Technical Note

Changes in Thermal Energy with Moisture Content for Representative Wood Pellet Fuels in the Northeast

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Abstract

Gross heating values for densified wood residues made in the northeastern United States are shown as a function of moisture content (MC). As expected, the trend is clear, and the fuel values decrease sharply as MC increases. What is also clear is that storage time and storage conditions are important considerations for those using pellet fuels as an energy source. Typically, large quantities of pellets are purchased and stored for months before use. Moist storage conditions or long storage times could substantially change the quantity of pellets required to heat a structure.

The use of mill residuals and clean biomass as a source for residential and commercial fuel continues to grow. According to Spelter and Toth (2009), wood pellet manufacturing capacity has expanded rapidly in North America from just over 1 million tons in 2004 to an expected capacity of over 6 million tons in 2009. As part of a larger study of thermal energy values, we have measured the thermal energy of wood pellets at four moisture content (MC) levels. The data show that storage conditions can affect the heat of combustion of pellets.

Although the change in thermal energy with MC of both wood and bark is well known, few data have been produced for northeastern species, and fewer still are available for pellet fuels from New England. Among others, data on gross and higher heating values[1] for wood and biomass have been reported or produced by Murphey and Cutter (1974), Corder (1975), and Ince (1979). All publications show a strong dependence of energy value on MC, and Corder and Ince show that softwoods tend to have a slightly higher energy value, per pound, than hardwoods, although exceptions exist. Density, although important, is seldom discussed directly.

Generally, pellet fuels are made from mill residuals, and most of those are hardwoods. Nationwide, about 53 percent of fuel pellets are made from hardwoods exclusively, 33 percent from softwoods exclusively, and 14 percent from a hardwood/softwood blend.[2] It is understood that furnish composition changes with availability and that a mill using either hardwoods or softwoods exclusively could easily use a blend of hardwoods and softwoods should the opportunity arise.

In New England, the common practice is to mix the residues, run them through an attrition mill to comminute them to a smaller size, and then dry them in a rotary, multipass drying system. The furnish is then stored for a short time before pelletizing at approximately 10 to 12 percent MC (wet basis). After pelletizing, the MC range is approximately 4.5 to 8 percent MC (wet basis) but tends toward the lower end of the range.

Materials and Methods

Pellets from a representative New England manufacturer were used for the testing. The pellets consisted of a blend of approximately 80 percent mixed hardwoods (typically beech, birch, maple, and aspen) and 20 percent softwoods (typically white spruce and Eastern white pine) obtained from clean (essentially bark-free), green mill residues.

Pellets from two different batches of pellets from the manufacturer were used for all tests. One batch was produced during the spring and the other during the summer. Portions from the larger batches from the manufacturer were sealed in commercial plastic bags at the time of manufacture and kept stored at the University of Maine. Using a riffler, small samples from the bags representing each batch were conditioned, and two subsam-

[1] It is common to describe energy values or heat of combustion values as higher heating values (HHV) for moisture-free material and gross heating values (GHV) or lower heating values (LHV) for material containing moisture.

[2] Unpublished results from a nationwide survey of pellet manufacturers completed June 2010 by Ning Lu and R. W. Rice, University of Maine, Orono.

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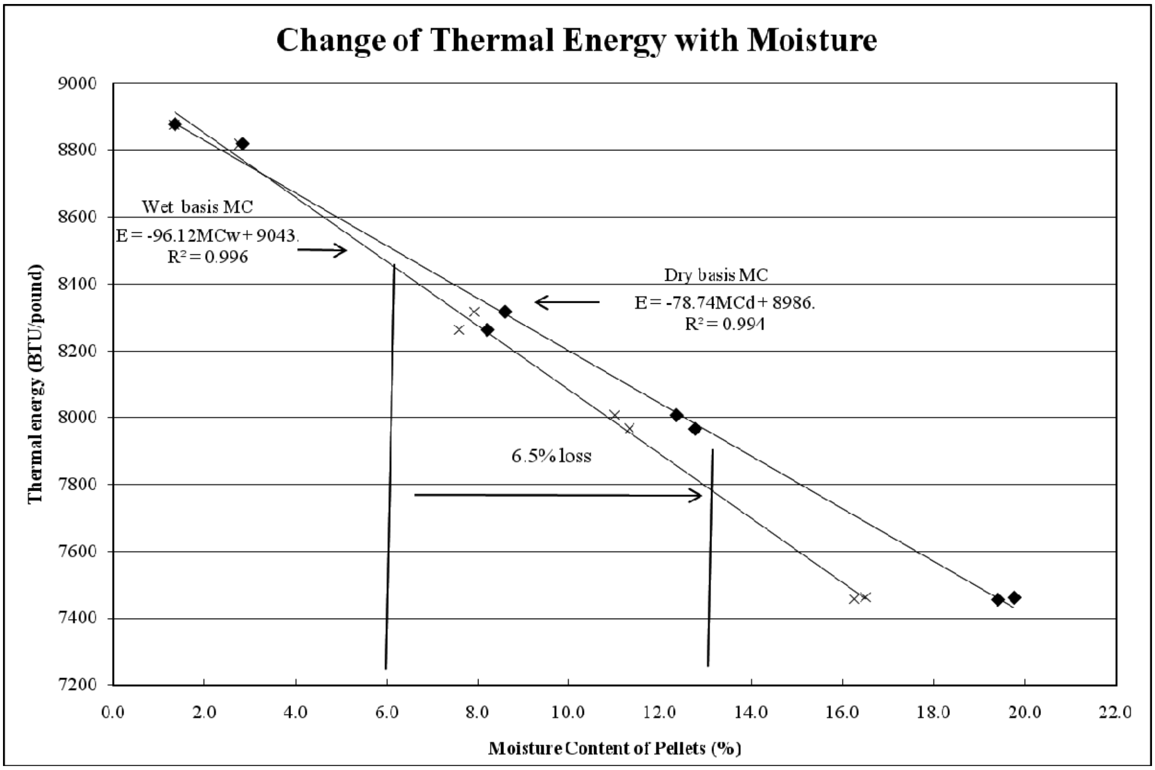

Figure 1.—Change of energy with moisture content (MC) using both wet- and dry-basis MC.

ples were fired in a Parr 6100 calorimeter to determine the energy values at each MC. The Parr 6100 is an isoperibol calorimeter and was recently calibrated.[3] Further, the oxygen bombs have undergone repeated calibration testing using a benzoic acid standard. Fuse and acid corrections were not used, as previous testing has shown them to be inconsequential.

The data were analyzed and graphed using Excel, and the regression analysis was done using a standard linear regression analysis built into that program. The *P* value or probability value listed in the ''Results and Discussion'' is a measure of how much evidence there is against the null hypothesis that the means are the same for both sets of data. The smaller the *P* value, the more evidence we have against the null hypothesis.

Results and Discussion

Table 1 is a summary of the gross heating values (GHV) and MC of the samples tested. Slight differences in MC are due to normal variations in environmental conditions, and the slight differences in thermal energy values are typical and related to the precision of the environmental conditions and to the slight variation of the calorimeter (see footnote 3). The bulk density of fuel pellets is fairly consistent and ranges from about 40 to 42 pounds per cubic foot. Ash values are generally less than 0.5 percent.

Among producers of fuel pellets, a commonly held belief is that the pelletizing process substantially lowers the hygroscopicity of the pellets. In this limited series of tests, the length of time needed to condition the pellets was short. Although the samples were small, the large amount of surface area is conducive to moisture change. The surface area, combined with the relatively low temperatures found during pelletizing, did not seem to affect the moisture sorption significantly, although further verification is needed.

The mean data from each batch at each MC were graphed and are shown in Figure 1. Although no values for fuel energy have been published for pellets made in the

Table 1.—GHV and MC for the pellets tested.[a]

			MC	
Batch no.	Sample	GHV (Btu/lb)	% wet basis	% dry basis
1	1	8,301.7	8.0	8.7
	2	8,332.2	7.9	8.5
2	1	8,274.1	7.6	8.3
	2	8,252.3	7.5	8.1
1	1	7,489.2	16.2	19.4
	2	7,424.5	16.3	19.5
2	1	7,429.4	16.3	19.5
	2	7,497.5	16.7	20.1
1	1	8,891.1	1.2	1.2
	2	8,860.1	1.5	1.5
2	1	8,826.7	2.8	2.9
	2	8,810.7	2.7	2.8
1	1	7,970.8	11.4	12.9
	2	7,963.6	11.2	12.7
2	1	7,999.0	11.1	12.5
	2	8,017.2	10.9	12.3

[a] GHV = gross heating value; MC = moisture content.

[3] The calorimeter is calibrated approximately semiannually using a benzoic acid standard from the manufacturer. The Parr 6100 has a standard deviation of about 0.2 percent of the mean when properly calibrated and used in a controlled environment.

Table 2.—Measured and calculated energy values assuming an HHV of 9,043 Btu/lb.[a]

MC (% wet basis)	Measured values (Btu/lb)	Calculated values (Btu/lb)
1.3	8,877	8,921
2.8	8,819	8,793
7.6	8,263	8,357
7.9	8,317	8,327
11.0	8,008	8,048
11.3	7,967	8,019
16.3	7,457	7,573
16.5	7,463	7,551

[a] HHV = higher heating value; MC = moisture content.

northeastern United States and the pellets tested are a blend of both softwoods and hardwoods, the higher heating values are in line with values given by Corder (1975), Murphey and Cutter (1974), Ince (1979), and our own unpublished data. The slope of the line and decrease of energy values with MC is as expected. Also shown in Figure 1 is the energy loss expected as the pellets gain moisture from 6 to 13 percent EMC, which is common in the Northeast. Finally, as seen from the graph, the HHV is 9,043 Btu/lb using the wet-basis MC and 8,986 Btu/lb using the dry-basis MC. The differences are due to the slight changes in slope of the regression lines.

Table 2 shows a comparison of the mean measured energy values, the mean wet-basis MC, and the energy values calculated using the standard relationship shown in the following equation (Bowyer et al. 2003):

$$\mathrm{GHV} = \mathrm{HHV} \times (1 - \mathrm{MCwet}/100)$$

where

GHV = the gross heating value,

HHV = the higher heating value, and

MCwet = the wet-basis MC as a percentage.

The measured and calculated data are reasonably well matched, but the actual and calculated values differ at higher MC levels, most likely because of moisture losses at the surface of the pellets when preparing the calorimeter samples. A simple statistical analysis showed that the correlation coefficient between the two data sets in Table 2 is 0.997, but the P value from a paired t test was lower at 0.015, reflecting the variation between calculated and measured energy values at higher MC.

Conclusions

Although the data are limited and more data are needed to assess the hygroscopicity of pellet fuels, it is clear that fuels can lose a substantial amount of thermal energy under common storage conditions. Many users of pellets purchase in bulk or buy multiple bags during the spring when the prices tend to drop. As such, they are often stored during periods of high heat and relative humidity. Those conditions, combined with the effects of nighttime conditions where the temperature is below the dew point, self-heating in the piles combined with condensation, and the tendency to store the fuels on moist concrete floors or to place them under tarps, can create substantial fuel value changes in a relatively short time period.

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