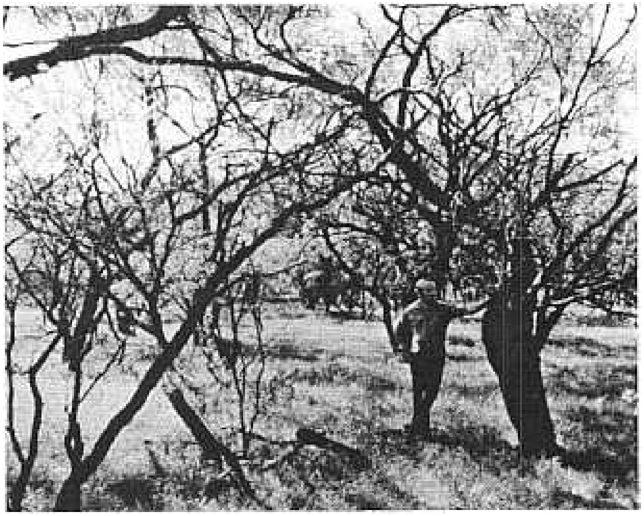

Mesquite in tree form.

Market Potential Of Mesquite as Fuel

A. T. Wiley

F. G. Manwiller

Abstract

The heat of combustion of mesquite heartwood, sapwood, bark, and a mixture of stems and leaves was tested. The values averaged 8,657, 8,021, 7,836, and 8,123 Btu per OD pound, respectively. If an industrial plant requiring 50,000 pounds of steam per hour were located in an area averaging 25 green tons of mesquite fiber per acre, a harvest radius of about 3 miles would be required to sustain the plant over a period of 10 years. Based on the costs of owning and operating a 20,000 lb./hr. steam generator, the dollar value of preprocessed mesquite to a potential user was estimated to be \$16.35 per ton (60% MC), or about \$390 per acre of heavily infested land.

WITH EACH INCREASE in the cost of fossil fuels there is a corresponding increase in the value of wood as a fuel. In 1972, Koch showed that at 32 cents per Mft.^{3} for natural gas, \$2.45 per ton could be paid for green southern pine bark (100% MC)[1] to obtain the same number of Btu's in the form of steam. Today, at 80 cents per Mft.^{3}, the equivalent price of bark would be \$5.90 per ton, and in certain areas of Texas, the price of natural gas may be as high as \$2.00 per Mft.^{3}. Since fossil fuel shortages will likely cause the price of these fuels to increase faster than inflation, and allocations may make them impossible to obtain, it is not unreasonable to presume that wood fuel could someday become a marketable commodity.

Previous authors have been pessimistic about the possibility of harvesting wood for fuel purposes (Grantham and Ellis 1974). The primary objection is the enormous acreage that would have to be set aside for rotating fuel crops. However, there occurs in portions of southwestern United States, a tree—mesquite (*Prosopis sp.*)—which might overcome this disadvantage.

Mesquite grows in two basic forms, a single-stemmed tree and a many-stemmed tree or brush. It has been estimated that in Texas alone, there are about 34 million acres containing 10 to 40 tons per acre of green mesquite fiber (Stayton 1973). These trees are choking out forage crops and drastically reducing cattle production; thus, it is possible that the fiber could be obtained "free," with the cost of harvesting shared by landowner and a contract landclearer. Cost increases (over that of normal landclearing operations) would be incurred in gathering, hogging, and transporting the fuel. The major economic question is whether the sale of mesquite fiber could offset these costs and yield a profit.

The purpose of this paper is to provide rough data as to the market value of mesquite wood as a fuel. To do this, the heat of combustion had first to be determined. It was then necessary to develop a method by which a price could be determined at which wood could sell competitively with other fuels. It has become common practice to use the price per ton at which the price per recovered Btu is the same as with the cheapest alternative fuel (Koch 1972, Anonymous 1975a, Anonymous 1975b). It is widely recognized that this method does not account for the relatively high cost of owning and operating a wood-burning steam generator; however, the literature does not include a

[1]All moisture contents are on an ovendry basis.

The authors are, respectively, Wood Technologist, Texas Forest Service, Texas Forest Prod. Lab., Lufkin, Tex., and Research Scientist, So. Forest Expt. Sta., USDA Forest Serv., Pineville, La. This paper was received for publication in October 1975.

concise method of doing so. This paper presents such a method, applied to mesquite; however, the method may be used with other species and applied to industrial plants which produce fuelwood as a byproduct of normal plant operations.

Analysis of the expense of preparation of the fuel must be left to others. An excellent discussion of present methods of mechanical landclearing has been given by Fisher, Wiedeman, Meadors, and Brock (1973) and Meadors, Fisher, Haas, and Hoffman (1973).

Experimental

The first step in determining the dollar value of mesquite fuelwood was to determine its heat of combustion. The species selected is that most common to west Texas—honey mesquite (*P. juliflora*). Since the wood has long been known by outdoorsmen to produce an exceptionally hot flame, it was hoped that the heat of combustion would be very high. However, the heartwood proved normal for a hardwood, while the other tissues tested were somewhat low in heating value.

Methods and Equipment

Heat of combustion was determined separately for bark, sapwood, heartwood, and a mixture of stems and leaves. Samples of bark, sapwood, and heartwood were taken from boards cut from several logs collected in Brown County near Brownwood, Texas. The samples were ground in a Wiley mill and screened to 40 mesh and below. The particles from each sample were thoroughly mixed to form a representative sample.

To obtain a representative sample of mixed stems and leaves, five stems were cut from specimens of many-stemmed mesquite trees growing in Bexar County near San Antonio, Texas. The basal diameters of the branches ranged from about 1 to 4 inches. The branches with leaves were shredded, and the shreds thoroughly mixed. From the mix, several random samples were taken and further reduced in a Wiley mill and screened to 40 mesh and below.

Measurements of heat of combustion were taken with a Parr adiabatic calorimeter with automatic jacket controls. The samples were sprayed with a fine mist of water to slow down combustion and prevent portions of the specimen from being blown out of the specimen dish. Nine measurements were taken of each tissue type.

Results

The heats of combustion of the various tissues are given in Table 1. The heat of combustion of mesquite heartwood is nearly the same as that of loblolly pine stemwood—8,600 Btu per ovendry (OD) pound (Koch 1972). However, due to the relatively high density of mesquite—44 lb./ft.^{3}—the heating value, per unit of volume, of mesquite heartwood is about 1.4 times that of pine.

Economic Aspects

Since branchwood is the form of mesquite which is most likely to find use as fuel, the following calculations are carried out assuming a heat of combustion of 8,120 Btu/OD lb. To determine the effective heating value of wood (Btu's recovered in the form of steam), deductions must be made for heat losses. According to Reineke (1961), if the flue gases are assumed to be at 400°F, the losses are 1,210 Btu per pound of water in the fuel, and 1,350 Btu/OD lb. of wood for heat losses associated with raising the temperature of flue gases and with water formed in combustion of hydrogen. In addition, about 1 percent of the total heat input may be assumed to be lost as radiation in a 50,000 lb./hr. boiler, and 1.5 percent of the total heat input may be assumed to go to unaccounted-for losses (de Lorenzi 1957). The expected efficiency of mesquite as a fuel at various MCs, e_{m}, is plotted in Figure 1. Efficiencies of southern pine bark (8,900 Btu/OD lb.) and stemwood (8,600 Btu/OD lb.) are also given for comparison. Efficiency multiplied by heat of combustion gives the effective heating value per OD pound. At 60 percent and 15 percent MC, the effective heating values of mesquite are 5,840 and 6,380 Btu/OD lb., respectively. This represents an increase of 8 percent, for which it might be worthwhile to allow fallen mesquite to dry in the field before hogging; however, it is doubtful that the average landowner would allow his land to be tied up for the length of time required to reach this MC.

The brushy form of mesquite.

Table 1. — HEAT OF COMBUSTION OF MESQUITE.

Tissue	Btu/OD lb. Average	Btu/OD lb. Range
Heartwood	8,657	8,469-9,079
Sapwood	8,021	7,907-8,235
Bark	7,836	7,043-8,176
Mixed stems and leaves	8,123	7,846-8,222

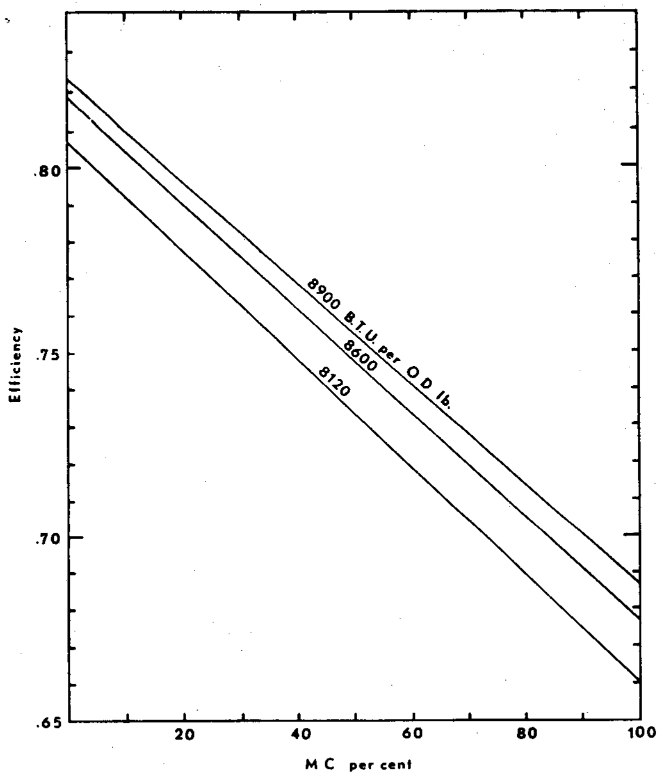

Figure 1. — Efficiency of wood as a function of MC and heat of combustion (Btu/OD lb.).

Large areas averaging 15 OD tons (25 green tons, assuming 70% MC) per acre could probably be located for installation of an industrial plant. Assuming the wood is utilized green (60% MC), such areas would contain about 200 million Btu (usable heat) per acre. Since saturated steam at 212°F contains 970 Btu more than saturated water at the same temperature, the heat required from the wood at 60 percent MC to evaporate a pound of water under these conditions is $970/e_{wx}$=1,350 Btu per pound of steam. Thus, a steam generating system which produces 50,000 pounds of steam per hour (from and at 212°F), operating 6,000 hours per year would consume (50,000) (6,000) (1,350)=405 billion Btu per year. This would require a harvest of about 1,700 acres of mesquite per year. Over a 10-year period, the harvest radius would extend about 3 miles from the plant. Such a facility could be used to run a medium-size industrial plant requiring large amounts of process steam. A much larger facility would be required to generate electricity competitively, due to the decrease in cost per unit of generating capacity with increasing size.

The maximum price that can be paid for fuelwood without increasing cost above that which would be incurred by use of an alternative fossil-fuel-burning system may be calculated by summing all yearly costs that would be incurred in owning and operating the alternative boiler, including fuel costs, and subtracting the yearly costs incurred in owning and operating a wood-burning boiler, *not* including fuel costs. The cost sums must include deductions for money saving such as income tax deductions and elimination of a waste burner. The difference of the annual cost sums is the amount which can be allotted to purchase fuel for the wood-burning boiler. From this figure, the maximum price per ton for OD wood is calculated. The maximum annual cost to be allotted for fuelwood is:

$$f_w = c_a + f_a - c_w \qquad [1]$$

where:

f_w = maximum annual cost to be allotted for fuelwood,
c_a = sum of all yearly expenses (less money savings) incurred in owning and operating the alternative boiler,
c_w = sum of all yearly expenses (less money savings) incurred in owning and operating a wood-burning boiler, and
f_a = annual fuel costs incurred in owning the alternative boiler.

Values for f_a may be approximated as:

$$f_a = u_a s h p_a \qquad [2]$$

where: u_a = number of units of fuel required to produce a pound of steam,
s = average pounds of steam required per hour,
h = the number of hours per year the boiler will be in operation, and
p_a = price of the alternative fuel per unit of measure.

The maximum price per ton, p_w, of OD wood is given by:

$$p_w = \frac{f_w}{u_w s h k} \qquad [3]$$

where:

u_w = the number of pounds of OD wood required to produce a pound of steam, and
k = the fraction of wood fuel which is to be purchased, i.e., not obtained free as a byproduct.

Values for u_a and u_w are given by:

$$u_a = \frac{H}{H_a e_a} \qquad [4]$$

and

$$u_w = \frac{H}{H_w e_{wo}} \qquad [5]$$

where H is the heat required to produce a pound of steam at the required steam and feedwater conditions,

Table 2. — HEAT OF COMBUSTION AND EFFICIENCY OF VARIOUS FUELS APPLIED TO STEAM-GENERATING SYSTEM (ANONYMOUS 1975a).

Fuel	Efficiency (%)	Heat of combustion
No. 6 fuel oil	82.5	150×10^3 Btu/gal.
No. 4 fuel oil	82.5	145×10^3 Btu/gal.
No. 2 fuel oil	82.5	140×10^3 Btu/gal.
Sub-bituminous coal	80.0	17×10^6 Btu/ton
Bituminous coal	85.0	27×10^6 Btu/ton
Natural gas	77.8	1×10^3 Btu/ft.^{3}

H_a and H_w are the heats of combustion of the alternative fuel and wood, respectively, and e_a and e_{wo} are the efficiencies of the alternative fuel, and wood at zero percent MC, respectively. Typical values for e_a are given in Table 2. The factor k in Equation 3, if very small, can cause p_w to be very large; therefore, an upper limit must be sought. A reasonable limit would be the price per ton at which the cost per recovered Btu is the same as that for the alternative boiler. This may be calculated as:

$$p_{wl} = \frac{u_a p_a}{u_w} \quad [6]$$

Both p_w and p_{wl} may be adjusted to various MCs by multiplying by

$$\frac{e_{wx}}{e_{wo}(1+m)}$$

where e_{wx} is the efficiency at the MC under question and m is the MC, expressed as a fraction.

If market conditions have fixed the price of wood fuel, then the annual OD tonnage t, of fuel which must be produced as a byproduct to keep costs in line with those incurred in owning and operating an alternative boiler is given by:

$$t = u_w sh - \frac{f_x}{p_w} \quad [7]$$

Here, p_w is the market price of OD fuelwood.

Example: Assume that a 20,000 lb./hr. wood-burning system has been installed which is run at full capacity for 6,000 hours per year. The least expensive alternative was a gas-burning system. The cost of natural gas is \$1.90/Mft.^{3} All fuelwood is to be purchased. What price should be paid for fuelwood?

Solution: The estimated cost figures are as follows:[2]

	Wood	Gas
Total cost of system installed	\$260,000	\$60,000
Interest (12% on 10-yr. loan)	20,000	4,600
Depreciation (average over 10-yr. period)	26,000	6,000
Insurance	500	100
Electricity	10,000	3,800
Maintenance (average over 10-year. period)	2,600	800
Tax credits		
Interest (48% of average annual interest payment)	-9,600	-2,200
Depreciation (48% of average annual depreciation)	-12,000	-2,900
Investment (10% of investment spread over 10-yr. period)	-2,600	-600
Subtotal	34,900	9,600
Fuel	258,700	284,000
Total	\$293,600	\$293,600

[2]The cost figures used are a compilation of data obtained from one manufacturer and two engineering firms.

The price of wood fuel is calculated as follows

$$u_a = \frac{970}{.778(1{,}000)} = 1.247 \text{ ft.}^3\text{/lb. steam}$$

$$f_a = 1.247(20{,}000)(6{,}000)(.0019) = \$284{,}000\text{/yr.}$$

$$f_w = 9{,}600 + 284{,}000 - 34{,}900 = \$258{,}700\text{/yr.}$$

$$u_w = \frac{970}{8{,}120\ (.808)} = .147 \text{ lb. OD wood/lb. steam}$$

$$p_w = \frac{259{,}000(2{,}000)}{.147(20{,}000)(6{,}000)(1)} = \$29.36$$

$$p_{wl} = \frac{1.247(.0019)(2{,}000)}{.147} = \$32.23\text{/OD ton}$$

Since p_w does not exceed p_{wl}, we use p_w as the price of wood fuel. At 60 percent MC, the price is \$29.36(.72)/(.808(1+.60))=\$16.35/ton and the value per acre of mesquite is \$16.35 (15 OD ton/acre) (1.60)=\$390/acre.

A note should be made regarding the flexibility of the method. Different situations are accounted for by manipulating the figures in the cost columns. For example, if a plant already owns a gas-burning system and is considering converting to a wood-burning system, the annual payment and tax credit figures are zero for the gas system. Based on cost data obtained from the same sources as those above, the price which could be paid for mesquite to fire a 20,000 lb./hr. system would be \$28.77/OD ton.

Conclusion

The market value of mesquite, calculated as \$390 per acre, is somewhat tenuous as it is highly dependent upon the volume per acre of mesquite and the price of natural gas, which appears quite unstable. However, it is substantial enough to indicate that mesquite is an energy resource which should not be overlooked. Any eventual use will be dependent upon developments of economic harvesting and fuel preparation methods. It must also be kept in mind that fuel allocations may soon drive the value of fuel that is readily available far above that which can be derived from simple cost comparisons.

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