EFFECT OF MOISTURE ON COMBUSTION OF LIVE LEAVES

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Background

- Fires have been suppressed for decades, resulting in more dense vegetation
- Dense vegetation produces higher intensity fires that are difficult to control and more damaging to environment
- Many uncontrolled wildland fires in California, Montana, Utah, Colorado, etc. in 2003
- Current fire spread models in the U.S. are based on the extensive empirical correlations
- These models are accurate under many conditions from which the empirical correlations were developed but less accurate in predicting fire spread in live vegetation
- Combustion data for live vegetation needs to be obtained to improve current fire models
- Susott* investigated the combustion behaviors of 20 live and dead fuels using thermal gravimetric analysis (TGA)
- Very little difference was observed in the pyrolysis behavior of leaves of different species
- TGA data imply that live fuels all burn the same (same chemistry)
- If chemistry is not dominant, then shape and mass transfer may have importance

***Susott, R. A., Forest Sci. 2, 404-420 (1982)**

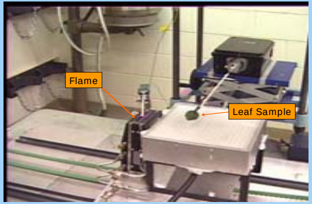
Overall Objectives

- To better understand the combustion behavior of live fuels.
  - Why do some fuels burn differently than others?
  - Causes of flare-ups
  - Causes for ground to crown transitions

•Experimental Approach

- Single Leaf Samples
- Optical/Visual Access for Observation of Ignition
- Measure the Temperature and Mass as a Function of Time
- Heating Rates Typical of Fires (~100 K/s)

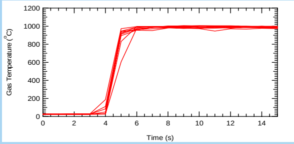
Experimental Forest Fire Conditions



Flat Flame Burner

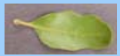
- Single Leaf Samples
- Gases Used
  - Air, H_2, CH_4, N_2
- Stoichiometry adjusted to manipulate post-flame conditions
  - T, O_2
- Very repeatable experiments within 2 inches of the burner surface

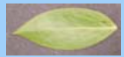
Gas Temperature Profiles
2" Above Flat Flame Burner



Shows the repeatability of the experimental conditions

Fuels Studied: California Chaparral


Oak


Manzanita


Ceanothus


Chamise

SPECIFIC OBJECTIVES

- **Determine qualitative and quantitative characteristics of how different leaf samples burn**
- **Determine the factors that influence the amount of energy it takes to bring a leaf to ignition (different ignition time and temperature)**
  - **Moisture content**
  - **Shape**
  - **Thickness**
  - **Species**
- **Make a correlation (model) of the ignition time and temperature as a function of the most important variables**

Qualitative Observations

Shape Effects

- Manzanita leaves were cut into different shapes
  - Square shaped leaves ignited first at the corners then propagated along the edge
  - Round shaped leaves ignited all along the edges first, then propagating into the middle


Square Manzanita


Round Manzanita

Orientation effects

- Manzanita oriented vertically ignited along the bottom edge then propagated up
- Horizontally oriented manzanita ignited at the tip and around the outer edges then propagated to the center


Vertical Manzanita

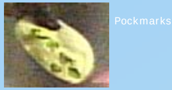

Horizontal Manzanita

Qualitative Observations cont.

Moisture Content Effects

- Manzanita leaves with high moisture content (approaching 100%) exhibited bubbling and pockmarks where the moisture escaped


Bubbling Manzanita

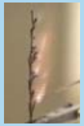


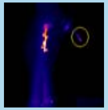
Bursting Oak

- Oak leaves at high moisture content (~80%) exhibited brand generation
- These brands were explosively thrown from the leaf accompanied by crackling and popping

Chamise

- Chamise burned in different phases:
  1. needles burned from bottom to top
  2. the stem burned later
- As shown in the IR-image, brands were also evident from burning this species



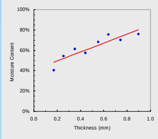


Summary of Qualitative Results

- **Fire behavior influenced by sample orientation and shape**
- **Different species ignite at different locations depending on shape and orientation**
- **Some species exhibit brands, bubbles, and pockmarks**

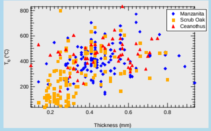
Quantitative Experiments

- Ignition Temperature (T_{ig})
  - Ignition point was determined as the first visual evidence of a flame
- Time to Ignition (t_{ig})
  - The difference between the time stamp of the ignition point and first thermocouple reading over 30°C
- Moisture Content and Thickness

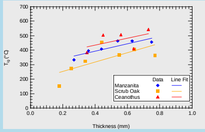


Moisture content appears to be inversely proportional to leaf thickness.
(Data is binned by thickness and represents Ceanothus, Manzanita, and Oak)

Ignition Temperature Data

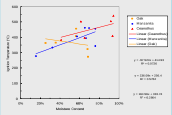


Original data plotted by species

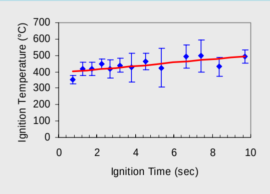


Data binned by thickness then averaged within bins.

Increased moisture content and thickness seems to increase ignition temperature!



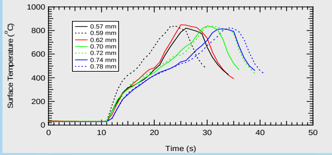
- Conventional models keep temperature of sample constant at boiling point of water during moisture evaporation
- These data show a different phenomenon, where the sample temperature rises even during moisture evaporation



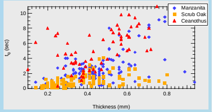
Data binned by Ignition Time and shown with 95% confidence intervals for each point

Ignition Time – Effects of Moisture Content and Thickness

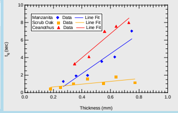
Temperature Profiles for Manzanita Leaves of Varying Thickness



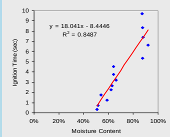
- Thicker leaves take longer to heat up to ignition temperature.
- Discrepancies may be due to variation in moisture content or shape



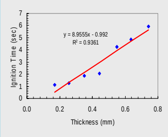
Original data plotted by species



Data binned by thickness then averaged within bins.



Ceanothus, Oak, and Manzanita data binned by t_{ig}



Ceanothus, Oak, and Manzanita data binned by thickness then averaged within bins.

Conclusions

- Different species have different burning characteristics
  - Manzanita ignites at the point and then along the edges
  - Oak ignites explosively along each of the spines sending brands into the air
  - Chamise ignites first at the needles then the stem, in the later stages of burning small pieces would be lofted into the air
- Ignition temperature appears to be a function of moisture content and thickness
  - The ignition temperature and time increase dramatically for chaparral samples of higher moisture content
  - Ignition temperature and time also increase with increasing thickness, magnitude depends on species
- Time to ignition appears to be affected by thickness and moisture content
  - Different trends observed for different species

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