning (Table 2.) confirm that the two most important fruit types are: plum trees, with 2.87 to 4.59 t/ha, which is an average of 7.46 kg per tree$^{-1)}$ and peach trees, with 2.42 to 4.68 t/ha, which is an average of 6.88 kg per tree^{-1}.

Table 2. Pruning yields for 2010/2011 (Radmilovac, Faculty of Agriculture, Belgrade, R. Serbia).

Species	Type	Number tress/ha	Average (kg tree^{-1})	Total (kg/ha)
Peach	Summerset	500	4,85	2425
	Cresthaven	500	6,43	3215
	Redhaven	500	9,36	4680
Plum	Stanley	500	5,74	2870
	Pozegaca	500	9,18	4590
Apple	Idared	2190	1,42	3110
	Jonagold	2190	1,59	3482

Peach trees are an important source of pruning residues, yielding 40% of total mass in mature pruning, and also giving vine cane (Table 3).

Table 3. Yields for some pruning grape varieties grown in Serbia

Yield	Grape vines						
	White Tamjanika	Game	Kreaca	Cardinal	Black Tamjanika	Župljanka	Vranac
kg/vine	0,619	0,778	0,806	1,026	1,073	1,205	1,237
kg/ha	1650	2075	2150	2740	2860	3220	3300

Pruning residue yield mostly depends on biological features of the grapevine variety, and their verdure. Climate and land conditions also have a great influence, as well as the agro-technical measures used during plantation exploitation.

Table 4 shows the average energetic potential of pruning residues of fruit trees and vines in the Republic of Serbia for 2011.

Table 4. Energy potential of pruning residues of fruit trees and vines in Serbia.

Fruit species	Number of trees / or vines	Remains of pruning, average	Thermal power		The amount of useful energy	
			Upper	Useful*		
	x 10^3	kg/ tru. vine	MJ/kg	MJ/kg	In total MJ/ tru. vine	In total GJ/ha
Plum	40,822	7,7	18,65	12,10	93,17	3.803.386
Apple	16,042	2,4	17,8	11,42	27,41	439.711
Pear	4,528	4,2	18,0	11,58	48,63	220.197
Peach	4,800	6,6	19,4	12,7	83,82	402.336
Quince	836	1,1	18,65	12,10	13,31	11.127
Apricot	1.781	1,2	19,3	12,62	15,14	26.964
Cherry	8.377	1,8	18,65	12,10	21,78	1.82,451
Grapes	274.000	0,96	18,3	11,82	11,35	3.109.900
Total						8.196.072

*Energy value is determined based on moisture (10–15%) of the ligneous plant mass and the appropriate level of stokehole usage during combustion, which is about 76% (International Energy Agency, OECD/IEA 2006).

The data (Table 4) show the collected biomass of individual fruit types for 2011. Plums with 3,803,386 TJ; apples with 439,711 TJ; pears with 220,197 TJ; peaches with 402,336 TJ: quince with 11,127 TJ; apricots with 26,964 TJ; cherries with 182,451 TJ and grapevines with 3109.9 TJ, or in total 8,196,072 TJ.

The potential of wood biomass (Dolenšek et al. 2008, Lasselsberger 2001), from the possible sources of wood biomass (Figure 2), can be shown by a formula:

% from the regular annual cutting
+ % from the unplanned annual cutting
+ 100% from forest nursing (for example, spacing)
+ 100% from maintaining traffic infrastructure in forest
+ 100% from the surfaces in forestation
+ 100% from agricultural surfaces
+ 100% wooden odds and ends (e.g., old furniture)
+ 100% residues from wood processing in the industry (eg., sawdust).
Σ Potentials of wooden mass for energetic usage

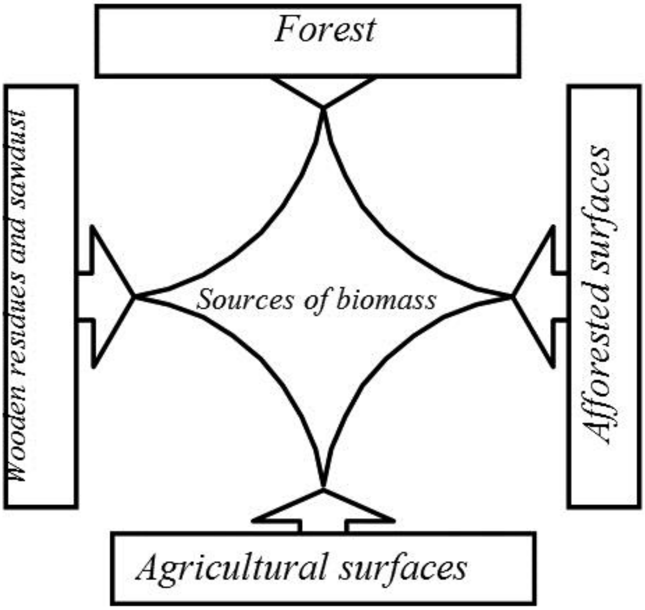

Figure 2. Potential and possible sources of wood biomass.

It is necessary to mention that an estimation of possible sources depends on usage, way of wood firing (classical or wood pellets) and minimal thickness.

Data (Brkić and Janić, 2011) on potential amounts of biomass for energy production show collection possibilities in the Republic of Serbia relating to crop farming (9,680,000 t of wasted biomass), and in fruit vineyard production (600,000) t. The amount of biomass from fruit yards and vineyards (Table 4), amounts to 600,000 t of pruning residue biomass, which could be the basis for the application of special collection technologies and the use of biomass energy for heating in households (Dolenšek et al. 2008, Dolenšek 2008).

Collecting pruning residues from fruit and vineyards

Collected pruning residues from fruit and vineyards (Živković et al. 2008) can be conducted in several ways (Dolenšek et al. 2008). When the residues are used as energetic fuel, there are two basic processing treatment methods:

Mechanical treatment: is a treatment of cutting, grinding and pressing biomaterial from pruning residues. Considering that pruning residues occupy a lot of space, that problem can be solved by cutting biomass (brushwood) to the length of 2–15 cm, using stationed machines – cutters (Figure 3), or cutting into very small pieces (sawdust form).

Residues conversion: this implies treatments that change the physical and often chemical compounds of the starting form. Conversion technologies can be divided into three big groups: thermochemical conversion, physical-chemical conversion and biochemical conversion. Each one of these three technology groups involves many different processes an technologies, and the main ones concerning production of energy and fuel.

Mechanical processing of biomass: this process involves cutting pruning residues of fruit and vineyards (Figure 5), increasing volume mass and making transport and manipulation easier.

Figure 3. The device for shredding plant mass from plantation of fruit and vineyards.

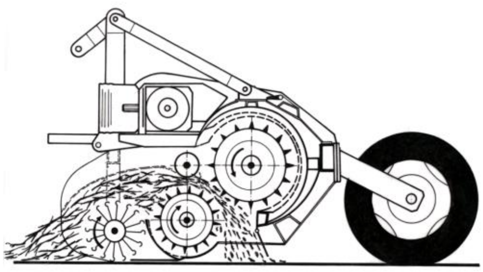

Figure 4. Machine for shredding pruning residues in fruit or vineyards.

A simple way to collect plant residues is with tools like mechanical rakes (Figure 5), which are installed on the front of a tractor, or on the backside. Biomass is collected and transported to some other place for storage.

Besides the examples of tractors and mechanical rakes for collecting biomass, there are also machines which can collect and at the same time press biomass (Figure 6).

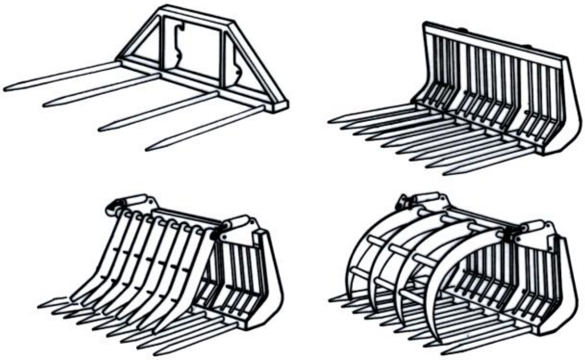

Figure 5. Different types of mechanical tools for collecting and temoving biomass (Živković et al. 2008).

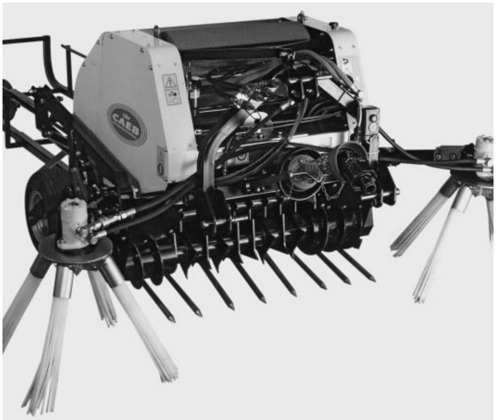

Figure 6. Machine for collecting and pressing pruning residues.

Depending on the type and construction of such machines, bales of square cross-section can be formed (Figure 7) or, alternatively, roll-bales (Figure 8).

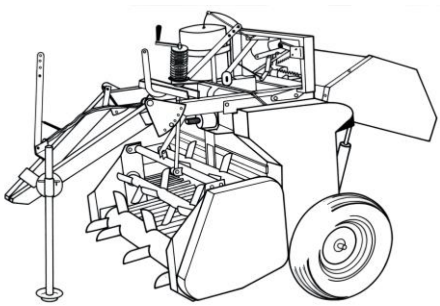

Figure 7. Press for rectangular bales.

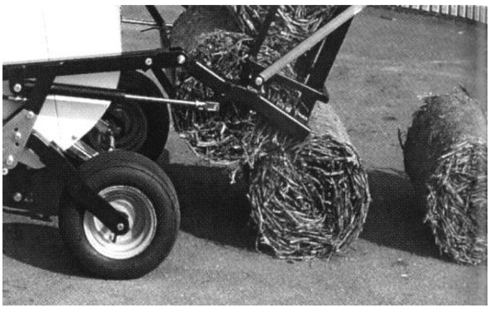

Figure 8. Pressing pruning residues into roll-bales.

Machines with bigger capacities for processing industrial logs into wood chips (residues of tree branches with diameters from 1 to 15 cm and 70 cm) include: connection types or self-propelled types (Figure 9) .

When cutting wood, the equivalent of operational energy is spent, which is later calculated at an amount of up to 5% energy, which cut wood contains (Dolenšek et al. 2008).

Figure 9. Machines for cutting collected wood biomass.

One of the ways to overcome the inexpediency of current applications is by forming bio briquettes. Plant mass is processed into sawdust or wood chips and pressed into briquettes for easier storage and usage. In this way, biomaterial is transformed into a compact form with high volume, which is suitable for further manipulation and usage in fireboxes.

Bio pellets (briquettes) are pressed cylindrical pieces of wood or similar material from around 20 mm long, with a radius of 6 mm. Making wood pellets nowadays is an industrial process (Figure 10).

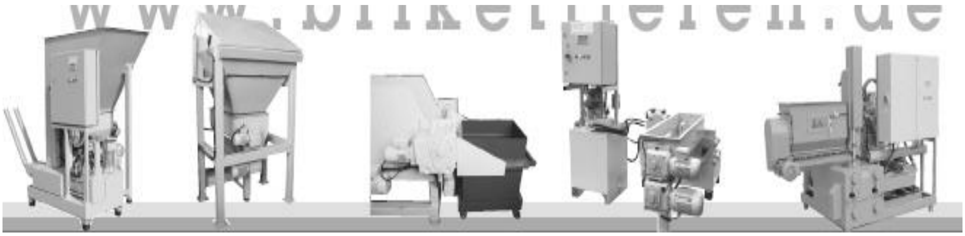

Figure 10. Different presses for making pellets or briquettes from wood and similar materials.

Figure 11. Forms of pellets or briquettes.

Pellets or briquettes are transported by trucks or pneumatic transporters directly to the storages of households, and are used in combustion processes (Figure 14).

In the production of briquettes without additional connective material, there are two procedures: dry procedure (with raw material with 10–18% moisture); and moist procedure (where raw material moisture is 25–40%). The volumetric mass of bio briquettes is more than 1000 kg/m^3. The usage level of bio briquettes ranges from 60–95%. Coefficient of storage from 0.1–0.4 indicates that bio briquettes make 10–40 % of the volume which biomass occupies after pruning fruit trees. A good characteristic of bio fuels is the low ash content: wood 0.75%, straw 6.03%, and Kolubara lignite up to 10%.

Besides that, biomass ash has value as fertilizer and it is not ecologically harmful. The average energetic equivalent of energy input for briquetting compared to received mass through briquettes and pellets is 1:5. By briquetting, biomass volume decreases 7–12 times, because the mass of briquettes is 1.0–1.4 N/dm^3. Briquettes can be used in any kettle hey have good heating power (15–18 MJ/kg). Volume heating power for biomass in its basic form is: 368–5194 MJ/m^3; for bio briquettes it is 13570–19300 MJ/m^3; for bio briquettes in bulk density it is 5990–12900 MJ/m^3.

The price of briquettes compared to the units of produced energy is of the same order of magnitude as coal, natural gas and oil fuel, slightly better than fire wood and significantly better than fuel oil, electric energy and liquid petroleum gas.

Such prepared bio residues from pruning can combust in stakeholes (Figures 12 and 14), and the basic demand of them is automatic delivery of mass or continuous flow of chopped wood branches. Biomaterials combust clearly and fully with 0,5 –7% ash, and they do not release sulphur, which makes them an ecological fuel.

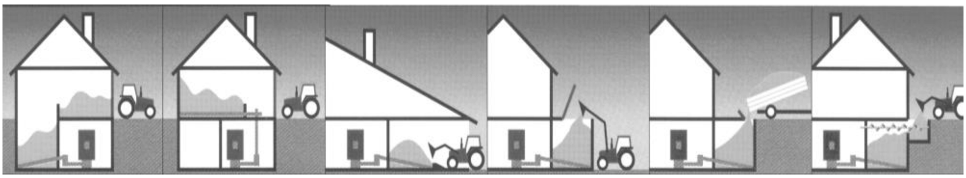

Figure 12. Process of transporting and storing pellets in households (Dolenšek 2004).

Technologies of contemporary energetic usage of wood biomass – heat production

Usage of wood biomass for heat production can be realised in several ways:

-Remote systems (heating plants of more than 1 MW rated power),

-Collective (for several houses, a village, of up to 1 MW rated power), and

-Individual (individual, houses with additional objects, from 100 to 200 kW rated power).

Modern cauldrons for wood biomass have usage levels of more than 90%, and harmful emissions through smoke are on same level as fuel oil or gas, or even less, according to the data from the graphic (Figure 13), showing a *decrease in CO emission of cauldrons tested within a period of 20 years.

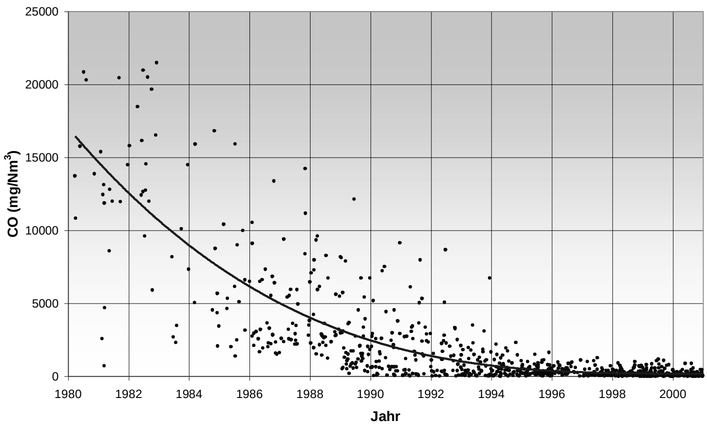

Figure 13. Decreasing emissions of CO of tested cauldrons.

Modern cauldrons are divided based on the shape of the firewood mass:
A) Cauldrons (Figure 14), use chopped pieces (petty chopped wood – sekanci), with automatic transportation of wood mass into the cauldron,
B) Cauldrons using pellets (pressed wood residues of different shapes and sizes).

The above-mentioned examples of cauldrons can be applied for individual systems in households. For example, rural households of Slovenia use cauldrons on sekance and classic firewood (Dolenšek 2004). Cauldrons using pellets as fuel are a good alternative to fossil fuels in urban areas (storage of purchased pellets, Figure 12).

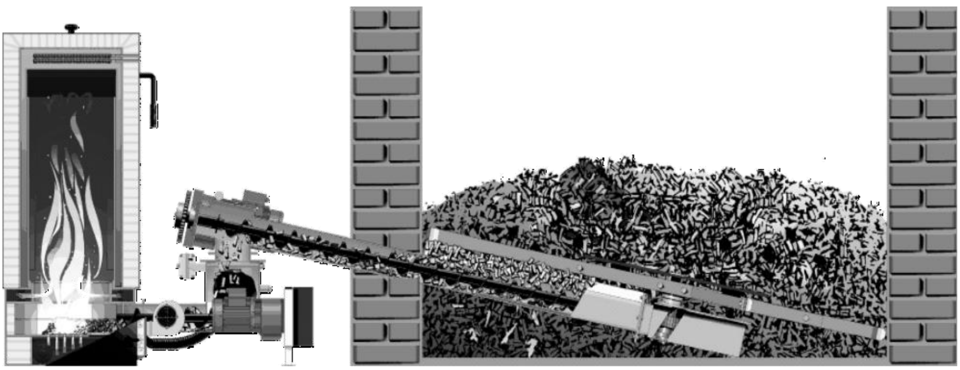

Figure 14. Working principle of contemporary individual cauldron on sekance.

Economics and subventions for investing in biomass energy usage

Investment into contemporary cauldrons using wood biomass (for example, sekance) is five times higher then investment into cauldrons using fuel oil (Table 5) (Dolenšek 2004). That is why all other advantages (using own energy source, automatic heating, mechanical preparation of sekanci) are not sufficient in order to make investors favour such systems.

Experiences of countries, such as: Austria, Finland, Sweden, Denmark, Slovenia (Dolenšek 2004), show that subventions in the amount of 30 to 40% of investment are obligatory in order to make investors start installing systems for heating using wood biomass (in Slovenia, currently up to 15% of investment, (Dolenšek 2004)).

Table 5. Fuel costs and investment of different systems in producing heating energy.*

Type of fuel	Amount	Price	Fuel/year	Investment €
Wood logs	13 pm^3	60 €/m^3	800	9.000
Sekanci	30 nm^3	15 €/m^3	450	15.000
Pellets-briquettes	6.000 kg	0,22 €/kg	1.400	11.000
Fuel oil	3.000 l	0,849 €/l	2.130	3.000

*example: 15 kW rate power of cauldron (family house 200 m^2, modern building – with thermo isolation), prices – November 2004, according to Dolenšek (2004).

CONCLUSION

1. With regard to late planting: Negative impact over almost all the analysed features was observed in the control plants which were not treated with radiation as compared to the control ones planted at the normal time. There were much less negative impacts in the late planting as observed in the irradiated plants.

The radiation caused positive impacts in physiological and yield features.

2. With regard to genetic diversity: The coefficient of variance is considerably increased in all analysed features of irradiated plants.

3. With regard to morphological features: Reduced plant height was shown in all irradiated versions when compared to the control, enabling the selection of dwarf lines with good resistance against lodging. Tall plants with lots of stubble for energy use purposes can be selected due to the high range of values observed and coefficient of variance, CV. According to the correlation coefficient between yield features and yield performance: dwarf plants with good yield performance can be selected among 15 and 25Kr plants and tall plants with good yield performance can be selected among 20Kr plants. These selected plants will be tested for their resistance against lodging as well.

The radiation has caused positive results with regard to morphological features such as reduced plant or increased plant height.

4. The results have to be proven on M2 generation plants as well.

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ASPEKTI KORIŠĆENJA POTENCIJALNE ENERGIJE BIOMASE NAKON REZIDBE NA PLANTAŽAMA VOĆA I GROŽĐA U REPUBLICI SRBIJI

SAŽETAK

Savremene tehnologije voćarske i vinogradarske proizvodnje podrazumevaju sprovođenje intenzivne rezidbe i na taj način se dobija velika količina biomase, koja ima ekološki i energetski značaj. Korišćenje biomase od ostataka rezidbe za dobijanje toplotne energije daje značajan doprinos očuvanju životne sredine zahvaljujući zatvorenom ciklusu proizvodnje i CO_2 emisije. Ostaci rezidbe na plantažama predstavljaju problem u sprovođenju agrotehničkih mera, pa je zbog toga neophodno njihovo iznošenje van voćnjaka. Ograničene rezerve fosilnih goriva i veliko zagađenje životne sredine nameću potrebu nalaženja izvora alternativne i obnovljive energije, što doprinosi smanjenju zagađenja.

Veoma aktuelan problem predstavlja definisanje optimalnih tehnologija i tehničkih rešenja mašina za korišćenje ostataka rezidbe što značajno povećava energetsku efikasnost ove proizvodnje. Zbog zastarele tehnologije, ekstenzivne proizvodnje i neracionalnog korišćenja energije u našim uslovima ne postoje adekvatna rešenja za prikupljanje, preradu, pripremu i korišćenje biljnih ostataka.

Preduslov za istraživanje ekonomske i tehničke opravdanosti korišćenja ostataka rezidbe (biomaterijala) predstavljaju relevantni podaci o količini energetskom potencijalu, načinu prerade, transportu, cenama, pogodnostima skladištenja, čuvanju i sagorevanju. Najvažnija polazna tačka ovog istraživanja je difinisanje energetskog potencijala ostataka rezidbe na godišnjem nivou. Republika Srbija ima u proseku 600.000 t biomase iz voćnjaka i vinograda.

Savremene tehnologije sagorevanja drvenaste biomase (različite vrste peleta ili drveta za potpalu) imaju visoku efikasnost, minimalnu CO_2 emisiju i veliki komfor korišćenja za grejanje. Prepreke za uvođenje ovih tehnologija u upotrebu su visoki troškovi investicija, a nephodne su subvencije iz budžeta države.

Key words: ostaci rezidbe, energija, upotreba biomase, voće, vinogradi.