COMPARISON OF SOLID BIOFUEL TYPES FROM LINSEED STEMS

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Abstract. The article deals with the possibilities of utilization of different linseed varieties stems for solid biofuel production. The tested varieties were: *Flanders*, *Amon*, *Biltstar*, *Lola*. The harvest residues yield depends on the variety, area, vegetation and used agrotechnical methods. It differs from 2 to 6 $t \cdot ha^{-1}$. But the values close to the lower threshold of this interval are more common in monitored cases, which have a negative effect on the profit. Linseed stems contain relatively high proportion of solid fibers; therefore, a disintegration of material by a cutting mechanism is necessary for further processing. In this case a cutting shredder Kovo Novák RS 650 was used. The processed material was utilized for pellet production at Kovo Novák MGL 200 production line and briquette production at BRIKLIS HLS 50. No adhesives or additives were used during these processes. The energetic and exploitation parameters of the production were monitored and calculated for the differences between these two types of biofuel determination. The basic parameters like dimensions, densities and net calorific values of the final products were measured. The samples of the production were also subjected to the emission analysis and mechanical durability test. The observed and calculated research outputs can provide an information overview for making the decision whether the harvest residues (especially stems) can be utilized for solid biofuel production. It is also important to determine a feasibility of pure linseed utilization or whether a further research of adding other materials for improvement of the results is needed.

Keywords: linseed, biofuels, pellets, briquettes.

Introduction

The purpose of this article is to evaluate a real possibility of linseed harvest residues utilization as sources of feedstock for solid biofuel production. The yield of crop residues (especially the stem) varies in a relatively wide range. It mainly depends on the variety, area, weather during the vegetation period and agrotechnical methods. The values are usually between 2 and 6 tons of dry matter per hectare. Due to focusing on the seed production the stem yield is usually close to the lower threshold of this range. Harvesting a small amount is often beyond feasibility. The most common varieties grown in the Central Europe were monitored in this project: *Biltstar*, *Lola*, *Amon* and *Flanders*.

Another disadvantage of linseed stems during processing is their composition. The stems contain a high proportion of solid fibers. The desired parameters of stems for further processing can only be ensured by disintegrating the material by a cutting mechanism. A study of pelleting and briquetting possibilities of this feedstock and their comparison is necessary. In both cases the largest advantage of the procedure is considerable volume reduction. Especially the briquetting technology is today used for a broad spectrum of wooden, straw and even metallic materials [1 – 3].

Materials and methods

The material was stored in a form of cylindrical bales with 120 cm in diameter and wrapped with a PE wire. These bales were manually dismantled and the feedstock was cleared from larger impurities (stones etc.). The water content was in the range of approx. 8 – 10 %.

Disintegration of the material was realized by the KOVO Novák RS 650 shredder. Its construction allows using sieves with different apertures diameters. The apertures diameters of the used sieves were 4 mm for pellet feedstock and 12 mm for briquette feedstock. Input of the material was manual and in small doses to achieve a continuous and balanced process.

For pellet production the KOVO Novák MGL 200 granulation line was used. This line can process sawdust, hay, paper or feeding mixtures as well as other specific types of biomass. The diameter of produced pellets can be set to 6 or 8 mm by using an appropriate matrix.

The receiving hopper contains a set of rotating steel rods in different heights for disruption of the camber that the feedstock can create. The feedstock is transported by the worm conveyor to the dosing aperture where the accurate dose passes through to the homogenization device and the surplus material falls back to the hopper. In the homgoneziation device the additive componets can be added or the material can be moistend or steamed. The granulation press consists of a matrix and a pair of rollers rotating on its surface. The pellets are then transported to the cylindric sorting apparatus and cooler. For continuous process a constant surveillance is need.

The briquettes were produced by BRIKLIS HLS 50. This device is a hydraulic piston press with one compressing chamber (65 mm in diameter). The press contains a filling hopper with 1 m^3 volume and a piston insertion mechanism. The pressure during production varies from 0.4 to 1 MPa in dependence on the material parameters. There is no need for constant surveillance.

The emission parameters were measured by TESTO 350 XL portable combustion analyzer with O_2, COx and NOx sensors. The measured values were used for calculation with 11 % and 13 % volume of O_2. The mechanical durability test was performed at the durability drum according to the ČSN P CEN/TS 15210-1 and ČSN P CEN/TS 15210-2 standards. The samples are rotating in the drum and are exposed to shocks when hitting each other and walls of the drum. The mechanical durability is calculated from the remaining weight of the samples. This test is important for estimating the behavior of pellets and briquettes during storage and manipulation [2 – 5].

Results and discussion

The measured parameters of the disintegration process (Table 1) showed a significant difference in the specific energy consumption between the used sieves. Its value corresponds to the difference in the aperture diameters. The results are also revealing that the mechanical properties of the stems vary between the varieties.

Table 1

Shredding parameters

Parameter	Variety			
	Biltstar	***Lola***	***Amon***	***Flanders***
Feedstock purpose	**Pellet production**			
Sieve apertures diameter, mm	4.00	4.00	4.00	4.00
Output, $kg \cdot h^{-1}$	44.10	43.10	46.00	41.60
$MJ \cdot kg^{-1}$	0.47	0.33	0.39	0.41
$kWh \cdot kg^{-1}$	0.17	0.12	0.14	0.15
Feedstock purpose	**Briquette production**			
Sieve apertures diameter, mm	12.00	12.00	12.00	12.00
Output, $kg \cdot h^{-1}$	101.30	100.50	103.40	110.00
$MJ \cdot kg^{-1}$	0.19	0.24	0.17	0.15
$kWh \cdot kg^{-1}$	0.07	0.09	0.06	0.05

No additives or binders were used during the pellet production. The material was only slightly moistened in the homogenization device when needed. The measured parameters are shown in Table 2. The production output of the production line is relatively low. Especially the values measured in the case of *Biltstar* variety are extremely low. According to [6], the products would be classified as alternative pellets – agropellets.

Table 2

Pellet production parameters

Parameter	Variety			
	Biltstar	***Lola***	***Amon***	***Flanders***
Feedstock purpose	Pellets production			
Matrix apert. Diameter, mm	6.00	6.00	6.00	6.00
Output, $kg \cdot h^{-1}$	14.90	33.60	53.30	35.00
Specific energy consumed, $MJ \cdot kg^{-1}$	1.43	0.41	0.48	0.38
Specific energy consumed, $kWh \cdot kg^{-1}$	0.52	0.15	0.17	0.14
Avg. length, mm	14.67	17.16	16.13	18.82
Density, $kg \cdot m^{-3}$	1068.97	1098.63	963.25	1024.00
Net calorific value, $MJ \cdot kg^{-1}$	16.08	15.86	15.82	16.53

The production output results of the briquette production line are more balanced than in the previous case; however, all the values are relatively low as well. The specific energy consumption per kg is significantly lower than for pelleting. The parameters are in Table 3.

Table 3

Briquette production parameters

Parameter	Variety			
	Biltstar	***Lola***	***Amon***	***Flanders***
Feedstock purpose	Briquettes production			
Matrix apert. diameter, mm	65.00	65.00	65.00	65.00
Output, $kg \cdot h^{-1}$	34.90	31.00	33.00	28.40
Specific energy consumed, $MJ \cdot kg^{-1}$	0.11	0.16	0.22	0.18
Specific energy consumed, $kWh.kg^{-1}$	0.04	0.06	0.08	0.07
Avg. length, mm	61.10	54.14	54.60	59.90
Density, $kg \cdot m^{-3}$	503.61	674.60	567.40	568.80
Net calorific value, $MJ \cdot kg^{-1}$	16.18	15.96	15.91	16.62

The net calorific value is almost equal for both types of products, which was expected. Minor changes can be seen across the varieties. A big advantage of pellets is higher energy density. The results of the product mechanical durability test, which are shown in Table 4, are very important.

Table 4

Mechanical durability results

Parameter	Variety			
	Biltstar	***Lola***	***Amon***	***Flanders***
Pellet mech. dur., %	95.60	97.05	96.78	96.82
Briquette mech. dur., %	46.33	73.81	60.30	68.48

The results of the produced pellets are very good considering the production method. On the other hand, the briquette results are very unsatisfactory. Especially in the case of *Biltstar* variety the mechanical durability is less than 50%. Similar problems have occurred, e.g., during the tests of reed canary grass briquetting [7].

Table 5 contains the results of emission analysis for the used varieties.

Table 5

Emissions and ash content of different varieties

Parameter	Variety			
	Biltstar	***Lola***	***Amon***	***Flanders***
CO, ppm	3274.77	1622.77	2966.06	1456.35
CO, $mg \cdot m^{-3}$	4093.47	2028.46	3707.58	1820.44
CO $mg \cdot m^{-3}$with O_2 13%	14659.29	7663.58	15382.14	6075.11
CO $mg \cdot m^{-3}$with O_2 11 %	18347.17	9591.52	19251.87	7603.44
NO ppm	71.41	34.14	50.80	46.73
NO $mg \cdot m^{-3}$	95.68	45.75	68.08	62.62
NO_2 ppm	0.00	0.08	0.08	0.07
NO_2 $mg \cdot m^{-3}$	0.01	0.17	0.16	0.14
NO_x $mg \cdot m^{-3}$ with O_2 13%	280.40	114.69	250.96	126.51
NO_x $mg \cdot m^{-3}$ with O_2 11%	350.94	143.55	314.09	158.34
CO_2 %	2.47	3.06	2.18	3.40
O_2 %	18.35	17.71	18.80	17.23
Ash cont. % weight	2.90	2.12	2.67	2.36

Conclusions

1. The difference between the energy consumption during production of pellets and briquettes from linseed stems is very significant. The energy consumption during briquetting represents approx. 40 – 55 % of the values measured during the pellet production. In case of *Biltstar* variety the difference is even higher.
2. Mechanical durability of briquettes is unsatisfactory. The used production setup is not suitable for market oriented production.
3. The energy output of the linseed biofuels can be evaluated as satisfactory. According to the measured and calculated values and relatively low yield in the conditions of the Czech Republic linseed should be considered for production of mixed solid biofuels.

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