# LABORATORY TESTING OF MECHANICAL PROPERTIES OF AGRI AND BLEND PELLETS

Viktória Papp, Dóra Szalay

University of Sopron, Faculty of Forestry, Bajcsy Zs. street 4., 9400, Sopron, Hungary

**Abstract**

*As an indirect consequence of climate change, the reduction of carbon dioxide emissions, the energy utilization of agricultural by-products will be increasingly emphasized in the future. Pellet production is one possible way to utilize the residues for energy purposes. Mixtures of different plant residues (wheat straw, rapeseed stem) and agri-pellets have different energetic and mechanical properties. Besides high ash content and low ash softening temperature, mechanical properties can also significantly affect the quality of pellets as well as the efficiency of firing. There were also significant differences in diameter, length, bulk density and mechanical durability of pellets.*

**Keywords:** *agripellet, mechanical testing, blend pellets, wheat straw, rape seed stem*

## INTRODUCTION

Since the Industrial Revolution, $CO_2$ levels have risen from 180 ppm to over 400 ppm and other greenhouse gases such as methane and $N_2O$ are rising, which, according to several researchers has triggered an irreversible warming process [National Atmospheric Administration 2018]. In addition to environmental reasons, energy supply based on fossil resources in the European Union and in Hungary also leads to strong import dependency. Due to its soil and climatological features, Hungary has a large potential of biomass for energy purposes. In order to increase the share of renewable energies, the energetic utilization of biomass is a possible alternative. Forestry, wood industrial and agricultural by-products are available in large quantities. The common feature of the raw materials is that they are difficult to handle in their original condition, their firing is problematic and they have low bulk density. Pelletizing is a compression process that produces fuel that can be used in automated systems.

The pellet sector has started to develop rapidly in Europe, and in recent years the number of wood pellet factories has been doubled, mainly using wood shavings as a by-product of wood industry. Due to increasing the share of renewable energies and the limited availability of wood-based stocks pellets are produced from agricultural by-products, mainly from straw and stems will play a greater role in the future. These herbaceous plants residues are re-produced on arable land every year and have significant potential for energy utilization. The use of agripellets in the European Union is also steadily increasing, but it is still dwarfing compared to a higher quality wood pellet.

There are several reasons for the slower spread of agri-pellets. The high ash content of the herbaceous plants and the low ash melting temperatures often cause problems in the burning systems. Melting and slagging temperatures of wood-based fuels are generally above 1000 ° C degrees, around 1100-1200 ° C degrees, in contrast, the herbaceous plants which melt around 600-850 ° C [Tóvári-Marosvölgyi 2011, Carborobot 2014, Papp –Marosvölgyi 2011, Toscano-Corinaldesi 2010]. In addition, the energy characteristics and the heating value are significantly lower than in wood pellets[Papp 2018].

Wood pellets and agripellets are produced under high pressure usually at 800-1000 bar. Wood shavings and various agricultural by-products have a low volumetric density therefore one of the best ways to increase energy density is to compress the raw material. The bulk density of the starting material during compaction is increased from 80 - 160 kg / $m^3$ [Fenyvesi et al. 2008] to 600-850 kg / $m^3$ [Ongrádi, 2006]. In Europe, pellets of 6 and 8 mm diameter have spread. Of the chemical components, the presence of lignin, pentosans, and protein greatly influences the properties of the pellets. The presence of lignin changes the bonding properties. It melts at a relatively low temperature of 140 $C^o$, and later holds together the particles after compaction [Dam, - Oever, -Teunissen 2004]. Protein content also plays an important role in the formation of pellets. The residence time,

temperature and high pressure cause partial denaturation of proteins [Wood 1987]. Caroll and Finnan studied chemical and physical properties of pellets by woody and herbaceous material, rapeseed straw, wheat straw, barley straw and energy crops, willow and mischantus reeds. According to their results, the upper heating value of rapeseed was 18.2 MJ / kg, the ash content was 5.3%. Different pellets were produced at 6 mm press hole with a small pelletizer (max capacity 150 kg / h). Among the investigated materials, the mechanical durability of Mischantus reed was 95,2% the rapeseed stem pellet was 95.8%, wheat and barley straw pellets were better 96.3% and 96.8%[Caroll-Finnan 2012]. The post-grinding fraction distribution has not been published, this may also be related to the mechanical properties of reed and rapeseed pellets.

The stems of cane and rapeseed are also fibrous, hard to grind, so the ratio of fiber fraction can be higher. Based on the chemical composition analysis, the rapeseed staw had the highest carbon content of 50.9%, wheat and barley straw was 46-47%. Hydrogen content in rapeseed stem was 6.6%, Miscanthus reed was 6.5%, while in case of cereal straw it was slightly lower 5.3-5.5%.

## MATERIAL AND METHOD (TEST PRESENTATION)

In the course of the experiments, a mixture of pellets of pure rape stem and wheat straw was produced by experimental (Kahl type) pelletizing equipment. The rape stem utilization is justified by the fact that in recent years its production area has increased significantly in Hungary, in the year 2018 it was grown on more than 300 thousand hectares [KSH 2019]. The amount of rape stem per hectare can be twice the weight of the seed. The largest area in the country is occupied by cereals, wheat and barley. Significant amounts of by-products, straw and stem are produced annually of which a significant part could be used for energy purposes.

In the course of the tests, three types of agripellets were produced, a pellet with a 6 mm diameter press hole from a pure rapeseed stem, a 8 mm diameter hole with rape stem and with the addition of 50 % wheat straw. The diameter and length of the finished pellet, the fine particle size and the mechanical durability were examined.

The determination of the fine particle is an important aspect of the combustion technology of pellets. If the fine proportion is too high, problems may arise during combustion, the flue gas composition changes, efficiency decreases. A perforated sieve made in accordance with ISO 3310-2 should be used - according to MSZ EN 15210-1 - to sieved the pellet to determine the fine particle size (the so-called "crumb").



**Fig. 1.** Determining the fine proportion by sieving

From a sample of about 1.2 kg, the sieve is used to manually remove the crumb by a few circular movements, which can be calculated with the following formula:

$$F = 1 - \frac{m_A}{m_E} \quad [\%] \qquad (1)$$

where

F – Fine fraction proportion [%]

mE - sample weight before sieving [g]

mA - sample weight after sieving [g]

Mechanical resistance and durability of pellets (DU)

The mechanical durability of pellets is described in MSZ EB 15210-2 standard. The measurement was carried out by the self-developed equipment of the University of Sopron, Institute of Mechanical Engineering and Mechatronics in accordance with the standard. The 500 ± 10 g pellet, which had to be sieved and weighed on a 3.15 mm perforated sieve, was loaded into the pellet testing apparatus (shown in Figure 2) and then rotated for 10 minutes at 50 ± 2 round/min the pattern. After the mechanical rotation, the pellet is filled into the sieve and weighted again.



**Fig. 2.** Measurement of mechanical durability

Determine the mechanical durability of the pellet using the two samples measured and the following formula:

$$D_U = \frac{m'_A}{m'_E} \quad [\%] \qquad (2)$$

where:

Du – Mechanical durability (%)

m'E - Weight of pellets above 3.15 mm before mechanical treatment (after sieving) [g]

m'A - Weight of pellets above 3.15 mm after mechanical treatment (after sieving) [g]

Pellet length and diameter

In the case of pellets, it is an important requirement, based on the ENplus recommendation using EN 14961-2, to have an average length of between 3.15 and 40 mm. The length of the pellets can be influenced by many factors. The particle size, moisture, and above all the material composition. The tests should be carried out on all pellets in a sample of 80 to 100 grams using a simple caliper. Measuring uncertainty is of paramount importance in measuring length, since subjective determination of the center of measurement of length and other random measurement errors can result in a

significant absolute error. According to the research of wood pellets published by Németh in 2014, the calculated total error was ± 1.66 mm (including the 0.02 mm error of the instrument) [Németh 2014]. Its significance lies in the fact that in case of measured pellet types it is not practical to simply accept the results obtained as an average, but it is necessary to give the mean length values together with the measurement error [Németh 2014].

Bulk (Volumetric) density ("BD")

Bulk density is an important parameter in the transport of pellets. According to MSZ EN 15103, an analytical balance and a standard 5 liter tank are required for testing as shown in Figure 3.



**Fig. 3.** Measurement of bulk density

Based on the following formula, this parameter can be calculated by taking the measured values into account:

$$BD_{ar} = \frac{(m_2 - m_1)}{V} \left[\frac{kg}{m^3}\right] \quad (3)$$

BDar - volume density of the sample taken (moisture content)

m1 - tank weight [kg]

m2 - total weight of the sample and tank (“saturated” tank weight) [kg]

V - tank volume [m3]

## RESULTS

There was a significant difference in the mechanical properties of the pellets due to the different diameters and the mixture of different materials. The measurements were repeated three times, the average of the results being shown in the following Table 1.

**Table 1.** Mechanical properties of rape seed stem and wheat straw bled pellets

| | Fine fraction proportion % | Bulk density kg/m3 | Mechanical durability % | Mean medium length mm | Mean diameter mm |
|---|---|---|---|---|---|
| Rapeseed stem pellet 6 mm | 0,3 | 638 | 97,3 | 17,1 | 6,4 |
| Rapeseed stem pellet 8 mm | 0,6 | 610 | 96,4 | 15,4 | 8,5 |
| Rapeseed stem-wheat straw(50%) 8 mm | 0,3 | 612 | 98,1 | 16,2 | 8,4 |

The average medium length of the 8mm pellet was significantly lower than the 6mm rapeseed stem pellet. The fine proportion of pure rapeseed stem pellets was higher than that of the blend pellets. Mechanical strength was also better for blend pellets, which is important from a firing point of view. If the proportion of small, fragmented fractions is too high, the efficiency may decrease. According to the quality requirements, the rapeseed straw pellets can be classified into EN-B category based on mechanical properties, while the mix pellet can be classified into EN A2 category. However, the ash content for each pellet exceeded the 3% allowed for the agripellets, which is only the EN-B category.

## CONCLUSIONS

There were significant differences in the mechanical properties of the examined pellets. The different press hole diameters and the different material composition also affected the results. Properties of pellets made from rapeseed stems was less favorable than wheat straw blends. The mechanical properties can significantly affect the firing parameters. In the future, flue gas analysis tests could be carried out to get information on efficiency and other firing parameters.

## ACKNOWLEDGEMENT

The described work was carried out as part of the „Sustainable Raw Material Management Thematic Network – RING 2017”, EFOP-3.6.2-16-2017-00010 project in the framework of the Széchenyi 2020 Program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

## REFERENCES

Carborobot (2014): Pellet, Agripellet, Pelletfajták - http://www.carborobot.hu/HU/Pellet.htm

Caroll J. – Finnan J. (2012) - Physical and chemical properties of pellets from energy crops and cereal straws, Biosystems enrineering, 151-159 p.

Fenyvesi L., Ferencz Á., Tóvári P. (2008): A tűzipellet, 11.p. Cser Kiadó, Budapest, ISBN 9639759848

J.E.G. van Dam, M.J.A. van den Oever, W. Teunissen, E.R.P. Keijsers, A.G. Peralta(2004)-Process for production of high density/high performance binderless boards from whole husk Part 1: lignin as intrinsic thermosetting binder resin-Industrial Crops and Products, 19, pp. 207–216

KSH(2019): Central Statistical Office, Főbb mezőgazdasági növények termőterülete, Idősoros jelentés, http://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_omn007a.html

Marosvölgyi B. (2006): Szilárd, biomassza alapú tüzelőanyagok energetikai tulajdonságainak vizsgálata-http://docplayer.hu/12093734-Szilard-biomassza-alapu-tuzeloanyagok-energetikai-tulajdonsagainak-vizsgalata-segedlet.html

Németh G. (2014): Kis teljesítményű faalapú pellet tüzelő berendezés környezeti hatásainak vizsgálata, Faipar, 62.évf. HU-ISSN -00146897

Ongrádi M.(2006): A szalma, mint energiaforrás, Cser Kiadó, Budapest, ISBN 9639666106

Papp V.(2018): Energetikai pelletek előállításának és hasznosításának ökoenergetikai vonatkozásai, Doktori értekezés, Soproni Egyetem, 67.p.

Papp V.-Marosvölgyi B.(2013): A pellet mint megújuló energiaforrás előállítása, hasznosítása és energetikai értékelése- Energiagazdálkodás, 21 pp. ISSN 0021-0757.

Papp V. –Marosvölgyi B. (2011): Research of energy balance of pellet and briquette production In: Bioenergy and Other Renewable Energy Technologies and Systems. Bucuresti: PRINTECH, 2011. pp. 16-17. (ISBN:978-606-521-686-0)

Szamosi Z., Lakatos K., Siménfalvi Z.(2012): Az agripellet, mint megújuló energiaforrás vizsgálata, GÉP Magazin, 63.évf/6 77.pp. ISSN 0016-8572

Tóvári P.- Marosvölgyi B. (2011) - BIOMASSZA TÜZELŐANYAGOK TERMIKUS KEZELÉSÉNEK LABORATÓRIUMI MODELLEZÉSE, NYME KKK Ökoenergetikai főirány, Jelentés, 12p.

Toscano P.-Corinaldesi F. (2010): - ASH FUSIBILITY CHARACTERISTICS OF SOME BIOMASS FEEDSTOCKS AND EXAMINATION OF THE EFFECTS OF INORGANIC ADDITIVES, Journal of Agricultural Engineering, Vol 2. 14.p.

Wood F. J. (1987): The functional properties of feed raw materials and their effect on the production and quality of feed pellets-Animal Feed Science Technology, 18, pp. 17.