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A COMPARISON OF HEAT ENERGY MODELS BETWEEN SCARLET OAK (*QUERCUS COCCINEA*) AND BLACK OAK (*QUERCUS VELUTINA*)

by
C. Forkong Njiti
F.H. Kung
D.R. McCurdy
The authors are research assistant
and professors respectively in the
Department of Forestry
Southern Illinois University
Carbondale, Illinois 62901, U.S.A.

ABSTRACT

Twenty scarlet oak (12) and black oak (8) trees were analyzed to determine the effect of age, specific gravity, size and height on the heat energy output. The two species had the same specific gravity and the same heat energy content. However, the effect of diameter, height, age and specific gravity on heat energy did vary between the two species.

INTRODUCTION

Wood is among the oldest sources of energy known to man, being used for over 500,000 years (Sharpe, 1976). The single largest use of wood in the world is for fuel. The less industrialized countries utilize between 70 to 95 percent of their annual harvest of roundwood for energy (Chow, 1977). Fifty percent of all wood harvested internationally is used for fuel (Karchesy and Koch, 1979).

According to Smith and Dowd (1981) approximately 14 percent of the world's heat energy consumption comes from wood, whereas only two percent of the United States' total energy requirements is supplied by wood. However, for the past ten years, an increasingly large number of Americans have been using wood energy in their homes as an alternative or a supplement to oil, gas or electricity. In 1973, there was approximately 200,000 wood stoves in use in the United States (Smith and Dowd, 1981). By 1978, however, there were approximately 5 million households with a working wood stove and approximately 18 million households with a working fireplace. An estimated 7.5 million cords of fuelwood were consumed in 1976 compared to 10 to 20 million cords in 1979 (Wood Energy Institute, 1979). These fuelwood consumption figures can be contrasted to the 1979 domestic roundwood production of 152 million cords.

Because of this increasing demand, some forest landowners are considering emphasizing fuelwood production by favoring those tree species with the greatest energy output. Therefore, the objective of this study was to determine the effect of a tree's age, specific gravity, size and height on the energy output. Energy output was expressed in terms of BTU per pound of oven-dry weight. Two common fuelwood species, scarlet oak and black oak, in southern Illinois were chosen for study.

MATERIALS AND METHODS

The sample trees (12 scarlet oaks and 8 black oaks) were collected from a half-acre of a native central hardwood stand located in the Shawnee National Forest, Illinois (Njiti, 1984). The diameter at breast height (d.b.h.) of the trees ranged from 1.7 to 9.0 inches and the height ranged from 17 to 53 feet.

After the trees were cut, sample disks were taken at stump height, at breast height, and at 1″ and 0.5″ diameter outside bark (Figure 1). Disks were also cut at every 2-inch diameter interval. Distances from the ground level to each disk were recorded. There were 65 disks from scarlet oak and 52 from black oak trees.

Laboratory analysis included determination of specific gravity by the water displacement method and age determination by counting the number of rings from pith to bark. Each disk was chipped separately with a band saw and sampled chips were ground to powder size smaller than 0.5 mm.

After the samples were oven-dried, they were pressed into pellets of approximately 1.0 gram using a press. The pellet formation was necessary to avoid the powder from being blown about during combustion. The combustion process was carried out within an adiabatic oxygen bomb calorimeter charged with thirty atmospheres pressure of oxygen.

An initial temperature in the calorimeter was recorded when five consecutive readings of the bucket and jacket temperatures were the same. Then the bomb was fired to ignite the charge. During this temperature rising period, heat transfer from the bucket to the jacket was prevented by admitting hot water into the jacket. The final temperature reading was recorded after there was no increase in the temperature readings. The heat energy of a sample was calculated as follows:

$$Hg = \frac{T \times W - N - F}{M} \times 1.8$$

Where

Hg = Gross heat of combustion in Btu/lb.
T = Temperature rise, or final temperature minus initial temperature in °F.
W = Energy equivalent of calorimeter, 1363 cal./°F.
N = Correction in heat of formation of nitric acid.
F = Correction for heat of combusion of Platinum fuse wire.
M = Mass of sample in grams
1.8 = Conversion factor from cal/gr. to Btu/lb.

RESULTS AND DISCUSSION

Comparison Between Mean Btu Values

There was no statistically significant difference between the mean Btu for scarlet oak (8,337) and for black oak (8,334). These findings were partially due to the lack of difference in the average specific gravity in scarlet oak (0.61) and black oak (.62). The similarity of specific gravity in two species can be interpreted as similarity in i) the size of cell, ii) the thickness of cell walls, and iii) the extractive content of wood. Since these factors influence Btu output, wood with similar specific gravity would have similar Btu values.

Comparison Between Btu Models

Although there was no significant difference in mean Btu between the two species, the models of Btu were different:

Scarlet oak. The combined effects of diameter, age, specific gravity, and height on Btu were significant and the R^2 was 18 percent. When each of the variables was tested for the effects of their partial contribution to Btu, the effect of diameter was significant while age, specific gravity, and height had no significant effects. The simple regression analysis also produced similar results except that the effect of diameter was significant not only at the .05 level but also the .01 level. There was no significant interaction effects.

Black Oak. The full model of the independent variables had a significant effect on Btu; R^2 was 19 percent. For partial contribution to Btu, the effect of age was significant (.01 level) and the effect of height was also significant. However, in the simple regression test, the effects of both age and height were non-significant. The interaction test showed that diameter, age, specific gravity, and height did not have any significant interaction effects between them.

Comparison of Disk Location

On both species, there was significant difference between Btu measurements on disks located at stump and at d.b.h. However, the direction of differences was not the same for the two species. In scarlet oak, the stump disk had a higher heat energy (38 Btu) than the d.b.h. disk. But in black oak, the d.b.h. disk had a higher heat energy (118 Btu) than the stump disk.

Disks with 1/2 inches diameter had higher Btu than disks at stump for both species. The half-inch disks also had higher Btu than one-inch disks and d.b.h. disks in scarlet oak but not in black oak (Table 1).

Disks with 1/2 inches diameter should contain more juvenile wood than mature wood, while the reverse would be true for the stump disks. Our study agreed with the previous study in sycamore that juvenile wood yielded a greater heat value than mature wood (Chow, et. al. 1980).

CONCLUSION

The objective of this study was to determine the effect of a tree's age, specific gravity, size, and height on the heat energy output. Twenty trees (12 scarlet oaks and 8 black oaks) located within the Shawnee National Forest in southern Illinois were analyzed. The major conclusions were:

1. Scarlet oak and black oak generally have the same specific gravity (0.61) and the same heat energy content (8,336 Btu). Wood with similar specific gravity should have similar heat value.
2. Although the mean specific gravity and the mean heat value are similar in the two species, the effect of diameter, height, age and specific gravity of each sample on its heat value may vary from species to species.
3. Because the heat value of wood varies with the position of the sample taken, the trend is not linear from stump to branches. Furthermore, the position effect may vary among species. Therefore, samples from a fixed position may not provide a valid comparison between species. Whole tree sampling would be more suitable for heat value study.

LITERATURE CITED

Chow, P. 1977. Wood as Fuel: Forest can be utilized more fully as an energy source. Illinois Research, University of Illinois Agric. Exp. Stn. 19 (2):6-7.

______, G.L. Rolfe, T.A. White, and C.S. Lee. 1980. Energy values of juvenile sycamores. Illinois Research, University of Illinois Agric. Exp. Stn. 22(4):12-13.

Karchesy, J. and P. Koch. 1979. Energy production from hardwoods growing on southern pine sites. USDA For. Serv. General Tech. Rep. SO-24. Southern Forest Exp. Stn., New Orleans, LA. 59 pp.

Njiti, C.F. 1984. Energy in Wood: The effects of age, diameter, height and specific gravity on the heat energy contents of scarlet oak (*Quercus coccinea*) and black oak (*Quercus velutina*). Master's Degree Thesis. Southern Illinois University at Carbondale. 73 pp.

Sharpe, G.W. 1976. Introduction to Forestry. McGraw-Hill Book Company, New York. 544 p.

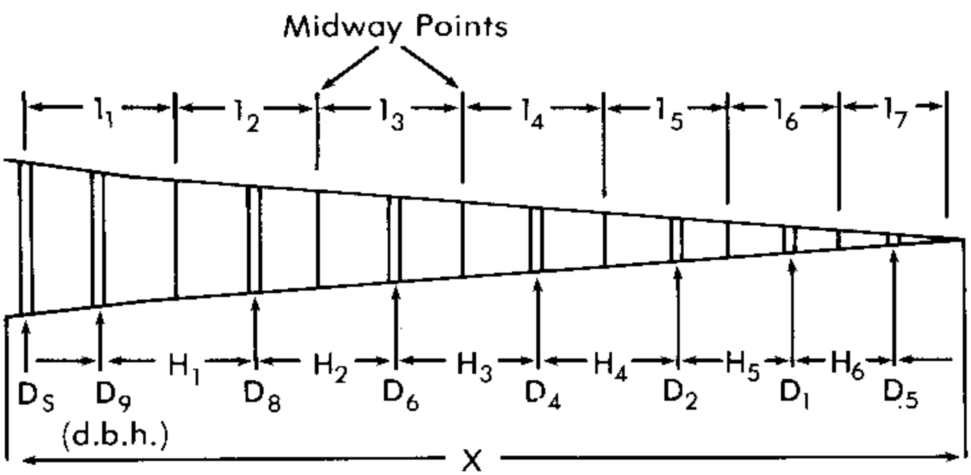
Smith, H.W. and Dowd, L.M. 1981. Biomass Production in Florida. *Journal of Forestry*, 79(8):508-511.

Wood Energy Institute. 1979. Wood used for energy. Report of a survey conducted by the Gallup Organization. Wood Energy Institute, Washington, D.C.

Table 1. Comparison of the Btu Contents from the Base to the Top of the Tree by Species.

Diameter Contrast	T-Value	Level of Significance
a. *Black oak*		
Stump vs. d.b.h.	4.15	.01
Stump vs. 1 inch	1.75	non-significant
Stump vs. 1/2 inch	2.28	.05
d.b.h. vs. 1 inch	1.72	non-significant
d.b.h. vs. 1/2 inch	0.89	non-significant
One inch vs. 1/2 inch	0.87	non-significant
b. *Scarlet oak*		
Stump vs. d.b.h.	1.82	.05
Stump vs. 1 inch	0.77	non-significant
Stump vs. 1/2 inch	2.02	.05
d.b.h. vs. 1 inch	0.37	non-significant
d.b.h. vs. 1/2 inch	3.70	.01
One inch vs. 1/2 inch	3.81	.01

Fig. 1. Schematic of Sample Disk Layout for a Nine-inch Tree.



D_S = stump diameter

D = disk location; subscripts stand for disk diameter in inches

X = total height of tree

H = height between sample disks

l = length of truncated cone; subscripts denote cone number