Change in humidity of solid biofuels

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ABSTRACT: Humidity, as one of the most important physical properties of pressed solid biofuels, affects thel calorific value of the biofuel and its consistency. Biofuel humidity depends on the initial humidity of raw material, which varies and depends on many factors. Method of manufacture and place and duration of storage have a considerable effect on solid biofuel humidity as well. Humidity of pressed solid biofuels changes not only during the pressing itself, when temperature increases by compression and a part of contained moisture evaporates, but also in the course of handling and storage under unstable environment conditions with high relative air humidity, when, on the contrary, their humidity gradually increases due to their hygroscopicity. Properties of solid biofuels change with their increasing humidity – their calorific value and consistency decreasing and the share of crumbles increasing.

Keywords: phytomass; solid biofuels; humidity; calorific value

Considering the expected development of phytoenergetics, we will not manage only with wastes or subproducts as till now, but it will be necessary to provide sufficiency of suitable substances also from purposefully cultivated, i.e. "energy crops" (KOVÁŘOVÁ et al. 2002). Today, potential of wood and wood wastes is utilised to the largest extent, but big reserves exist as to the utilisation of straw and specifically cultivated woody species and herbs. To accelerate biomass utilisation, biofuel market should be supported and consumers should be persuaded to use biomass energy. To reach this goal it is necessary to offer biofuels with properties comparable to those of the existing fossil fuels. These properties include especially the physical and chemical characteristics, price, environmental friendliness etc. Solid biofuels are manufactured of various raw materials of different properties and therefore their standardisation is necessary (SLADKÝ 1998). Technology procedures for utilisation of solid biofuels put high demands on their physico-mechanical properties, primarily on humidity, specific weight, shape, size and consistency. Determination of the fuel properties is important not only from the manufacturer's point of view, but also from the point of view of customers and businessmen. Nowadays, there are no standards for biofuels (except for biodiesel), which is a principal obstacle to the establishment and development of the market with solid biofuels.

MATERIAL AND METHODOLOGY

Energy crops having great energy yield – white melilot *(Meliotus albus)*, sorghum hyso *(Sorghum vulgare)* and

Fig. 1. Pressing machine and granulator

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Table 1. Specification of storing conditions

Storehousing conditions	Parameter	Monitoring time (week)			
		0–2	2–4	4–6	6–8
Storehouse	Average temperature (°C)	17.0	16.5	15.8	17.2
	Average relative humidity (%)	75	75	75	75
Shelter	Average temperature (°C)	–0.4	–4.1	–2.6	1.2
	Average relative humidity (%)	99	95	95	99

secondary raw materials – oat grass straw (after extraction of seed) (*Arrhenatherum elatius)* and cereal straw (after seed extraction), which are some of the most suitable energy plants (USŤAK 2002), were selected for measuring physico-mechanical characteristics of solid biofuels.

This phytomass was pressed by the pressing machine modified to enable cutting of the matter, the pressing itself, cooling and storing of the pellets in a silo (Fig. 1). A key part of the machine consists of a shaping press with the plate matrix (Fig. 2). Diameter of pellets produced was 21 mm and their length ranged from 5 to 10 mm. A 185kW diesel engine was used to drive the machine (HENEMAN 2003).

Pellets manufactured were subject to detection of humidity change during pressing, subsequent cooling and in the course of storing. These pellets were stored for differently long period and under different storing conditions (Table 1). Following variants of pellet storage were used:
- In an insulated fuel store with a relatively constant environment (temperature and relative air humidity);
- In plastic bags stored inside the same warehouse;
- Under an outside shelter with variable conditions of storage (temperature and relative air humidity).

Test samples were taken at the identical time intervals of two weeks. Total time of monitoring was 2 months.

RESULTS

Table 2 presents the values of pellet humidity for 4 different crops during pressing, cooling and storing under various conditions. Figs. 2 and 3 show the curves in the changes of monitored variables.

CONCLUSION AND DISCUSSION

The analysis revealed that the relative humidity of pressed material was significantly reduced during pressing due to high temperature used in this process (approx. 85°C) and due to the subsequent evaporation of partial humidity in the course of cooling pellets in a silo using the air stream (Table 2). The highest decrease in the moisture content of pellets was detected in oat grass (by 7.79%) and the lowest decrease was recorded in straw (by 4.55%), which was given by their different humidity – lowest for straw (13.56%) and highest for oat grass (22.09%).

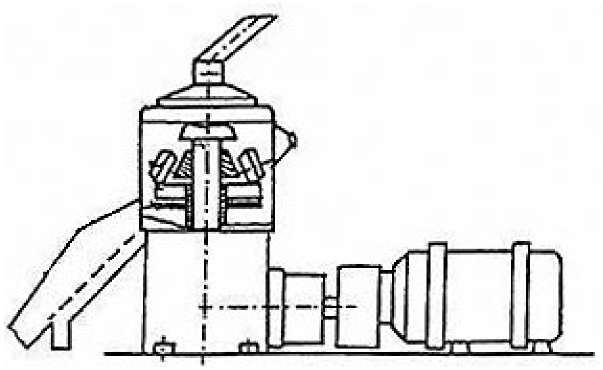


Fig. 2. Diagram of the shaping press with the plate matrix

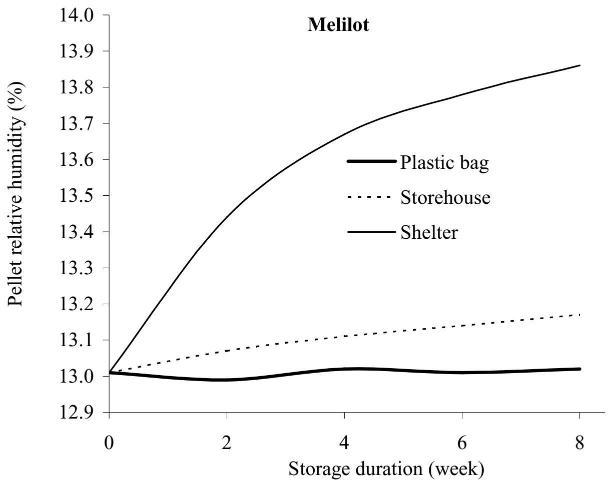
Correlative coefficients and regression equations for dependence of pellet relative humidity change on storage duration were calculated using StatSoft program statistic methods. Regression equations and coefficients are shown in Fig. 4. Level of significance was 95% in all cases.

Table 2 and Fig. 3 reveal a pellet humidity increase during storage, which is also demonstrated by the correlation coefficients – high dependence of pellet relative humidity change on storage duration. Humidity of pellets stored in plastic bags practically did not change. Pellets stored outside under the shelter (wet and unstable environment conditions) got wet most, pellets stored inside the storehouse (dry and relatively stable environment) got wet at a minimum. Relative humidity of straw pellets (pellets with the lowest initial humidity) increased most. The minimum increase of humidity was recorded in oat grass pellets (the highest initial humidity). These graphs also very well demonstrate the rapid initial increase of pellet relative humidity and then the slow humidity stabilisation. A complete static humidity could not be achieved, however.

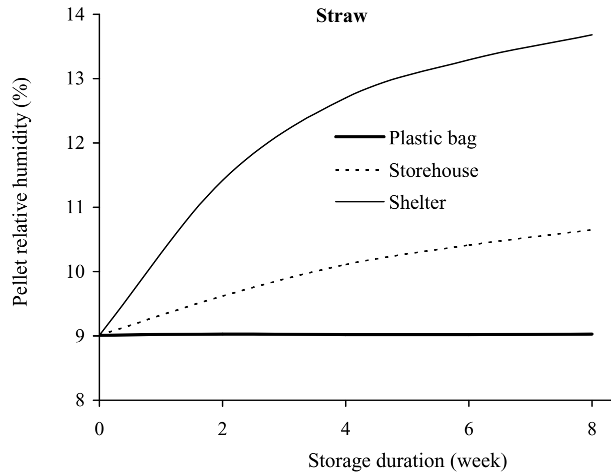
Pellets stored in humid conditions are observed to become wet, swollen and thus expanded, with strength bonds established by pressing being destroyed, which results in the change of physico-mechanical characteristics, especially calorific value and strength properties. Pellets are observed to exhibit crumbling and gradual disintegration, which results in the subsequent problems in both handling and burning the pellets due to the change of their granularity. For these reasons, the pellets and all biofuels pressed should be stored in protective

Table 2. Change in pellet relative humidity during pressing, cooling and storing

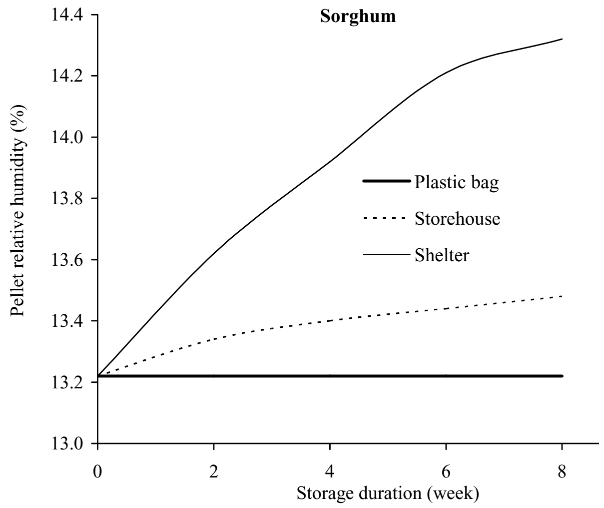
Crop	Item. No.	Chopped straw humidity	Pellet relative humidity during individual time segments (%)														
			Plastic bag					Storehouse					Shelter				
			0	2	4	6	8	0	2	4	6	8	0	2	4	6	8
Melilot	1	20.47	13.1	12.84	13.22	12.69	12.88	13.1	13.18	12.94	13.12	13.11	13.1	13.3	13.75	13.62	13.82
	2	20.46	12.84	13.04	13.11	13.21	12.97	12.84	12.98	13.06	12.81	13.02	12.84	13.41	13.83	13.84	13.61
	3	20.31	13.08	13.09	12.73	13.13	13.21	13.08	13.05	13.33	13.49	13.38	13.08	13.61	13.44	13.88	14.15
	∅	**20.41**	**13.01**	**12.99**	**13.02**	**13.01**	**13.02**	**13.01**	**13.07**	**13.11**	**13.14**	**13.17**	**13.01**	**13.44**	**13.67**	**13.78**	**13.86**
Straw	1	13.14	8.84	9.11	9.2	8.94	9.06	8.84	9.75	9.88	10.33	10.53	8.84	11.19	12.68	13.61	13.61
	2	13.48	9.25	9.06	8.98	9.17	9.02	9.25	9.37	10.2	10.58	10.7	9.25	11.48	12.82	13.01	13.74
	3	14.06	9.21	8.92	8.87	8.95	9.01	9.21	9.74	10.25	10.32	10.72	9.21	11.59	12.59	13.25	13.69
	∅	**13.56**	**9.01**	**9.03**	**9.02**	**9.02**	**9.03**	**9.01**	**9.62**	**10.11**	**10.41**	**10.65**	**9.01**	**11.42**	**12.7**	**13.29**	**13.68**
Sorghum	1	20.1	13.2	13.22	13.22	13.2	13.18	13.2	13.26	13.3	13.28	13.47	13.2	13.51	14.09	14.17	14.02
	2	19.54	13.21	13.2	13.21	13.19	13.23	13.21	13.41	13.46	13.51	13.58	13.21	13.73	13.82	14.18	14.48
	3	19.88	13.25	13.21	13.23	13.24	13.22	13.25	13.35	13.44	13.53	13.39	13.25	13.62	13.85	14.28	14.46
	∅	**19.84**	**13.22**	**13.21**	**13.22**	**13.21**	**13.21**	**13.22**	**13.34**	**13.4**	**13.44**	**13.48**	**13.22**	**13.62**	**13.92**	**14.21**	**14.32**
Oat grass	1	21.87	14.31	14.28	14.35	14.33	14.31	14.31	14.27	14.38	14.31	14.33	14.38	14.5	14.75	14.91	15.06
	2	22.2	14.26	14.3	14.31	14.32	14.29	14.26	14.36	14.32	14.41	14.4	14.14	14.69	14.9	14.82	14.89
	3	22.2	14.33	14.32	14.3	14.28	14.3	14.33	14.39	14.35	14.39	14.41	14.38	14.67	14.81	14.97	14.87
	∅	**22.09**	**14.3**	**14.3**	**14.32**	**14.31**	**14.3**	**14.3**	**14.34**	**14.35**	**14.37**	**14.38**	**14.3**	**14.62**	**14.82**	**14.9**	**14.94**



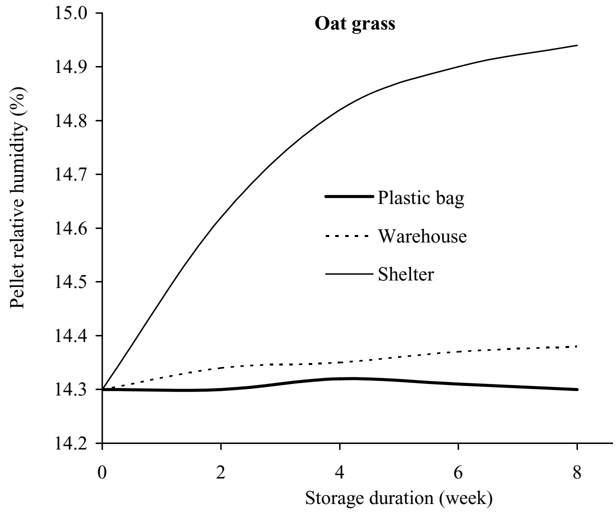
Plastic bag: $y = 13.002 + 0.002000 \times x$ $r = 0.51640$
Storehouse: $y = 13.022 + 0.01950 \times x$ $r = 0.98742$
Shelter: $y = 13.144 + 0.100200 \times x$ $r = 0.94392$



Plastic bag: $y = 9.0160 + 0.00150 \times x$ $r = 0.56695$
Storehouse: $y = 9.1460 + 0.20350 \times x$ $r = 0.98159$
Shelter: $y = 9.7780 + 0.56050 \times x$ $r = 0.93904$



Plastic bag: $y = 13.099 + 0.02130 \times x$ $r = 0.74082$
Storehouse: $y = 13.252 + 0.03100 \times x$ $r = 0.96686$
Shelter: $y = 13.300 + 0.13950 \times x$ $r = 0.98342$



Plastic bag: $y = 14.304 + 0.05003 \times x$ $r = 0.76781$
Storehouse: $y = 14.310 + 0.00950 \times x$ $r = 0.96458$
Shelter: $y = 14.404 + 0.07800 \times x$ $r = 0.93711$

Fig. 3. Change in pellet relative humidity depending on various storing conditions and storage duration

waterproof packages to prevent damages during the handling, or at least in insulated stores (HARTMANN 2000).

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Změna vlhkosti pevných biopaliv

ABSTRAKT: S předpokládaným rozvojem fytoenergetiky nevystačíme jen s odpady či vedlejšími produkty jako doposud, ale bude nutné zajistit dostatek vhodné hmoty také z cíleně pěstovaných, tj. „energetických" plodin (KOVÁŘOVÁ et al. 2002). V současnosti se nejvíce využívá potenciálu dřeva a dřevních odpadů, velké rezervy však existují ve využití slámy a cíleně pěstovaných dřevin a bylin. Aby bylo co nejrychleji dosaženo zvýšeného využití biomasy, je třeba podpořit trh s biopalivy a přesvědčit spotřebitele k využívání energie biomasy; toho dosáhneme především nabídkou biopaliv srovnatelných vlastností proti palivům dosavadním (fosilním). Mezi ně patří především vlastnosti fyzikální a chemické, dále pak cena, šetrnost k životnímu prostředí a mnoho dalších faktorů. Pevná biopaliva jsou vyráběna z různých surovin s odlišnými vlastnostmi a je proto nutná jejich standardizace (SLADKÝ 1998). Technologie využití pevných biopaliv kladou vysoké nároky na jejich fyzikálně mechanické vlastnosti, a to především na vlhkost, měrnou hmotnost, tvar, velikost a soudržnost. Zjištění vlastností biopaliv je důležité nejen z pohledu výrobce, ale také z pohledu zákazníka a obchodníka. V současné době však neexistují žádné normy na biopaliva (s výjimkou bionafty), což je hlavní překážkou pro tvorbu a rozvoj trhu s pevnými biopalivy.

Klíčová slova: fytomasa; pevná biopaliva; vlhkost; výhřevnost

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