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THE EFFECT OF REDUCED EXTRACTIVE CONTENT ON THE BURNING RATE OF ASPEN LEAVES

C. W. Philpot[1]

ABSTRACT

Diethyl ether and acetone were used to reduce the extractive content of aspen leaves. The leaves were burned in 0.5-ft.^{2} baskets and the weight loss rate was recorded. A direct relationship between extractive content and burning rate was found. This relationship emphasizes the importance of seasonal trends in extractive content and differences between species.

The burning properties of plant fuels depend on both physical and chemical characteristics. Study of the chemical constituents of plants and their relation to flammability is necessary for evaluation of fire hazards.

A primary element in flammability is the heat content of the fuel, which varies, depending on fuel composition. Heat content, measured in B.t.u./lb., partly determines the intensity of burning, and the availability of heat content affects the rate of fire spread. Plant fuels consist mainly of carbohydrates (in the form of cellulose and other substances) and lignin; in addition, a variety of waxes, fats, oils, and terpenes, generally called ether extractives, are present in varying quantities depending on the species and the season of the year.

Past research on wildland fuels has shown that generally the extractives have the greatest heat content of any major component of the fuel (Philpot 1969). There are indications that the extractives do not undergo the complex pyrolytic changes that carbohydrates do before ignition; that is, the heat content they provide is more easily available for ignition and combustion. Some of the extractives also form a surface deposit, thus becoming even more easily available.

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The specific effects of the extractives on fuel flammability are not known. To test the effect of different amounts of extractives in plant fuels on such properties as heat content, burning rate (rate of weight loss), and flame characteristics, burning studies were made using leaves of aspen (Populus tremuloides Michx.) extracted with organic solvents. Aspen leaves were used because they have a normally high extractive content, can be burned in small fuel beds, and are also being used in studies of seasonal differences in fuel characteristics. Several authors have found seasonal trends in the extractive content of leaves (Richards 1940; Philpot 1969; Short et al. 1963). Maximum content values as high as 18 percent dry weight have been reported (Dietz et al. 1962). Although we hope ultimately to find out how seasonal and species variation in extractives affects burning rate, such differences are not examined in this paper. Some differences in the extractive content of the leaves may be due to the date at which they were gathered, but no conclusions from this can be drawn.

METHODS

Whole, living aspen leaves were collected in the field once in July and once in August of 1967. After being allowed to air-dry at 72° F., the leaves from one sampling date were used for ether extraction and a matching control; those from the other date were used for acetone extraction and its control. Approximately 60 grams of leaves were extracted at once for 60 hours in a modified Soxhlet apparatus with either diethyl ether or acetone. The solvent was removed by drying in a fumehood.

Subsamples of the extracted (test sample) and nonextracted (control sample) leaves were ground to 40 mesh and analyzed for ash (mineral) content, extractive content (by ASTM procedures), and high heat content (ASTM 1956a, 1956b, 1966). Values for ash and extractives are expressed as percent dry weight. Moisture content for the above procedures was determined by Karl Fischer titration to establish the dry weight base.

Four hours before the burning tests, the leaves were spread out in the combustion chamber and allowed to reach equilibrium with controlled conditions (Anderson 1964). Moisture content at this point was not determined because there was not enough extracted sample material; the difference in moisture content between treatments was assumed to be insignificant. The dry-bulb temperature was 85° F. and the relative humidity was 22 percent. Sixty grams of leaves were placed in a circular 0.5 ft.^{2}, 1/4-inch mesh hardware cloth basket. The fuel bed was 4 inches deep. Three control and three ether-extracted fuel beds were alternately placed on a load cell and ignited with the aid of 1 ml. acetone poured directly in the center. We used this method of ignition to try to accentuate the differences in rate of spread between treatments as the fire moved out from a point source. The load cell continuously recorded weight loss over time and its rate of change per unit of time or derivative, until flaming ceased. Flame height and duration were observed and recorded. Two acetone-extracted fuel beds and three controls were burned at a later date under the same conditions.

RESULTS

The results of the chemical analyses are presented in table 1. As can be seen from the data for the controls, the leaves collected on different dates had different original extractive and ash contents. Extraction by ether and acetone affected ash content slightly or not at all. Ash contents expressed on a percent basis should increase after extraction, because of the resulting mass change. Expressing the ash contents of both the control and extracted samples on a basis that excludes the extractives reveals whether any minerals were removed by the solvents. For the ether treatment and control, the figures show the expected increase. For the acetone treatment and control, the relationship is not as close, but it still does not indicate any reduction in ash content. The heat contents of the leaves in each sample were dissimilar; these would be expected to reflect differences in the original extractive content (Philpot 1969).

Table 1.--Analyses of controls and solvent-treated leaves

Sample treatment	Extractive content, dry weight	Ash, dry weight	Ash, dry weight, extractive-free basis	Heat content
	- - - - - - - - Percent	- - - - - - - - - -		B.t.u./lb.
Ether control	13.53	5.64	6.52	9,026
Ether extracted	11.03	5.72	6.43	8,615
Extractive reduction	2.50			
Acetone control	12.96	6.51	7.48	9,011
Acetone extracted	3.51	7.44	7.71	8,094
Extractive reduction	9.45			

Flame heights of the controls ranged up to 2 feet (fig. 1) and most of the fuel was consumed. A shiny band of liquid extractives could be seen on the surface of the leaves adjacent to the flame front. This liquid was not apparent when the extracted leaves were burning. Flame heights of the extracted leaves ranged only as high as 6 inches. Only about one-third to one-half of the fuel was consumed. The acetone-extracted leaves stopped flaming combustion much sooner than the ether-extracted leaves. The rate of flame spread from the ignition point was much slower for the extracted leaves.

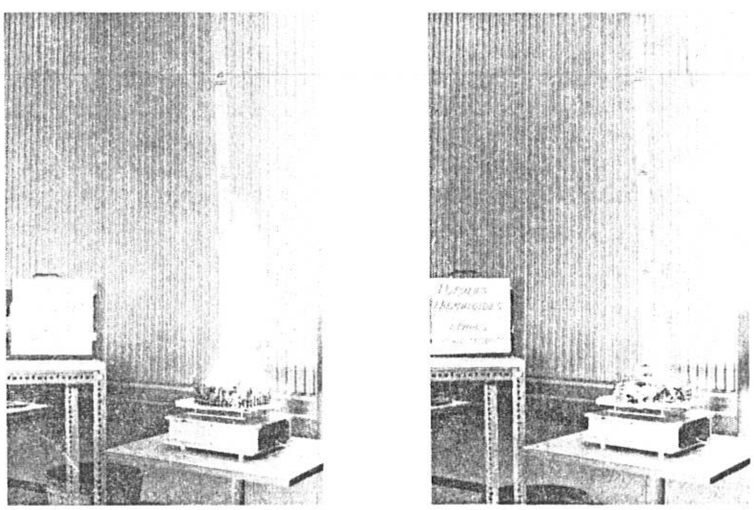

Figure 1.--Flame heights during maximum burning of control and acetone-treated aspen leaves.

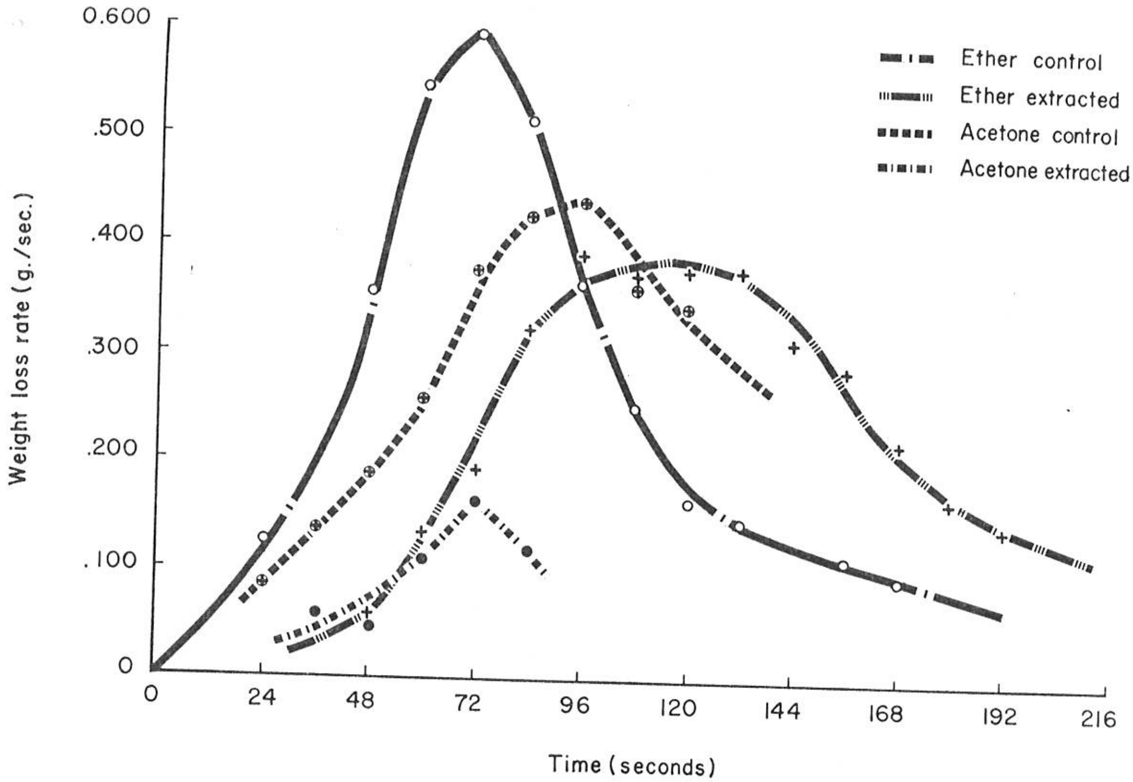

Figure 2.--Weight loss curves for natural and extracted aspen leaves. Data points are averages for the burning tests for each group.

The characteristics of the burning of the various fuel beds are tabulated below. Conditions were constant as described earlier.

	Flame height (Feet)	Maximum weight loss rate (Grams/sec.)
Ether control	2	0.59
Ether extracted	1.5	.37
Acetone control	2	.43
Acetone extracted	0.5	.15

The large variability in buildup time between the replicate fires in each treatment group made the raw data on weight loss rate extremely hard to analyze. This variability was mainly due to the method of ignition described earlier, which made buildup time dependent on the orientation and sustainability of one or two leaves at the center of the bed. In spite of this buildup variability, the shapes of the weight loss curves were found to be similar within the treatments if the time period from ignition up to active combustion was discounted. Therefore, a weight loss rate of 0.125 gram/sec. was chosen as an orientation point for the curves for all of the fires, because once this rate was achieved the combustion that was characteristic of the treatment continued. All of the replicate curves for each control and treatment were alined with this value to produce the average curves in figure 2. The maximum weight loss rate was then plotted against the extractive content (fig. 3). This relationship fits the equation:

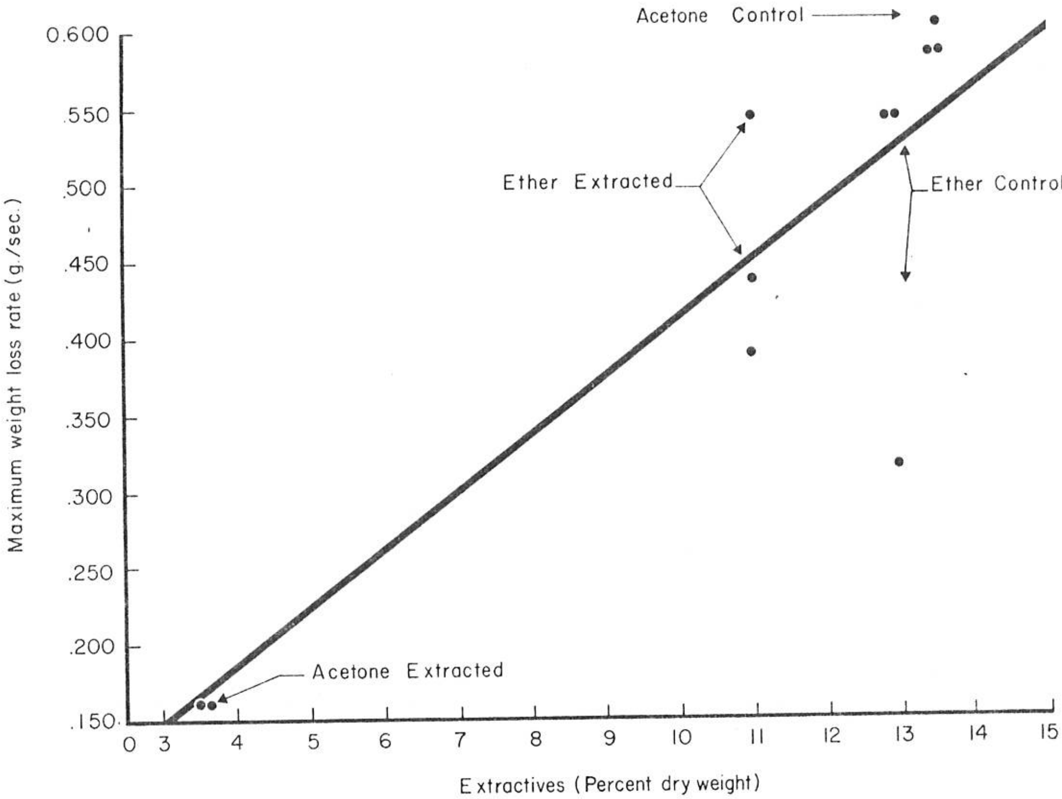

Figure 3.--The relationship between extractive content of aspen leaves and maximum weight loss rate. Each data point represents a single burning test.

$$Y = 0.0316 + 0.0377X$$

where

Y = maximum weight loss rate (grams/sec.)
X = extractive content (percent dry weight).

The coefficient of determination, r^2, is 0.76 and the level of significance is >75% but <90% as determined by the F test. The line was fitted by least squares.

CONCLUSIONS

This experiment, by no means conclusive, showed the maximum burning rate of the aspen leaves was directly proportional to their extractive content. Extraction by acetone was the most effective and reduced combustion almost to nonsustainability. Apparently, the extractives volatilize ahead of the flame front and help support combustion. The higher heat content of the nonextracted leaves, resulting from the presence of the extractives, probably accounted for some of the higher weight loss rate. Some of the reduction in burning rate of the acetone-extracted leaves and their control with respect to the ether group could be due to higher mineral content of the acetone group as a whole (Philpot 1968).

Seasonal trends in extractive content, which apparently exist in many fuels, could be quite important in assessing fuel flammability. Many plants that are considered a fire hazard show an increase in extractive content during the summer months. This increase, coupled with mineral and moisture trends, may have to be considered in the evaluation of natural fuel flammability. Further experiments are now underway to test effects of change in extractive content of aspen and other fuels on burning rate, to determine the ignition characteristics of extractives, and to establish seasonal-trend prediction equations for natural fuels.

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