GROSS HEAT OF COMBUSTION OF LIVING AND SPRUCE BUDWORM-KILLED BALSAM FIR

Douglas P. Barnes and *Steven A. Sinclair*

Research Associate and Assistant Professor
Department of Forest Products, School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

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ABSTRACT

The gross heat of combustion has been determined for living and spruce budworm-killed balsam fir. Results indicated the average calorific value of living balsam fir to be approximately 20 megajoules per kilogram of oven-dry material with negligible differences noted for the heat content of spruce budworm-killed material. Moisture losses associated with time after tree death strongly influence usable heat. Usable heat of budworm-killed material should be higher than living balsam fir since the moisture content of budworm-killed material is expected to be lower.

Keywords: Heat of combustion, spruce budworm, balsam fir, usable heat content, adiabatic calorimetry.

INTRODUCTION

The utilization of spruce budworm (*Choristoneura fumiferana* Clem.) threatened or damaged balsam fir (*Abies balsamea* [L.] Mill.) has many possible alternatives. Several recent studies (Fereshtehkhou 1982; Govett 1982; Hughes 1981) have reported on the utilization of budworm-killed material for pulp, dimension lumber, and composite panel products. Generally, these studies indicated that the utility of budworm-killed material decreases with time after tree death and is dependent on the type of product produced from the material.

Another possible alternative is the use of budworm-killed balsam fir in the production of energy. Lieu et al. (1979) reported that the heat content of oven-dry material from downed and standing dead western white pine (*Pinus monticola* Dougl.) and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) was similar to the heat content of material from green trees of each species. Determining the gross heat of combustion is a standard technique to define the quantity of heat that can be evolved from the complete combustion of an oven-dry material (ASTM Standard D 2015-77 1981). This technique has been employed to compare the caloric content of spruce budworm-killed balsam fir with the caloric content of the living balsam fir.

PROCEDURE

Field plots of budworm-infested balsam fir were established in the summer of 1979 in St. Louis County, Minnesota. Individual trees were identified prior to death, and external tree characteristics were observed to determine the time of tree death. These observations were made monthly from early spring through late fall for three consecutive years. A detailed description of this procedure is given by Govett (1982).

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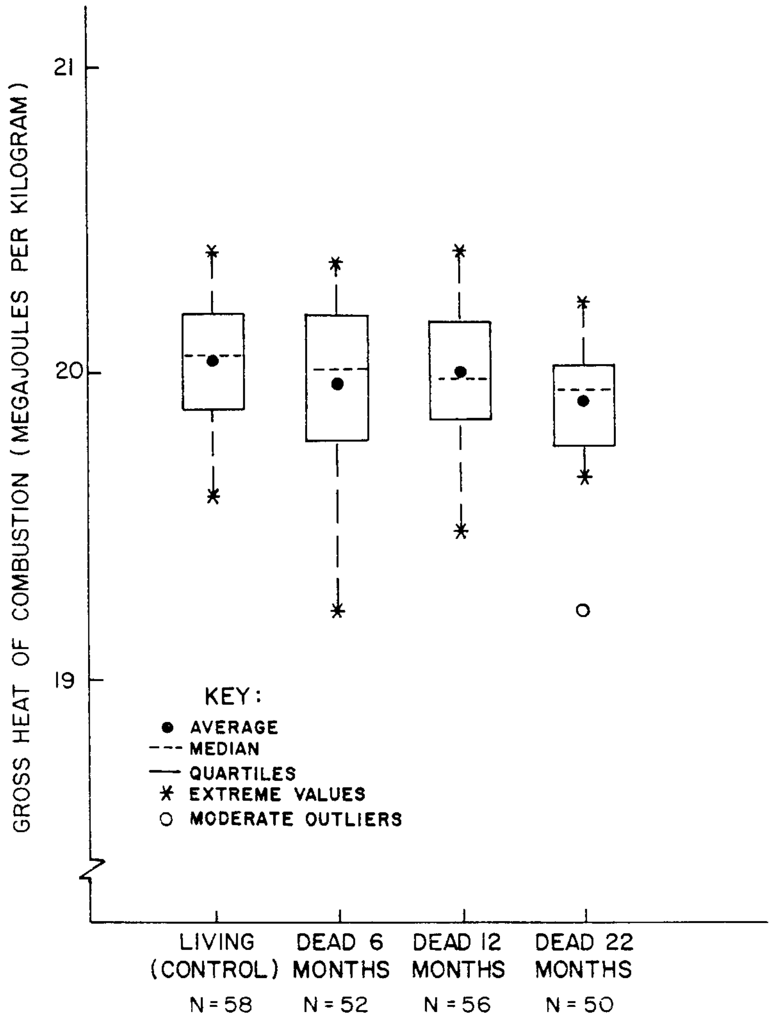

FIG. 1. Box and whisker plots of gross heat of combustion determinations for oven-dry material from each tree category.

Five trees having similar breast-height diameters[1] (dbh) were chosen from each of the tree categories; living (control), dead 6 months, dead 12 months, and dead 22 months. One-inch-thick disks were removed at 100-inch intervals starting at the base of the tree up to a 3-inch (outside bark) top diameter. Bark and knot free wedges were cut from each disk for use in moisture content and gross heat of combustion determinations. Moisture content was determined following the

[1] Average dbh of balsam fir trees from categories of living (control), dead 6 months, dead 12 months and dead 22 months were 24.4 cm, 25.1 cm, 23.9 cm and 24.1 cm, respectively.

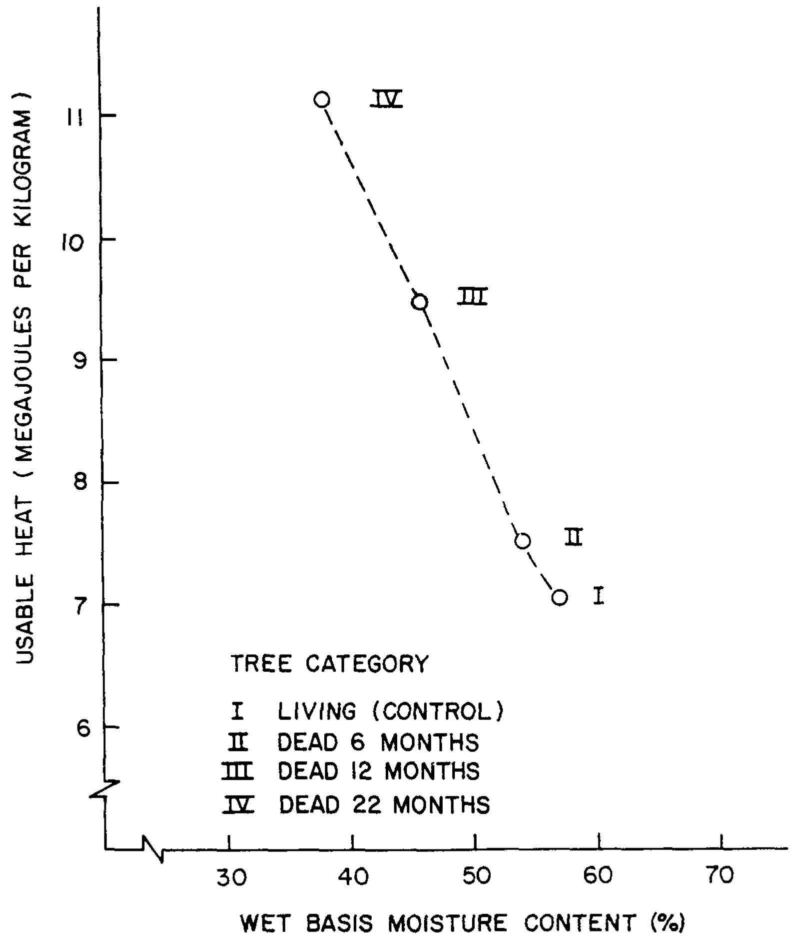

FIG. 2. Average usable heat for each tree category calculated using the standing trees' wet basis moisture content and gross heat of combustion values of oven-dry material.

oven-drying method in ASTM Standard D 2016-74 (1981) but is reported on a wet basis as recommended by Arola (1976). Wedges used for gross heat of combustion determinations were Wiley-milled, and the resulting material was oven-dried.

Two oven-dry samples of Wiley-milled material from each disk were combusted in a Parr 1241 adiabatic calorimeter according to procedures recommended by the Parr instruction manual and in accordance with ASTM Standard D 2015-77 (1981). Correction factors for the formation of acids were not included in the gross heat of combustion calculation (Murphey and Cutter 1974). Average values of heat of combustion and moisture content presented in the results are sums of all the values in a tree category divided by the number of samples in a tree category.

RESULTS

The calorific values of oven-dry material from living and spruce budworm-killed balsam fir are presented in the box and whisker plots (Fig. 1). Such plots graphically display the range, median, and a rough measure of skewness for a sample distribution (Tukey 1977). The upper and lower lines of each box indicate the upper and lower quartiles, and the broken line within each box locates the median. The average calorific value of each tree category is shown as a dot and the asterisks at the end of a vertical broken line indicate extreme values for each distribution. The number of combusted samples (N) is also given for each tree category.

The range of average calorific values for the tree categories was 19.90 MJ/kg to 20.04 MJ/kg, and little difference can be noted between tree categories. However, moisture content averages for the tree categories exhibited a decrease with increased time after death. Moisture content averages of 56.8%, 54.4%, 46.0%, and 38.8% were found for the categories of living, dead 6 months, dead 12 months, and dead 22 months, respectively. These moisture content averages are comparable to those reported by Barnes and Sinclair (1983).

Wood, being both hydroscopic and porous, may contain water that reduces the amount of heat available for use. Usable heat from burning wood can be estimated by reducing the measured gross heat of combustion value for oven-dry wood to compensate for the heat loss associated with wood moisture content[2] (Koch 1972). An example of this is given in Fig. 2, which shows how the wet basis moisture content of wood can affect the estimated usable heat. Wood from the dead material should have more usable heat available since the expected moisture content should be lower. Calculations show that an increase of approximately 3.5–4 MJ/kg of wood can be realized if material from trees dead 12 and 22 months were used as a fuel rather than living trees.

CONCLUSIONS

1. The average gross heat of combustion for living balsam fir was 20.04 MJ/kg, and the calorific value of dead balsam fir ranged from 19.90 MJ/kg to 20.00 MJ/kg. In practice, differences in calorific content between tree categories may be considered negligible.
2. The use of dead balsam fir, because of an expected lower moisture content, would supply more usable heat than living balsam fir.

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REFERENCES

AMERICAN SOCIETY FOR TESTING AND MATERIALS. 1981. Standard test method for gross calorific value of solid fuel by the adiabatic bomb calorimeter. ASTM D 2015-77: Philadelphia, PA.

———. 1981. Standard test methods for moisture content of wood. ASTM D 2016-74: Philadelphia, PA.

AROLA, R. A. 1976. Wood fuels—how do they stack up? *In* Proc. of the Forest Products Research

[2] Heat loss associated with hydrogen combustion and heat loss in other flue gases were not incorporated in the calculations but they should be considered on the basis of individual combustion conditions.

Society Energy and the Wood Products Industry Conference; No. P-76-14. Nov. 15–17, 1976, Atlanta, GA.

BARNES, D. P., AND S. A. SINCLAIR. 1983. Time related changes in specific gravity and moisture content of spruce budworm-killed balsam fir. Can. J. For. Res. 13(2):257–263.

FERESHTEHKHOU, S. 1982. The properties of pulp and paper from spruce budworm-killed balsam fir. M.S. thesis, Dept. of Forest Products, University of Minnesota, St. Paul, MN. 48 pp.

GOVETT, R. L. 1982. The potential for increased utilization of spruce budworm threatened, damaged, or killed balsam fir in the production of dimension lumber. Ph.D. thesis, Dept. of Forest Products, University of Minnesota, St. Paul, MN. 192 pp.

HUGHES, M. T. 1981. Waferboard and flakeboard from healthy and spruce budworm killed balsam fir. M.S. thesis, Dept. of Forest Products, University of Minnesota, St. Paul, MN. 49 pp.

KOCH, P. 1972. Utilization of southern pines. USDA For. Serv. Handbook 420, Vol. II, pp. 1382–1383.

LIEU, P. J., R. G. KELSEY, AND F. SHAFIZADEH. 1979. Some chemical characteristics of green and dead lodgepole pine and western white pine. USDA For. Serv. Res. Note, INT-256, 8 pp.

MURPHEY, W. K., AND B. E. CUTTER. 1974. Gross heat of combustion of five hardwood species at differing moisture contents. Forest Prod. J. 24(2):44–45.

TUKEY, J. W. 1977. Exploratory data analysis. Addison-Wesley Pub. Co., Reading, MA. 499 pp.