Effect of Differing Charcoal Types Upon Handmade Lift Powder

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ABSTRACT

Experimental production of charcoal via the retort method is discussed. Charcoals were made from various substances; of special interest were woods belonging to the Salicaceae (willow) family. Lift powders were made using these charcoals and their performance compared using a device for testing powders under conditions similar to those used for propelling fireworks aerial shells. The author found that handmade powders often outperformed commercially available powders in this application.

Keywords: Black Powder, charcoal type, performance testing

Introduction

Charcoal is the largest single variable in the performance of Black Powder. The author undertook the testing of different charcoals as a result of "pyrogolf"[1] testing that was done during the Pyrotechnics Guild International (PGI) convention in Stephens Point, Wisconsin during 1995. Very similar research and testing has been done by others, particularly by Roger O'Neill[2] and Stan Williams.[3]

Charcoal Production Method

The retort method for destructive distillation was used to produce the various charcoals tested. The retort was fabricated from a medium sized steel pet food can, which can survive several distillations at red heat. Tabs were cut at three equidistant locations on its end and folded down to secure the end cover.

The can was prepared for distillation by packing it tightly with carbonaceous material. This minimized the volume of oxygen initially in the retort without impeding outflow of gasses. When wood was used to produce charcoal, the bark was first removed. It was then sawed to a length about one inch less than the height of the retort and made into ½-inch thick sticks.

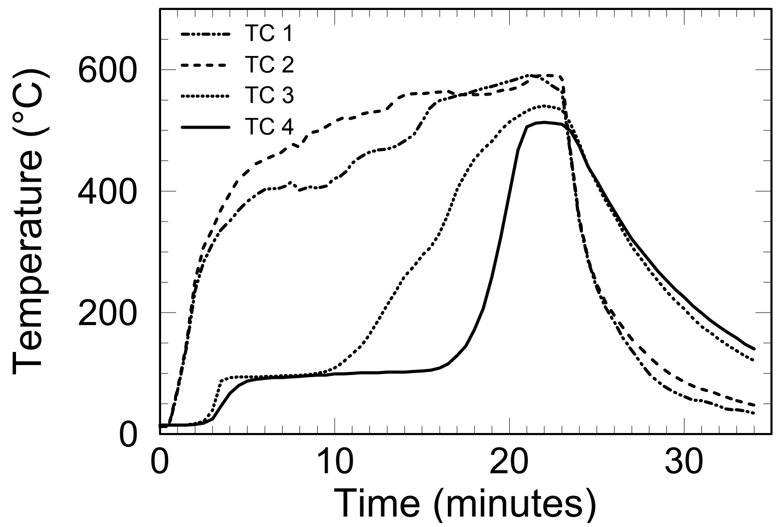
A large outdoor charcoal barbecue with a separate smoke compartment was used as a readily available heat source.

A moderately large fire was constructed using commercial charcoal briquettes, about 1 gallon by volume. Once they were completely red hot, the can was placed in a circle of briquettes, which were then piled up against the sides of the can. An extra briquette placed on top of the can also helped to distribute heat more evenly. The can was placed with its vented end down; its cover secured with the tabs. After a few minutes, the exhaust from the vent would ignite. This extra heat raised the retort temperature and completed the carbonization of the contents without oxygen.

Any leaks in the side of the can ruined the experiment because oxygen inside the can either consumed the contents, leaving little charcoal, or decreased the yield while increasing ash content of the charcoal.

If the retort was kept at red heat, the contents were turned into a high quality charcoal in about 35 minutes. When gasses from the retort stopped flaming, the can was removed from the heat by lifting it straight up and placing it on bricks with the vented end again facing down.

The resulting charcoal sticks were cool within an hour. At that point, the can was opened. Exposure to air can be unfortunate if the charcoal is pyrophoric enough to re-ignite at this point. The author has seen this happen on one



TC1 – Thermocouple placed on metal surface of the can

TC2 – Thermocouple placed just inside can

TC3 – Thermocouple placed between center and edge of can

TC4 – Thermocouple placed inside a stick of wood in the center of the can

Figure 1. Temperature profiles from retort during distillation.

occasion. For this reason, a small batch is safer than a large one.

Figure 1 shows the temperatures during a test run as measured by thermocouples placed in four locations. Peak temperature in center of can was 540 ºC, and peak temperature in the wood sample tested was 513 ºC. No sign of any exotherm was observed in these data, although many commercial charcoal producers see one beginning at about 275 ºC.[5] There is considerable evidence that temperature of pyrolysis affects the reactivity of the charcoal. In the author's experience, the appearance of the finished charcoal sticks is a good indication of the reactivity and performance of a given charcoal in lift powder. Good charcoal should have a smooth surface with few, if any, cracks or fissures.

This method relied upon the small size of both the retort and the carbonaceous material being pyrolized to control temperature. Batch to batch differences were obtained when the retort was not fully loaded. In addition, the cross sectional area and thermal insulating properties of a given material affected the quality of the charcoal. This was clearly seen in test results.

Starting Materials

Many species of wood were tested. Table 1 lists the common names and classification of trees considered for wood samples. In addition to various woods, Kentucky bluegrass clippings, cotton balls and cotton fabric were also used to make charcoal. The materials used to produce commercial charcoals are unknown.

Aspen grows abundantly in the Rocky Mountain region and is usually readily available as firewood. Maple used was the variety known as Silver Maple, widely grown as a shade tree in many parts of the US. Some species of trees used in this test grow in similar locations at elevations of up to 7500 feet. Narrow Leaf Cottonwood, Rocky Mountain Willow, and Thinleaf Alder can often be found growing within a few feet of each other.

Narrow Leaf Cottonwood (NLC) and Aspen are both members of the Willow family, in the Poplar group. In particular, NLC bears a strong resemblance to Black Willow, which explains the initial interest in its use. Other Poplar species may also be interesting but have not yet

Table 1. Classification of Trees Considered for Wood Samples.

Common Name	Family	Classification
Ailanthus (Tree of Heaven)	Ailanthus (Quassia)	*Ailanthus altissima*
Alder, Red	Birch	*Alnus rubra*
Alder, Thinleaf	Birch	*Alnus tenufolia* Nutt.
Apple (Oregon Crabapple)	Rose	*Malus fusca*
Aspen	Willow	*Populus tremuloides* Michx.
Buckthorn, Alder	Buckthorn	*Rhamnus frangula* L.[4]
Buckthorn, Carolina	Buckthorn	*Rhamnus caroliniana*
Cherry (Chokecherry)	Rose	*Prunus virginiana*
Cottonwood, Narrow Leaf	Willow	*Populus angustifolia* James
Grape (unknown variety)	Grape	*Vitis*
Maple, Silver	Maple	*Acer saccharinum*
Serviceberry	Rose	*Amelanchier* Medic. sp.
Teak	Vervain	*Tectonia grandis*
Willow, Black	Willow	*Salix nigra*
Willow, Rocky Mountain	Willow	*Salix monticola* Bebb

been tried. Willow has historically been credited with producing the highest performance charcoal for Black Powder. Unfortunately, none of the current literature distinguishes among the various species of Willow that have been found effective. Two different species of Willow were tested for this article.

For comparison purposes, test data includes a powder made from charcoal supplied by Guy Lichtenwalter. This charcoal was made from an unidentified species of Willow (although thought to be Black Willow) from the Sierra foothills of California. This charcoal was produced using a larger retort method, which has been described elsewhere.[6] A sample of Black Willow-based powder made by Jack Fielder was also tested. A sample of Aspen based powder and a second made from Skylighter[7] "air float charcoal" was contributed by Steve Hubing.

It has been suggested that Maple[8] is the source of charcoal currently used by Goex[9] to make their Black Powder. Unfortunately, the species of Maple is unknown. One would suspect that wide variation in performance could be obtained between hard (i.e., Sugar and Black Maple) and softer species such as Silver Maple. This author and others have concluded that softer woods should produce the fastest charcoal for Black Powder lift.[10]

Of particular interest was the Alder Buckthorn charcoal, much praised in nineteenth century Britain for its high gas and lower solids output. The British refer to this tree as a Dogwood.[11] The author is indebted to Paul Judd for a sample of wood from the native American species of *Rhamnus*, Carolina Buckthorn, which was found growing in Oklahoma. He also contributed a sample of powder made from Carolina Buckthorn.

The French are known to have used Alder (*Alnus Glutinosa*) charcoal in Black Powder. Two varieties of Alder found in the US were used for this paper.

An interesting aspect of the various charcoals is the appearance of the powdered forms. Silver Maple turns into a very black substance, which in turn produces a very dark Black Powder. The cotton balls used in these trials were obtained at the grocery store. Yield from these was extremely low, and produced a whitish-gray charcoal. Cotton fabric was obtained from discarded T-shirts.

Don Kark provided Teak wood samples. The author is indebted to Rich Weaver for providing a sample of Ailanthus wood and for acting as a sounding board. Ailanthus was targeted as a likely candidate for lift quality charcoal because of the characteristics of fast growth and relatively low density. It is believed that Ailanthus may never have been tried as a charcoal source for Black Powder in the US, since it has only recently been introduced here as an ornamental. It may be a good source of charcoal as the tree is now considered a weed.

Production of Lift Powder

Over the years, much debate has centered on the methods used to make high quality Black Powder. Lichtenwalter has consistently demonstrated that simple ball milling procedures can produce good powders, and the author used a similar approach for this work.

The author feels that the so-called CIA method is simply more trouble than it is worth. For those not familiar with this method, a good description may be found in McDowell's work.[12]

Better ball mill designs[13] and implementations than those used by the author will expedite powder manufacture.

To be made into lift powder, the charcoal sticks are first placed in a heavy-duty polyethylene bag. The bag is rapped with a light mallet until the sticks have been reduced to smaller chunks and dust. These were placed in a hobbyist rock tumbler along with a handful of 0.54-inch lead rifle balls. The tumbler jar used for these tests had a volume of less than one liter.

The tumbler was operated out of doors, well away from any structures. Twelve hours of milling may have been more than was necessary; however, it meshed with other daily activities. After twelve hours, the mill contents were separated with a sieve and the charcoal powder "air float" was put in a suitable container.

The next step was to produce an intermediate charcoal plus sulfur fuel powder using a weight ratio of three to two. A l60 gram batch thus contained 96 grams of charcoal and 64 grams of sulfur. The mill jar and media were cleaned before starting this phase. The charcoal and sulfur were also milled for twelve hours.

The last milling step combined the mixed fuel powder with granular potassium nitrate oxidizer. A weight ratio of one to three will produce a resulting powder with the Waltham Abbey 15/3/2 (75/15/10) proportions. The mill jar and media were again cleaned before this step. The mill was operated outdoors for twelve hours, preferably during a snowstorm, under heavy walled HDPE buckets stacked together.

Much of the debate over Black Powder manufacture centers on the next step. It is well documented that lift powder grain size (and density?) will determine its suitability for a particular size and weight of shell. The power of the lift is affected by the method used to produce the grains of powder. This experimenter has found that reasonably durable powders produced with a simple hand operated arbor press and a high quality comet pump offer the best combination of durability and performance.

The milled powder was combined with a small amount of distilled water in a steel bowl in the same manner as a pyrotechnic star composition would be prepared to make pumped stars. When the dampened powder had just reached the stage of clumping together, it was pumped into pellets with a one-inch star pump under an arbor press. The pellets were allowed to dry for a week before they were "corned".

For testing purposes, two of the powders were grained by dampening the mill dust and forcing it through a sieve. The dried rough powder was then sieved through a 12-mesh screen; the portion remaining on a 20-mesh screen was used. These powders were made from Aspen and Maple charcoal and are denoted by the letter "**S**" in Table 2.

The pressed powders were grained by hammering the dry powder pellets between heavy polyethylene sheets. The "corned" powder that passed a 4.5-mesh sieve and remained on a 12-mesh screen was tested as 2FA powder, and the passing powder that remained on a 20-mesh screen was tested as 4FA powder. Other mesh sizes were not used.

Table 2. Powder Tests (5 gram Samples).

Charcoal Type	Ave. Velocity (ft/s)	Ave. Peak Pres. (psi)	Bulk Density (g/cc)
Goex 4F	250	130	1.00
Commercial Air Float	14	7	0.54
Cotton Balls	36	19	0.71
Grape	180	80	0.72
Cotton Fabric	180	91	0.75
Apple	210	110	0.68
Teak	220	130	0.71
Cherry	230	120	0.68
Serviceberry	260	180	0.75
Rocky Mountain Willow	300	290	0.74
Alder Buckthorn	320	340	0.75
Silver Maple **H**	330	390	0.68
Aspen **H**	360	460	0.68
Silver Maple **S**	360	560	0.61
Carolina Buckthorn(1)	380	550	0.69
Aspen **S**	380	600	0.56
Carolina Buckthorn(2)	383	547	—
Red Alder(1)	410	640	0.68
Red Alder(2)	410	640	0.68
Pacific Willow	420*	730	0.75
NLC	430	660	0.71
Goex 2F	200	84	0.86
NLC 2F	220	170	0.74

* Based on less than three successful tests.

All tests used 5.0 grams of powder and were run at approximately 80 ºF.

The apparatus was cleaned after every set of 10 tests, and the order of powder types was varied.

Everything is reported to 2 significant figures.

Bulk densities were determined by settling in a tube 1.0 cm in diameter. Thus there was an edge effect making large grains appear less dense.

(1)(2) Red Alder was run in both the first and second series of tests. Carolina Buckthorn was produced in two different batches from two charcoal runs, and tested in the first and third series of tests. Note the close agreement in the findings.

S and **H** versions of powder refer to Soft and Hard grain.

Note: Moisture determinations were run on all powder samples in the second series of tests (4 hr. at 75 °C). In no case was there more than a 0.4% weight loss.

Table 3. Results of Powder Tests (3.5 gram Samples).

Charcoal Type	Ave. Velocity (ft/s)	Ave. Peak Pressure (psi)
Skylighter Air Float(Hubing)	70	—
Carolina Buckthorn (Judd)	226	117
Aspen (Hubing)	237	—
Thinleaf Alder	270	240
Ailanthus	328	396
Alder Buckthorn (Fielder)	445	762
Black Willow (Fielder)	473	819

Note that the best powders in Table 3 outperform those in Table 2. If the Aspen performance is used as a baseline, the values for speed in Table 3 should be multiplied by 1.6 to obtain the expected speed if 5 grams had been used.

Results

Powder performance was determined using a test apparatus designed to simulate the approximate conditions in the firing of aerial shells.[14] Results are shown in Tables 2 and 3. The interpretation is rather straightforward, and only a few comments are needed. The best performance was obtained first from the Willow charcoal obtained from Guy Lichtenwalter and the Black Willow based powder from Jack Fielder. The author's NLC based powder was a significant performer as well. Note that Goex brand Black Powder gives results that are lower than most of the handmade samples. The Fielder Buckthorn-based powder and the author's Ailanthus-based powder also performed respectably.

Future Research

The production of the best charcoal from Carolina Buckthorn and Alder Buckthorn is still being studied. It is possible that these Buckthorn varieties require more careful drying before pyrolysis than other types of wood. The high performance of Ailanthus also merits more research to elucidate the relationship between the physical and chemical properties of the wood with the charcoal produced from it.

There have been numerous pyrogolf competitions over the past few years, and it is quite likely that the best charcoal from any one wood species has yet to be made. One PGI pyrogolf participant very nearly won the first event with a Maple based lift powder. Another participant made a very good powder from Red Cedar.

The author plans to obtain scanning electron micrographs of several of the charcoals discussed here. A heuristic method of determining the degree of graphite structure in the charcoal will then be applied. In a related study, the volatile components of a particular charcoal could potentially be removed with solvents. Then the charcoal would be compared to itself, with and without these volatile components. Oglesby[16] indicates that powder made from so-called "stripped" charcoal is just as fast as or faster than the original.

The effects of the various pressing methods also need to be studied. It is clear that, in general, the lower the density of the grains, the faster the powder.

Another aspect of a given charcoal is the percentage used to produce the powder. All of the experimental lift powders discussed in this work and by O'Neill[17] use the 15/3/2 Waltham Abbey proportions, but a given charcoal may produce better results in a 6/1/1, 25/5/4 or even 5/1/1 mixture. This has not been studied.

Finally, a significant aspect of commercial Black Powder should be examined. Namely, Goex brand powder burns significantly cleaner than the handmade lift powders discussed here.

For most pyrotechnic applications this is of no great importance, but for lift powders it could mean more successive firings from a given mortar without the need for cleaning. The measurement of a relatively clean burning property with respect to ball mill type, chemical purity and other physical factors should be examined.

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