A simple barrel kiln for household charcoal/biochar production

By Josh Kearns, photos by Erica Bush
Winter 2008/09

This paper describes a simple and inexpensive method for the production of high-quality charcoal (also called biochar in some applications) at the household scale. The design uses a 200 L steel drum and is popular in Southeast Asia and other areas around the world.

Simple barrel-and-earth kiln

First, using a machete or other suitable blade, cut a square hole in the lid of the drum, approximately 20 cm x 20 cm.

Cut a round hole in the bottom of the drum approximately 15 cm in diameter. Lay the drum on its side in a shallow excavation.

Using some adobe bricks and cob (a mixture of mud and straw), connect the chimney pipe to the outlet opening in the bottom of the drum.

Use a generous amount of sticky cob to seal the chimney pipe to the bottom of the drum.

The easiest way to insulate the kiln is to make a simple bamboo structure around it and backfill with earth, sand and straw.

Here banana leaves are used to contain the earth in within the bamboo mesh.

Straw is added outside the earth for insulation.

An inlet is made with adobe bricks, and the lid plastered with mud for insulation and to seal the kiln.

Enhanced adobe barrel kiln

In order to attain greater insulation and thermal mass and thereby promote intensified pyrolysis, adobe and cob enhancements were made to the simple barrel-and-earth kiln design depicted above.

A structure of adobe bricks was constructed to house the kiln and backfilled with earth.

The earth was well tamped and covered with a thick layer of straw for insulation. A cob plaster was applied to cover the straw.

The kiln was loaded with wood packed as tightly as possible. A log laid across the bottom supports the wood and provides space for airflow from the inlet into the center of the kiln.

Adobe bricks and mud plaster were used to create the inlet area for the fire.

Note the bucket attached to the bamboo chimney for collection of wood distillates (pyroligneous acid, or wood vinegar).

After some experimentation making charcoal with this kiln, a tin baffle was attached with rivets to the inside of the lid. This directed the airflow during the burn to the sides of the kiln to promote more consistent pyrolysis within the different zones inside the kiln.

Temperature observations

A thermocouple probe (K-type) was inserted into the kiln and connected to a temperature datalogger. The tip of the probe was placed as near to the center of the kiln as possible.

Temperature data for five batches of charcoal are given in the plot below.

Observation and notes

Achieving high temperatures during charcoal synthesis has a great deal to do with the skill of the operator as well as with the dryness of the fuelwood. Well-seasoned and dried firewood achieves higher temperature and more rapid heating rates than wet or green firewood. Moreover, less energy is required to pyrolize dry feedstock wood as water vapor is the first component to be driven off as the kiln is heated. Much less fuelwood is thus required to fire a kiln when both the fuelwood and the feedstock inside the kiln are well dried – higher pyrolysis temperatures and faster heating rates are attained, and the resultant charcoal is of higher quality.

Skillful technique in firing the kiln is also critical to efficient production of high quality charcoal. Once a modest amount of hot coals have been produced in the kiln inlet, only 2-3 pieces of wrist-thickness firewood are necessary to keep the kiln well heated during the burn phase. The critical parameter during the burn phase is airflow – too much fuelwood in the entrance of the kiln blocks airflow, limiting pyrolysis temperatures and consuming excessive fuelwood. Placing the tips of no more than two to three medium-sized logs in the kiln entrance permits a strong draft to suck the heat and combusting gases from the fuelwood into the kiln – a slight to moderate “roar” should be observed if sufficient draft is achieved.

The following observations were recorded during several rounds of charcoal synthesis at Pun Pun Farm in northern Thailand during winter 2008-2009.

16-Dec 2008

Charcoal was made with longan wood. The fire was stoked from about 9 AM until about 5 PM. The kiln was sealed with mud a little after 5 PM, and opened the next day about 5 PM. The wood around sides was not well carbonized; the wood in center of kiln was fairly well carbonized.

23-Dec 2008

Previously the charcoal on the sides of the kiln was not well carbonized. So a piece of tin was affixed to the entrance hole of the barrel lid to deflect airflow to the sides of the barrel (see photograph above). The wood on the sides was perhaps better carbonized though the maximum temperature of the process was significantly less than the previous run. This was perhaps due to impeded airflow by the tin baffle, or perhaps the fire was stoked less vigorously although it was intended to make it more intense. Also, some of the fiberglass insulation was burned away from the thermocouple wire about 8 inches before the probe tip - when the wires touch a short occurs and temperature readings are erratic and perhaps lower than the actual temperature at the probe tip. Thus perhaps a short in the wire effected the data collection.

29-Dec 2008

This time various feedstocks were used for charcoal making, e.g. longan wood, bamboo, and coconut husks. The temperature plot is explained as follows: during the burn period the temperature peaked at about 650 ^{o}C. At about 5 PM the kiln was closed. Sometime after 10 PM that night an air leak formed and oxygen began to leak into the kiln - this caused some of the kiln contents to ignite and burn. This slow burn maintained until after noon the next day when the temperature was observed to be > 500 ^{o}C. The kiln was opened and doused with water to quench the remaining charcoal and stop it from burning. Thus this batch had a low yield since much of the charcoal turned to ash as a result of the air leak. The solution to this problem is to inspect the kiln for possible air leaks (cracks in plaster) and to plaster the front very well after subsequent burn periods.

14-Feb 2009

This time charcoal was made with longan wood. The maximum temperature achieved in this run was about 850 ^{o}C. The front of the kiln was very well sealed with a lot of adobe to prevent air leaks that could cause internal ignition in the kiln as in the run on 29-Dec 2008. Note that in the runs during February and March 2009 the highest temperatures were achieved, and that heating to these high temperatures occurred rather rapidly compared with runs during December of 2008. This is explained by the increased dryness of the wood in February compared with December. The rains finished in November of 2008 and the wood was more freshly cut at that time. By February and March 2009 the feedstock wood, which was the same wood that was used as fuel for the burn periods, was much

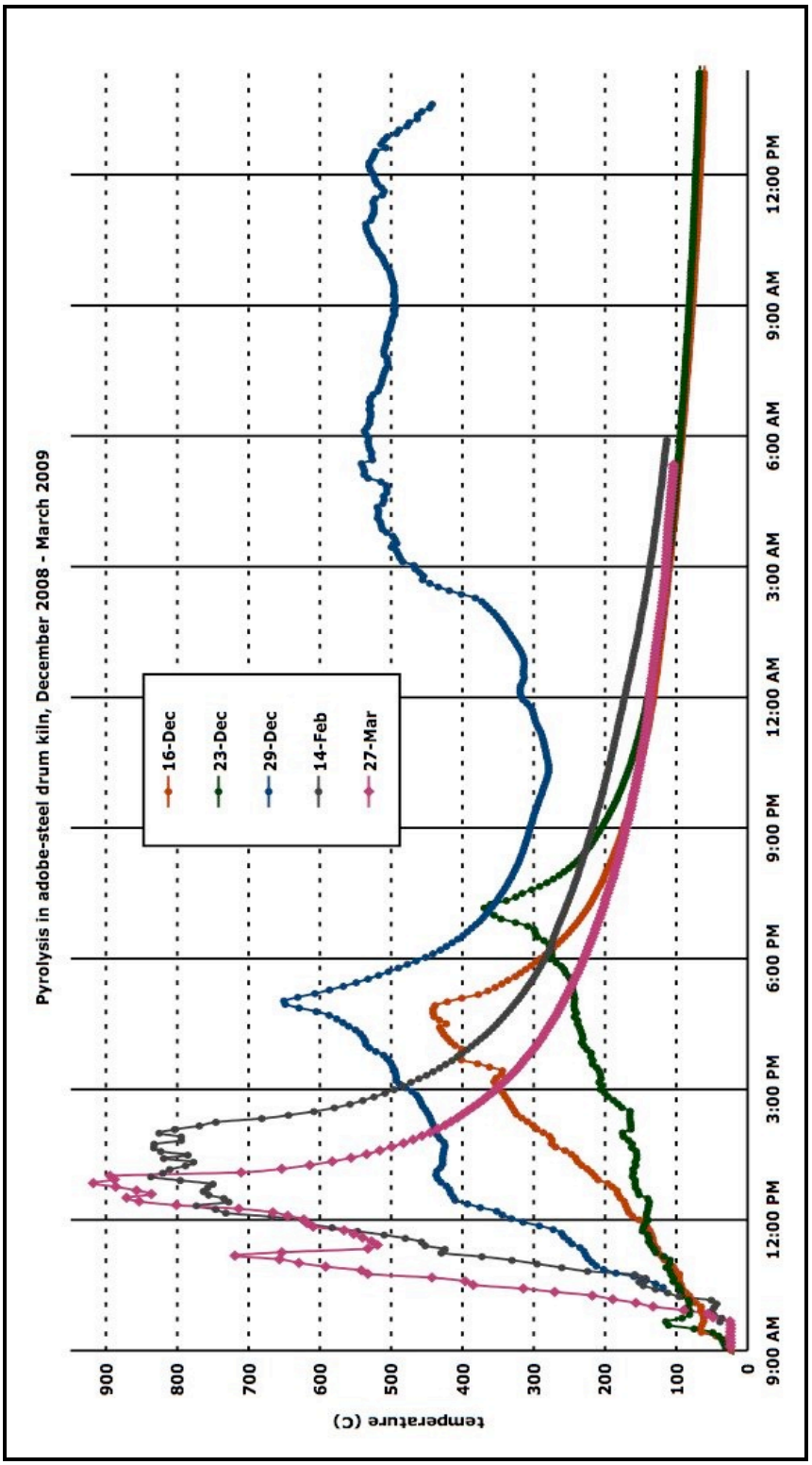
drier. Thus it was easier to burn and the kiln could achieve higher temperatures, and achieve them more quickly, since less heating energy was required to drive off the water.

27-Mar 2009

This charcoal was made from with longan wood by a local farmer (as opposed to Westerners who were primarily responsible for previous batchers) as a demo for a group of Burmese monks and their colleagues at a learning center in Burma. The wood was very dry so a high temperature was achieved relatively rapidly. The kiln was plastered well enough that no air leaks formed to ignite the contents as on 29-Dec 2008. It was not, however, as well plastered in the front as on 14-Feb 2009 and this is reflected in the more rapid drop in temperature after the kiln was closed - the run on 14-Feb would have had a bit more insulation to prevent heat escaping from the front of the kiln overnight. The drop in temperature from 11:10 AM - 11:25 AM was because the fire was unattended. Then it was stoked again beginning about 11:30 when the group arrived nearby for lunch (monks have to eat before noon, and others have to wait while the monks eat first)…

Acknowledgements

This work was supported by a grant from the Charles A. and Anne Morrow Lindbergh Foundation.


Pyrolysis in adobe-steel drum kiln, December 2008 - March 2009
16-Dec
23-Dec
29-Dec
14-Feb
27-Mar
temperature (C)
0
100
200
300
400
500
600
700
800
900
9:00 AM
12:00 PM
3:00 PM
6:00 PM
9:00 PM
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM