CHARCOAL PRODUCTION

Introduction

Charcoal is widely used as a domestic fuel for cooking in many towns and cities in developing countries as it is cleaner and easier to use than wood.

Small-scale charcoal production is labour-intensive. It can be divided into different stages of operation.

- Growing the fuel
- Harvesting the wood
- Drying and preparing the wood for carbonisation
- Carbonising the wood to charcoal
- Screening, storage and transport to warehouse or distribution point

However, it can have a detrimental effect on the surrounding environment when demand for fuel increases beyond what can be supplied on a sustainable basis.

The amount of charcoal produced varies, with the methods employed to produce it, and the skill of the operator.

Figure 1: Charcoal production. Photo: Practical Action Sudan.

This brief looks at some of the approaches in the production of charcoal and on a small scale in developing counters where efficiencies can be greatly improved through the adoption of better techniques and equipment.

Although wood is the most common fuel source many other sources have been tried including agricultural waste such as millet stems and corn cobs as well as coconut shell. These biomass materials are made up of cellulose, lignine and volatile substances and water. During the production process the volatile components are driven off and the cellulose and lignine are decomposed. The process is divided into the following stages.

- Combustion: oxygen supply is high and temperature rises from ambient to over 500°C and when the fire is established, the oxygen supply is reduced after the firing point is closed and temperature drops to about 120°C.
- Dehydration: free water is driven out at a reduced temperature of about 100°C and the kiln gives out thick, white and moist steam.
- Exothermic reaction: when the wood has dried, temperatures rise to about 280°C and the wood begins to break down into charcoal, water vapour and other chemicals; the smoke at this stage is yellow, hot and oily and the temperature is maintained by controlling the air flow through holes and vents to help burn more wood.
- Cooling: when carbonisation is complete, the kiln cools to below 100°C and charcoal can be removed for further cooling.

The process of carbonisation is greatly dependent on the carbonisation temperature, the moisture content of the wood used (the drier the better), the skill of the producer and the condition of the wood (lignin content).

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The success of the carbonisation process is the efficiency of a kiln, defined as the mass of charcoal obtained expressed as a percentage of the mass of wood initially put into the kiln:

$$E_k = M_C/M_W$$

Where E_k = kiln efficiency
M_C = mass of charcoal produced
M_W = mass of wood put into the kiln

Strictly speaking, this is the *recovery efficiency* whereas the *conversion efficiency* includes the charcoal fines (rejects) that may not be packaged for sale due to their small size. Both efficiencies are calculated on wet/dry air or oven dry basis. For example, if a piece of wood weighing 100kg has 20kg of free water, then the actual weight of the wood is 80kg. The moisture content is thus:

$$\text{Moisture content (MC)} = \frac{\text{Mass of water}}{\text{Mass of wood (dry or wet)}} \times 100\%$$

Wet or dry air basis: $MC = 20/100 \times 100\%$
$= 20\%$

Oven dry basis: $MC = 20/80 \times 100\%$
$= 25\%$

Thus if a kiln produces, say, 10kg of charcoal, then the kiln conversion efficiency (E_{kc}) at,

Wet or dry air basis: $E_{kc} = 10/100 \times 100\%$
$= 10\%$

Oven dry basis: $E_{kc} = 10/80 \times 100\%$
$= 12.5\%$

Now, assuming 5% of the charcoal ends up as fines or dust that cannot be packaged, 0.5kg of charcoal will remain in the kiln and the kiln recovery efficiency, E_{kr}, can be calculated as follows:

Wet or dry air basis: $E_{kr} = (10-0.5)/100 \times 100\%$
$= 9.5/100 \times 100\%$
$= 9.5\%$

Oven dry basis: $E_{kc} = (10-0.5)/80 \times 100\%$
$= 9.5/80 \times 100\%$
$= 11.9\%$

Normally, kiln efficiencies are based on the simplest conditions, that is, conversion efficacies on dry air basis, as these are the easiest to measure and calculate. Most small-scale charcoal production relies on partial combustion of the wood charge to provide the heat necessary for carbonisation hence yields depend heavily on the moisture content (Stassen, 2002).

Kilns

Traditional charcoal production is an acquired skill. The most critical factor in the efficient conversion of wood to charcoal is the careful operation of the kiln. Wood must be dried and carefully stacked to allow an even flow of air through the kiln and sufficient time for reactions to take place. If kilns are not operated correctly, yields can be half the optimum level.

Traditional kilns

Much charcoal for domestic consumption in developing countries is produced in pit kilns (holes dug in the ground), or in mound kilns (piles of wood stacked on the ground and covered with soil), by farmers and landless labourers. Yields (weight of charcoal/weight of wood) from pits vary from less than 10 per cent to over 25 per cent.

Brick and concrete kilns

Kilns made of bricks can be more efficient than earth mounds, can be operated all year round and have longer lifetimes than metal or mud kilns, and are less susceptible to poor operator practices. However, the high-grade charcoal that they produce may not be acceptable to domestic users, since it is difficult to ignite. Switching to large, efficient kilns, has many economic and social implications, as most charcoal is still produced by farmers and landless peasants who, under normal circumstances, might not be able to benefit from the switch and, indeed, might suffer from it.

Brick kilns are ideal for replacing traditional kilns when consistent high-quality charcoal is required in large quantities. The throughput of a battery of seven "beehive" kilns, for example, is around 15,000 cubic metres per year. However, the construction of such kilns requires a relatively high level of brick-building skills, as well as a supply of bricks. This restricts the scope of such kilns in many countries, but in areas where they can be cheaply built and maintained, they have proved to be a very effective method of charcoal-making. The "beehive" kilns cost approximately $200-300 with yields of up to 35 per cent of input wood.

One of the major advantages of the brick kiln over earth kilns of similar size earth kilns is that their carbonization cycle is much quicker. Typically, a 50 cubic metre brick kiln has a carbonization cycle of 8-10 days, whereas that of the comparable earth kiln is, at least, twice as long. Moreover, the labour involved in operating the brick kiln is very much less than that required to construct and manage the earth kiln. Furthermore, the operation of the brick kiln is generally much simpler than the earth kiln: workers can be trained in its use relatively easily and shortages of skilled labour are not likely to be a constraint on production.

Brick kilns, however, are usually permanent structures: they are, thus, only suitable in locations where there is a supply of wood within easy transport distance and sufficiently large to last the working life of five or more years of the kilns.

Portable steel kilns

Portable steel kilns are in the form of a cylinder with a conical top. A kiln breaks down into three components which are designed to be easily rolled along the forest floor to new burn areas or to be transported by truck. Portable steel kilns have a small output: the annual production from a typical demountable kiln with a volume of 7 cubic metres is in the range of 100-150 tons. They are not, therefore, particularly suitable for areas where there is a need for high-volume production. Their ideal application is where the source of wood is dispersed and charcoal-making is carried out on a relatively small scale.

Figure 2: Using a portable metal kiln in Sudan.
Photo: Practical Action Sudan.

The advantages of the portable steel kiln are that it requires less labour than the small earth kiln and has a generally greater yield of more consistent and higher quality charcoal. It is also much quicker: the total carbonization cycle with a 7 cubic metre demountable steel kiln is 3-4 days; with a similar size earth mound, the cycle is likely to be 10-14 days.

The mobile steel kiln, like the brick kiln, has the substantial advantage over the earth kiln in that training in its use is very easy. The steel kiln can, therefore, be used even in areas where there is no tradition of charcoal-making.

The major disadvantage of the portable steel kiln over traditional kilns is its increased cost: even with local manufacture, this is about $1000 and, in many places, considerably more. Given a working life of 2-3 years, it can be very difficult to justify economically in areas where labour costs and charcoal prices are low.

Charcoal from mesquite shrubs in Sudan

Practical Action has made use of portable steel kilns in Sudan to make charcoal from Mesquite (Prospois) which is a perennial woody plant that can grow in the arid conditions of Sudan. It was promoted in the 1970s and 1980s and a source of fuel wood, pods for fodder and as a way of stabilising soil in efforts to combat desertification. However, it has caused problems when unmanaged as it spreads into area of grazing and farming land and has become very difficult to control. The situation has resulted in the plant being declared a noxious weed in Sudan and there is a program of eradication. charcoal production using mesquite is part of this eradication program that can also provide an opportunity for some to improve their income.

The project uses mobile metal kilns based on the design for carbonization of cotton stalk as part of the Biomass Technology Group at the Energy Research Institute in the 1980s which is similar in design to a MARK V metal kiln (a well known charcoal kiln) but of smaller volume and weight to allow for easy transportation, with a volume of about $2m^3$. Its nominal carbonization efficiency is around 25%. The metal kilns additional advantage over the normally used earth-mound kiln is that it enables fine charcoal to be made from the small branches of the Mesquite shrub.

The metal kiln can be fabricated locally at a low cost as it can be made from empty oil barrels which are purchased in Kassala market.

Mini-Charcoal Kilns
The mini-charcoal kilns in used in many locations. One design of mini Charcoal kilns is described by E G K Rao, India in the Magazine Boiling Point No 6, April 1984. This describes a kiln that is constructed from an oil drum based on a traditional design form the Philippines used to process coconut shell. It yields over 30% high grade charcoal from an 80 kg charge of firewood.

One person could operate a batch of about 10 oil barrel kilos, producing up to 250 kg of high quality charcoal per day. The major drawback of this type of kiln will be its short lifetime, but where there are cheap oil barrels and a good market for high quality charcoal, it could be a profitable small business.

Charcoal briquettes
Briquettes made of agricultural waste can compete with traditional woodfuel if they are of sufficient quality and are priced correctly. This allows the conversion of low-grade residues to marketable fuels. The work by MIT D-Lab in producing charcoal briquettes is described in the technical brief *Fuel from the Fields: Charcoal from Agricultural Waste.*

technical brief

Biomass wastes for charcoal in Kenya

In Kenya a study in 2004 looked into using biomass waste to make charcoal briquettes. The study encompassed criteria such as availability, conversion potential, fuel quality and enterprise potential.

In order create a short-list of a manageable set of materials with real potential,

The study considered the total quantity available across the country as the most important parameter for fuel production. It was also important to consider any annual or seasonal variations in supply and any pre-existing or competing uses. Finally, the lower the ash content of the biomass waste, the better the quality of fuel production.

Based on this analysis, the following biomass wastes showed potential commercial viability based on their availability within Kenya:

- Bagasse (a by-product of sugar processing)
- Sawdust
- Coconut husk
- Coffee husk
- Wattle bark
- Macadamia nut shell

The study showed that all of these apart from coconut husk have high potential to form the basis of a viable briquetting business the country.

Source: The Use of Biomass Wastes to Fabricate Charcoal Substitutes in Kenya- Feasibility Study, Chardust Ltd. and Spectrum Technical Services, 2004.

Experience in Gambia and elsewhere has shown that residue and charcoal briquettes may not burn well in existing stoves. See Boiling Point special Edition on Briquettes 1989/90.

Issues of production and use

Charcoal is important in terms of energy and economies within most African countries. The production of charcoal employs a considerable number of people in rural areas. However, charcoal users as the group are most strongly exposed to carbon monoxide (CO), followed by wood users. Charcoal use also results in high volumes of carbon dioxide (CO_2) emissions contributing to global warming.

Increasing end-use efficiency requires the promotion of improved stoves. Traditional stoves are normally made by the informal sector; models with higher heat transfer efficiencies should be developed in collaboration with end-users and stove producers, and manufactured by the private sector.

Inefficiencies inherent to the production and use of charcoal, rapid urbanization, and the preference of urban dwellers for charcoal place a heavy strain on local wood resources.

This led to Practical Action investigating the potential for fuel substitution on a number of locations including Kassala, Kenya where households were helped to switch from wood and charcoal use to LPG and Kerosene. Financial loans helped people cover the costs of converting as cost was seen as the dominant constraint. Introducing LPG or Kerosene reduces the particle pollutants, which result in improved long-term health benefits when compared with traditional fuel wood or charcoal use for cooking.

Kerosene and LPG is affordable for many upper- and middle-level households but further improvements in pricing and delivery (particularly of LPG) are required to enable households lower on the income scale to make the switch away from traditional fuels. See *Kerosene and Liquid Petroleum Gas (LPG)* Practical Action Technical Brief.

Electricity is not a potential substitute for woodfuels. Although electricity is affordable and practical in many areas for lighting, communications, and possibly for refrigeration, few households, rural or urban, will be able to afford to cook with electricity if it is priced at cost-reflective tariffs.

Conclusion

Improved charcoal kilns require some capital outlay but also require better understanding and control of the carbonization process. Drying of wood, better stacking methods, and better process control, in combination with a chimney to force inverted draught, can greatly increase carbonization efficiency. However, they takes more time and effort to prepare the kiln and control the carbonization process.

In areas where wood is feely available traditional charcoal makers may not have an incentive to improve their production and may use several traditional kilns. Increasing the efficiency of charcoal production requires regulatory measures, systematic training, and demonstration programs.

References and further reading

- *Biomass as a Solid Fuel* Practical Action Technical Brief
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- *Charcoal of Simple Kiln Systems* GTZ (now GIZ)
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- *Charcoal Making in Developing Countries Technical Report No 5* Gerald Foley, Earthscan
- *The Charcoal Dilemma: Finding a sustainable solution for Brazilian industry* Practical Action Publishing 1996
- *Charcoal in the Value Chain in Western Kenya* Alannah Delahunty
  Alannah Delahunty completed an Msc in Africa & international Development at the University of Edinburgh. For her dissertation research she spent time in Western Kenya researching aspects of gender in the charcoal value chain. This research was carried out as part of the PISCES project, which is developing new knowledge on sustainable bioenrgy production through action research and policy development in Kenya, Tanzania, India and Sri Lanka. www.pisces.or.ke

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A small private energy consultancy and technology development company in the UK. BES has just completed the development of a prototype charcoal making system. This is a very innovative system that makes charcoal and uses the by-product gases to generate electricity. The development of the prototype has been part supported by the DTI.

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Pro-Natura International was started in Brazil in 1985 and by 1992 had become one of the very first 'Southern' NGOs to be internationalised following the Rio Conference. The head office of Pro-Natura International is currently situated in Paris, France with offices in Brazil, USA, Ghana, Nigeria and the UK.

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In an attempt to reduce deforestation, Pro-Natura has developed Green-Charcoal. This technological innovation, using agricultural residues and unused biomass, produces an environmentally friendly and economically competitive alternative to wood. Carbon sequestration is another means of mitigating global warming. Reforestation and agroforestry practices allow the excess of carbon dioxide in the atmosphere to be stored in trees and in soil (in the form of organic matter). The consequent revitalization of the soil also improves agricultural productivity. In this field Pro-Natura collaborates with Eco-Carbone.

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