AGING MASTICATED FUELS — HOW DO THEY CHANGE OVER TIME?

NORTHERN ROCKIES FIRE SCIENCE NETWORK

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Mastication is becoming a common fuel treatment method in forests and shrublands of the United States, especially where prescribed fire or mechanical fuel removal is difficult. Such sites are often located in the wildland urban interface (WUI) where fuel treatments must be carefully administered because of the risk to nearby communities. Mastication is used to grind the canopy and/or understory vegetation into small pieces, leave the particles on the ground, and reduce the chances of a fire spreading through the forest canopy. Once on the ground, fuels are either burned by prescribed fire or left to decompose.

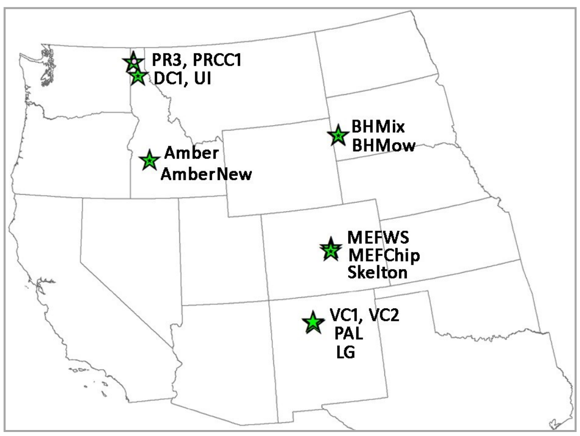

Figure 1. Location of study sites for each state. Site field code abbreviations available in Appendix 1.

Recently, several large fires have burned where masticated materials were left on the ground to decompose – including in Colorado (Brewer et al. 2013), Washington, and New Mexico (Umpries et al. 2014). Burning under extreme weather conditions with strong winds, these fires have challenged the benefits of using mastication, even though mastication can provide many positive environmental effects, such as soil moisture retention and cool, moist environments for soil microbes (Battaglia et al. 2015). Currently, there are still many questions about this fuel treatment, such as: 1) What happens as masticated materials age on the ground, and 2) does aging affect the flammability of these fuels?

This study was designed to quantify how the properties (size, shape, and fuel chemistry) of masticated fuels change with age and how these changes affect their burn characteristics (flame height, rate of spread, heat flux, and below fuel bed temperatures).

To address these questions, 15 mixed-conifer forest sites across four states in the Rocky Mountains and Great Plains were evaluated (Figure 1). The sites ranged from wet to dry, and masticated fuels were six months to 10 years old. Samples from each of the sites were sorted by shape and size to test whether aging differences were related to the different types of masticating heads (Figure 2). Individual particles were analyzed for chemical content, including carbon, nitrogen, mineral contents, lignin, cellulose, and heat content, to test whether these properties varied with age. Individual particles and fuel beds were evaluated for their drying properties using changes in heat and humidity.

Figure 2. Masticated fuels in the Priest River Experimental Forest, Idaho. Top: materials masticated by rotating head; Bottom: materials masticated by horizontal drum head.

Finally, samples were experimentally burned in a burn chamber to characterize how burning occurred in masticated fuels. Fire behavior was examined for the various fuel ages during the burn chamber experiments; however, no prescribed burns were conducted at the fuel-collection field sites to compare the experimental burning conditions to burns that may occur in their natural environmental conditions.

Key Research Findings

- **Chemistry (i.e., C, N, C:N ratio, heat content) differed between old (≥ 5 yr) and young (< 5 yr) particles.**
- **Particle size and shape did not significantly correlate with age across the study area.**
- **Age was correlated with moisture gain and loss in individual particles, and old fuels held water longer than new fuels of the same particle size.**
- **Age was not correlated with moisture loss in simulated fuel beds. For all samples, moisture evaporated completely in seven days at 80°F and 30% relative humidity.**
- **Age did not significantly affect flame lengths (FL) or rates of spread (ROS) in experimental burns. For all burns, FL was less than 3 ft and ROS was less than 1 ft/min.**

Fuel Chemistry and Age

This study found three important chemical changes with particle age. These generally matched current understanding of chemical changes that happen with wood aging and decomposition (Battaglia et al. 2009). In wood, cellulose and lignin together form a dense, ridged fibrous structure that makes a strong frame for tree growth. Cellulose and lignin together also form a dense physical barrier to rapid breakdown by microbes but, over time, microbes eventually invade dead wood and break down the cellulose, leaving lignin to become gradually more abundant as particles decompose.

First, this study found that the carbon-to-nitrogen ratio, which was tested separately from heat and cellulose content, was lower in older than younger materials (Figure. 3). This result fits with previous studies where carbon in cellulose is broken down during decomposition and the nitrogen from lignin remains (Swift 1977). The second important chemical change in the masticated fuels was that, when adjusted for particle density, intact particles had greater heat content than fragmented particles (Figure 4). Intact fuel particles are short cylindrical wood pieces from chopped branches, and fragmented particles are shapes resulting from chopping and chewing by the masticator

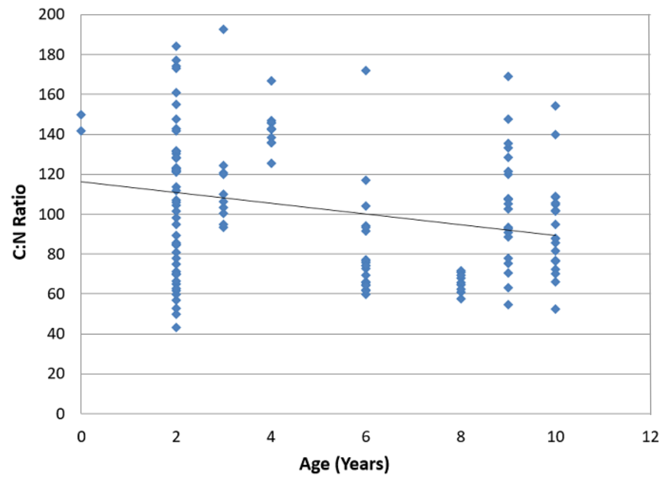

Figure 3. Relationship of fuel age to C:N ratio across all sites.

head. Heat content was greater in intact wood particles because the equipment used to measure the heat capacity, a calorimeter, burns cellulose rather than lignin. These findings indicate that fragmented particles have undergone structural changes that support a more rapid rate of decomposition than occurs in intact fuel particles.

Finally, we found that heat content and percent carbon in masticated particles declined with age. Heat content of young masticated particles (< 5 years) was significantly greater than that of old particles (≥ 5 years), again indicating more lignin and less cellulose with age. Young particles also had significantly more carbon per unit volume than old particles.

Fuel Size, Shape, and Age

Differences in the shape and size of particles produced by the different masticating heads were not correlated with age when all sites were analyzed together. When compared as paired (young (< 5 yr) and old (≥ 5 yr)) plots, the correlations were stronger, but most still were not significant.

Fuel Age and Fire Behavior

There was no correlation between masticated fuel age (≤10 years) and maximum flame height, total fuel load, or heat flux in the experimental burns. All experimental fuel beds burned, but they burned as relatively patchy fires. Many had inconsistent spread and burned as backing fires. Flame heights were generally less than 3 feet, and rate of spread averaged 0.3 ft/min. Flames were usually out within 30 minutes, but a few fires burned for longer than 1 hour. Fire behavior of the experimental burns could not be modeled because it was unpredictable, leading to poor model fit (Heinsch et al., in press).

Smoldering tests showed that duff moisture and fuel load were important to burning, but masticated fuel age was

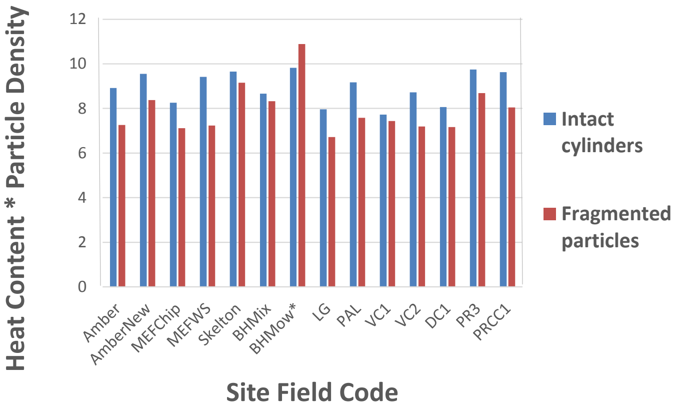

Figure 4. Heat content of intact cylinders and fragmented particles at each site.

not. Generally, smoldering beds with wet duff did not burn. Those with dry duff or dry sand and fuel loads greater than 0.22 lb/ft^2 burned readily. For fuel beds that burned, temperatures were elevated, on average, 160-175° F at 0.8 inch depths.

Fuel Age and Moisture Retention

There was no correlation between age and moisture retention in masticated fuel beds. When tested in an environmental chamber at 80°F and 30% relative humidity, moisture was completely depleted from saturated fuels of all ages within seven days, and their flammability was greatly increased. Tests on individual fuel particles 0.25-1.0 inch in diameter (10-hr fuels), however, showed that older materials held more water than younger 10-hour fuel particles. For individual particles, moisture gain and loss was determined by age and degree of fragmentation of the fuel.

Management Implications

Fuel particles left on the soil surface take a long time to decompose in Rocky Mountain forests. Even after 10 years, chemistry and particle density were the only detectable fuel changes, and these changes were most prominent in the fragmented particles. Decomposition is slow in both dry and wet areas of the Rocky Mountains, and fuel moisture is lost quickly during dry, hot weather. Moisture changes are evident in individual particles after 10 years but these changes are not obvious at the fuel-bed scale. It is important to recognize that masticated materials can ignite and burn under these conditions, and sometimes burn severely and unpredictably. The machinery used to process these materials will affect fuel bed thickness, particle sizes, and the abundance of fine material. These fuel characteristics will affect decomposition rates and potential fire behavior.

Additional Reading & Information

Battaglia, M.A., Rhoades, C., Fornwalt, C. and Rocca, M. 2015. Mastication effects on fuels, plants, and soils in four western U.S. ecosystems: trends with time-since-treatment. JFSP Project No. 10-1-01-10.

Battaglia, M., Rhoades, C., Rocca, M., and Ryan, M. 2009. A regional assessment of the ecological effects of chipping and mastication fuels reduction and forest restoration treatments. JFSP Project No. 06-3-2-26.

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Heinsch, F.A., Sikkink, P.G., Smith, H., and Retzlaff, M., *In press.* Laboratory burns of multi-aged mixed-conifer masticated fuels from the Rocky Mountains and Great Basin. USFS Research Paper. Fort Collins, CO.

Keane R.E., Sikkink P.G., and Jain, T.B. 2017. Physical and chemical characteristics of surface fuels in masticated mixed-conifer stands of the western U.S. Gen. Tech. Rep. RMRS-GTR-370 Fort Collins, CO: FS, RMRS.

Sikkink, P.G., Jain, T.B., Reardon, J., Heinsch, F.A., Keane, R.E., Butler, B., Baggett, L.S., 2017. Effect of particle aging on chemical characteristics, smoldering, and fire behavior in mixed-conifer masticated fuel. Forest Ecology and Management 405(): 150-165.

Swift M.J. 1977. The ecology of wood decomposition, Science Progress. 64(254): 175-199.

Umphries T., Nicolet, T., Romero, F. 2014. San Juan fire fuel treatment effectiveness report, USFS, Apache-Sitgreaves National Forest, Arizona. 26p .

The following data are available at from the USFS- RMRS at fsweb.rmrs.fs.fed.us/ statistics/archiving/: Particle and fuel load characterizations; experimental burn and smoldering data; chemical compositions; Moisture data; sample locations; and depth measurements of masticated layers.

Appendix 1. *PRCC1=Priest River Exp. Forest (PREF) Canyon Creek; PR3=PREF Benton Creek; DC1=Deception Creek Exp. Forest; Amber=Boise Exp. Forest (BEF) (oldest); Amber New =BEF (youngest); BHMix, BHMow=Black Hills Exp. Forest; MEFWS = Manitou Exp. Forest (MEF) White Spruce; MEFChip= MEF Chip area; VC1=Valles Caldera National Monument oldest; VC2=youngest; PAL=Paliza, Santa Fe National Forest (NF); LG=Los Griegos, Santa Fe NF; Skelton= San Juan NF; UI=University of Idaho Exp. Forest.*

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The Northern Rockies Fire Science Network (NRFSN) serves as a go -to resource for managers and scientists involved in fire and fuels management in the Northern Rockies. The NRFSN facilitates knowledge exchange by bringing people together to strengthen collaborations, synthesize science, and enhance science application around critical management issues.