Energy and Environment Research; Vol. 3, No. 1; 2013
ISSN 1927-0569 E-ISSN 1927-0577
Published by Canadian Center of Science and Education

Comparative Study on Charcoal Yield Produced by Traditional and Improved Kilns: A Case Study of Nyaruguru and Nyamagabe Districts in Southern Province of Rwanda

Alphonse Nahayo[1], Isaac Ekise[1] & Alphonsine Mukarugwiza[1]

[1] Higher Institute of Agriculture and Animal Husbandry (ISAE-Busogo), Department of Forestry and Nature Conservation (FNC), Musanze, Rwanda

Correspondence: Alphonse Nahayo, Higher Institute of Agriculture and Animal Husbandry (ISAE)-Busogo, Department of Forestry and Nature Conservation, P. O. Box 210, Musanze, Rwanda. E-mail: nahayo1@yahoo.fr

Received: November 5, 2012 Accepted: November 26, 2012 Online Published: January 16, 2013

doi:10.5539/eer.v3n1p40 URL: http://dx.doi.org/10.5539/eer.v3n1p40

Abstract

Deforestation and shortage of wood are serious environmental issues in Southern Province of Rwanda. This is likely to happen due to inadequate strategies and capacity to produce and utilize wood for energy on a sustainable basis. Furthermore, the production of charcoal in rural areas is done through the earth mound kilns causing more pressure on forests due to increased demand of charcoal. The main purpose of this study was to compare the charcoal yield produced from improved and traditional methods. This study was conducted in Nyabimata sector of Nyaruguru District and Tare sector of Nyamagabe District in June and July 2012. Improved charcoal and traditional charcoal were produced in order to determine the best method to be used. Data were analyzed using the Gen Stat Discovery 4th Edition. The results revealed that improved techniques can increase the charcoal production and reduce the air pollution where one can obtain at least 3 bags of charcoal in 1 m^3 of wood and 15 liters of tar collected from the chimney containing the major elements responsible for green house gases emission. The yields of charcoal obtained according to the weight of wood used were less in traditional earth mound kiln (T_1) techniques with the percentage of 7.5% than what improved earth mound kiln (T_2) and casamance kiln (T3) techniques produced with 19% and 20% respectively. Measures should be taken in order to increase the level of improved charcoal making adoption, such as encouraging people to invest in improved charcoal production, organizing the trainings to the charcoal makers and planting more trees.

Keywords: improved earth mound kiln, traditional earth mound kiln, Casamance kiln, charcoal yield

1. Introduction

Charcoal is a fuel commonly used by households for cooking food and heating in certain parts of the developing world. Biomass users prefer charcoal over other biomass fuels such as wood, residues and dung because charcoal has a higher energy density than other biomass fuels. It also has excellent cooking properties because it burns evenly, for a long time, and can be easily extinguished and reheated (Kammen & Lew, 2005).

The Food and Agriculture Organization (FAO) has estimated that the total charcoal production in 1992 was 24 million tons. About the half of the world's charcoal use is in Africa, where traditional production techniques lead to low conversion efficiency (Kammen & Lew, 2005).

In Kenya, concerning the urban household energy use, 66% is supplied by charcoal and 18% by fuelwood. For rural household energy, 90% is from fuelwood and only 5% from charcoal (O'keefe, Raskin, & Bernow, 1984).

In Tanzania, around 91% of all energy consumed is woodfuel. Miombo woodland is the source of about 70% of the annual consumption (Monela et al., 1993). It accounts for 97.6% of the total wood products consumed in the country (MNRT, 2001). The estimated national annual fuelwood consumption in Tanzania is 44.8 million m^3 (Kaale, 2005). The major consumer centres are households for cooking (95.4%), rural industries (2.8%) and agriculture (1.4%). The rural industries and agriculture use exclusively fuelwood. On the other hand, the rural households use almost fuelwood exclusively.

In year 2000, the charcoal consumption was estimated in three African cities to about 140,000 tons for Maputo (Mozambique), about 314,000 tons for Dar es Salaam (Tanzania) and about 245,000 tons for Lusaka (Zambia).

In these countries, the households used certain fuel energy sources for cooking certain foods or for other kind of activity requiring energy such as lighting or heating (CHAPOSA, 2002). The same author reported that in Lusaka (Zambia), 65% of the households used charcoal as the only energy source while the rest of the households used charcoal in combination with firewood (23%), kerosene (17%) and electricity (1%). As for Dar es Salaam, 69% of the households used charcoal for cooking as their first choice.

Charcoal is essentially produced by heating fuelwood (or any other raw biomass) in some types of kilns with limited access to air, a process called carbonization. Charcoal making kilns can vary greatly in structure and size, from simple earth mound kiln to semi permanent brick ovens to large and permanent metal structures. Carbonization creates a fuel of higher quality than the original fuelwood because of inherent inefficiency in the process (Kokou, Nuto, & Atsri, 2009).

Wood collection is the main cause of deforestation. Therefore, the improved charcoal making decreases the quantity of wood used for charcoal production through the improvement of technique and the utilization of chimney helps reduce the pollution of atmosphere through the smoke. With improved methods of charcoal making, a greater quantity of charcoal could be produced. There is no much waste, air pollution in the burning process as with more traditional means. Improved kiln for charcoal making also plays a role in reducing exposure to indoor smoke, and it is the cheapest source of energy we can use in our country in order to reduce deforestation, cooking time, smoke in the kitchen and to economize the cooking materials because a given quantity of wood in improved kiln produces about twice as much charcoal as the same quantity of wood in traditional kiln, also a given quantity of charcoal produces approximately twice as much heat as the same weight of wood. Burning charcoal produces temperature in excess of 1,000 degrees Celsius and it is relatively easy to make it (Gerald, 1986).

In Sub-Saharan Africa, the production and consumption of charcoal lead to high associated Green house gas emissions which are the result of three factors (Müller, Michaelowa, & Eschman, 2011):

1) An unsustainable supply of biomass in which forests are being depleted for the production of the fuel.
2) The use of inefficient technologies to convert wood into charcoal with yields as low as 10% observed in certain countries (10 kg of wood required to produce 1 kg of recovered charcoal).
3) The use of specific technologies in which the conversion of wood into charcoal leads to a high level of methane emissions

The potential for reducing green house gas emissions by promoting the application of improved kiln technology is tremendous, not only due to higher charcoaling efficiencies, but also due to the application of green house gas reducing technologies (e.g. destruction of the methane stream) and the possibility of electricity co-generation as stated by Sander, Hyseni and Haider (2011). These opportunities can refer either to the technology and practices for charcoal making or to a decrease in non-renewable share of biomass used.

International Center for soil Fertility and agriculture Development **(**IFDC) through its department of value chain has undertaken different activities aiming at improving sustainable energy in Rwanda. Private forests owners have been, since the beginning, among the targeted groups with IFDC and charcoal makers have worked with them. With the contribution of IFDC, the sensitization and training about the use of improved kiln for charcoal making in Nyaruguru and Nyamagabe districts started in 2010.

Charcoal production is one of the primary causes of deforestation in Rwanda. Changing behavior of farmers through the adoption of improved kiln will play an important role in environmental protection by reducing deforestation and air pollution. The main objective of this study was to compare the charcoal yield produced from improved and traditional charcoal making techniques in Nyaruguru and Nyamagabe Districts in Southern province of Rwanda. The specific objectives were (i) to determine between improved and traditional kiln the best technique to be used in order to produce much charcoal by using less wood; (ii) to determine between the traditional and improved kilns the technique to be used in order to produce the charcoal intended for domestic uses of high consistency in terms of weight. The following hypotheses were formulated: (1) There is no significant difference in the charcoal yield among the three charcoal making methods (traditional earth kiln, improved earth kiln and casamance kiln) at p-value of 5%; (2) There is no significant difference in weight of charcoal measured by each bag from three kilns of charcoal making at p-value of 5%.

2. Material and Methods

2.1 Study Area Description

The District of Nyaruguru (1010.267 km^2) is located in Southern Province of Rwanda. It has 14 administrative sectors which are Munini, Kivu, Cyahinda, Nyagisozi, Ngoma, Ngera, Rusenge, Muganza, Ruheru, Busanze, Mata, Ruramba, Kibeho and Nyabimata. The study was conducted in Nyabimata sector. The altitude varies between 2000 and 2500 m a.s.l. The Eastern part of the District is characterized by the central plateau with an altitude varying between 1500 m to 2000 m a. s. l. The annual average temperature is around 17 °C in the region of high altitude and 20 °C in the region of average altitude.

The District of Nyamagabe lies between Huye and Rusizi in the South-West of Rwanda. It also contains the half of Eastern Nyungwe National Park, a popular tourist destination, being one of the last remaining forest areas of Rwanda and home to chimpanzees and many other species of primate and birds. Nyamagabe District is divided into 17 sectors: Buruhukiro, Cyanika, Gatare, Kaduha, Kamegeli, Kibirizi, Kibumbwe, Kitabi, Mbazi, Mugano, Musange, Musebeya, Mushubi, Nkomane, Gasaka, Tare and Uwinkingi. The study was done in Tare sector. Nyamagabe District has an average altitude varying from 1800 to 2700 m a.s.l. It has uneven altitude with some summits going beyond 3000 m high. Nyamagabe District relief is characterized by irregular slopes ranging from 60° to 120° making the soil susceptible to soil erosion and degradation. Nyamagabe District enjoys a humid tropical climate moderated by the effect of high altitude. Annual rainfall varies from 1300 to 1450 mm with average temperature of 18 °C.

2.2 Material

Table 1. Materials used

Materials	Use
Wood of *Eucalyptus maidenii*	The Eucalyptus trees are the most suitable for charcoal making and suitable to increase the consistency of charcoal.
Panga and axe	For cutting wood
Hoe	For digging and land leveling
Spade	For digging and land leveling
Taper	For measuring
Balance	For weighing wood or charcoals
Rake	For collecting charcoal in the kiln
Pitch fork	For collecting charcoal
Hygrometer	For measuring humidity

2.3 Methods

Experimentation design.

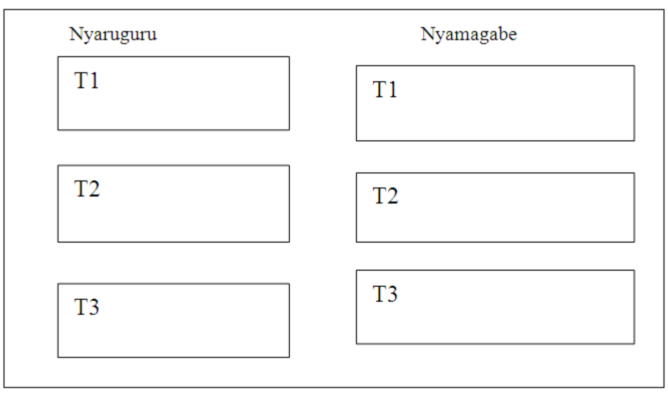

Figure 1. Experimental layout

Experimental kilns were laid out by using randomized complete block design (RCBD) with 3 treatments and 2 replications. The treatments were: T1= Traditional earth kiln; T2= Improved earth kiln; T3= Casamance kiln.

3. Preparation of Kilns and Carbonization Follow Up

3.1 Cutting down Trees, Site Selection and Loading the Kiln

The wood was cut for three weeks and dried in solar energy before the carbonization operation begins; this is necessary to reduce the amount of water content in order to minimize the amount of heat energy wasted during the drying stage. As the rate of carbonization is sensitive to many factors, the wood used had the same moisture content and the same size of length of 2 m each. The site was selected from the dry places, free from stumps; small vegetation was removed and the land was leveled roughly to produce square or circular platform. The transport of wood was reduced to minimum level by making the kiln in or near the forest.

Before charging the kiln, the pit was covered with a layer of branch litter. This is needed during carbonization process because the soil takes the heat and continues to burn the charcoal. Then, the charcoal burns completely and produces high content of ash and carbon. This layer was put between soil and wood as it had the importance of collecting charcoal from clear ground. The first layer of wood in the kiln is composed of small wood in length playing the role of circulating smoke in the kiln and preventing the soil from touching the trees. Trees were loaded into the kilns with the aim to not lift any place between trees. Small branches were used to fill the empty spaces between trees. The installation of chimneys was done before covering the kiln with the soil. The chimneys were placed in the middle of the kiln on the upper side.

Figure 2. The chimney installation in improved kiln

After loading the kiln, the wood was covered with the leaves of *Eucalyptus maidenii*. The earth layer was sealed without any hole in the kiln.

3.2 Care Taken during Carbonization and Discharging Charcoal

The labor was available during the day and night in order to control the kilns. Then the supply of air to the kiln was carefully controlled and all air entries were completely excluded during carbonization.

The kiln was kept tightly and sealed in order to reduce the danger of the whole load to burst into flame and to be lost. It was prohibited to walk on the top of the kiln for avoiding the fire. The end of this process was shown by the reduction of the smoke and the appearance of the bluish color from the chimney. It consisted in the removal of the heated soil layer on the top of the kiln and the addition of another wet soil without disturbing the leaf litter. Once it was exposed to the open air, charcoal was left for a period of about 24 hours. During this time, the charcoal was cooled to air temperature. The danger of spontaneous combustion disappeared and the charcoal was ready for packing.

Figure 3. Liquid products in casamance kiln

The smoke from the kiln was left in the chimney in the form of water vapor or gas. Reddish water and mixture of tars and other unknown products were collected. Note that the composition of those substances is not known, but research is under process. This liquid product was sticky with strong and pungent smell which lingers on anything with which it is in contact. All these liquids, if there were no chimneys, they would have gone in the atmosphere to pollute and damage the environment.

The Table 2 below summarizes the methodology used to produce charcoal in Traditional kiln (T1), Improved kiln (T2) and Casamance kiln (T3).

Table 2. Charcoal production in Traditional kiln (T1), Improved kiln (T2) and Casamance kiln (T3)

Characteristics	Traditional kiln (T1)	Improved kiln (T2)	Casamance kiln (T3)
Size of wood used	2m	2m	Wood with the same moisture content and the wood size was 2m; 1.8m;1.7m; 1.5m; 1.3m; 1.1m; 0.9m; 0.7m and 0.5m in order to respect the circular plat form of the kiln.
Pit kiln measurements	2.5 m for both length and width	2.5 m for both length and width	2.5 m of radius
Materials	The same materials used: See Table 1 above		
Site selection	Level land roughly to produce irregular form	Level land roughly to produce rectangular plat form	The site was selected from dry places, free from stumps and vegetation was removed. The site was also leveled roughly to produce circular plat form of 2.5m of radius

Characteristics	Traditional kiln (T1)	Improved kiln (T2)	Casamance kiln (T3)
Loading the kiln	Layers of loading the kiln: disorganized loaded wood was the first layer in the pit kiln	The layers of loading the kiln: On the pit kiln, put a layer of branch litter followed by wood and put the layer of branch litter again and finally a layer of the soil to cover all kilns. For this method, the first woods loaded in the kiln were composed of small wood in length and diameter with the role of circulating the smoke in the kiln and preventing the soil from touching the trees. Small woods were loaded with the aim of not leaving any space between trees.	The layers of loading the kiln were as follows: a layer of branches and a big layer of wood followed by a layer of branches: all were covered with a layer of soil
Internal capacity	$17m^3$	$17m^3$	$17m^3$
Chimney	Not used: The kiln was not covered completely so as to simplify the aspiration of smoke in the kiln	The chimney was installed in the middle part of the kiln, on the upper direction. After, the kiln was covered completely and the air entry was opened and closed when needed	Three chimneys were used: one was installed on upper side, other on the left side and the last was installed on the right side
Smoke	The smoke emerges everywhere on the top	The smoke was released through one chimney	The smoke was released through three chimneys
Care during carbonization	The labor was available during the day and night in order to control the kiln	The kiln was kept tightly and sealed in order to reduce the danger of the whole load to burst into flame. The labor was available during the day and night in order to control the kiln.	The same as for improved kiln
Methods used to cool charcoals	The end of this process was shown by the reduction of the smoke. This phase consisted of removing the heated soil layer on the top of the kiln and the addition of wet soil. Charcoal was exposed to open air for about 4 hours. During this time, the charcoal was cooled to air temperature. The danger of spontaneous combustion disappeared and the charcoal was put into different packages	The end of this process was shown by the reduction of the smoke and its bluish color from the chimney. This phase consisted of removing the heated soil layer from the top of the kiln and the addition of another wet soil without disturbing the leaf litter. Charcoal was then exposed to open air for a period of about 4 hours to be cooled to air temperature. The danger of spontaneous combustion disappeared and the charcoal was put into packages and the tar was collected.	The same as for the traditional and improved kilns

3.3 Data Collection and Analysis

The mass of the wood loaded into each kiln was determined either by direct weighing or from the wood volume where each kiln had $17m^3$ in Nyaruguru District and $17m^3$ in Nyamagabe District. The moisture content of wood was determined by hygrometer. During the charcoal making process, the emission was released from the kiln through one or more chimneys at a time. In order to test the degree of emissions released from different kilns, we have collected all liquids (tar) released in the chimney from each kiln and measured them in liter. After the end of firing, each kiln was sealed and allowed to cool. After cooling, charcoal was removed and weighed. The quantitative data obtained were analyzed by means of Gen Stat Discovery Edition 4 software.

4. Results and Discussion

Means of charcoal making in three treatment areas of T1 (Traditional method), T2 (Improved method), T3 (Casamance kiln) in two different Districts, Nyaruguru and Nyamagabe, are presented in the Table 3 below.

Table 3. Means of charcoal making in three treatment areas of Nyaruguru and Nyamagabe Districts

Parameters	T_1	T_2	T_3	P<0.05	L.S.D	C.V.%
Carbonization in days	12.500^a	5.000^b	5.000^b	<0.001	1.299	5.4
Bags/m^3 of wood	2.000^c	3.000^b	3.250^a	<0.001	0.1299	1.5
Humidity in %	76.5	76.5	76.5	ns	42.76	17.6
Bags for each kiln	29.50^b	52.50^a	55.00^a	<0.001	3.182	2.2
Charcoal in Kg	930^b	2362^a	2475^a	<0.001	203.5	3.3
Charcoal in %	7.5^b	19.0^a	20.0^a	<0.045	9.75	19.8
Tar in Liter	0.00c	15.00b	15.75a	<0.001	0.6496	2.0

Values followed by the same letters in a row are not significantly different at P <0.05; n.s. = not significant, L.S.D= Least significance difference, C.V= Coefficient of variation in percentage.

The Table 3 shows that the charcoal yields obtained by using casamance kiln (T_3) and improved traditional earth mound kiln (T_2) are significantly different in two Districts at $p < 0.05$. The charcoal yields obtained using the improved kilns were higher than the ones obtained by using traditional earth mound kiln (T_1) with the mean value of 55.00^a, 52.50^a and 29.50^b respectively.

The duration of carbonization in days, bags of charcoal obtained from 1m^3 of wood, bags of charcoal obtained from 17 m^3 of wood, weight of charcoal, charcoal in % and tar collection were very significantly different among three types of kilns at $p<0.05$. The number of bags of charcoal obtained in 1m^3 of wood from casamance kiln (T3) technique was different from the one obtained by using traditional (T_1) and improved traditional earth mound kiln (T_2) techniques with the mean value of 3.350 got from casamance kiln (T3). Other techniques presented the mean value of 3.000 and 2.000 respectively. Even if the weight of bags used for packing were the same in each technique, the charcoal weight obtained in three techniques was totally lower in traditional earth mound kiln (T_1) (mean weight of charcoal: 930kg =29.50 bags) than casamance kiln (T3) (mean weight of charcoal: 2475 kg= 55.00 bags), and improved traditional earth mound kiln techniques (T_2), (mean weight of charcoal: 2362 kg= 52.50 bags).

The yields of charcoal obtained in percentage according to the weight of wood used was less in traditional earth mound kiln (T_1) techniques with the percentage of 7.5% than what improved traditional earth mound kiln (T_2) and casamance kiln (T3) techniques produced with 19% and 20% respectively. The weight of charcoals had a significant difference ($p<0.05$) in terms of bags of charcoal obtained from the 1m^3 of wood and in terms of weight of charcoals obtained from each kiln of 17m^3 of wood while the yield of charcoal in percentage was significantly different at p- value <0.05. The days spent for carbonization by using traditional earth mound kiln (T_1) was higher than the improved traditional earth mound kiln (T_2) and casamance kiln (T3) techniques with the means of 12.5 and 5.00 respectively.

There was no difference of moisture content in wood used among three types of kilns. Concerning the quantity of tars collected during wood burning for three techniques, results showed that there was no tar produced in traditional earth mound kiln (T_1). However, there was a higher amount of tars produced by improved traditional earth mound kiln (T_2) and casamance kiln (T3) techniques with the means of tars equal to 15 and 15.75 liters respectively. This means that the improved kilns reduce the air pollution by retaining the harmful chemicals into the tar filtered by the chimney. The tars collected in improved (T_2) and casamance kiln (T3) presented a significant difference at $p<0.05$.

The chimney plays an important role in reducing the air pollution by filtering the smoke. The tar can be considered as a secondary product of charcoal production because it is often used as an insecticide or in painting the houses. Traditional kiln techniques contribute much to the environmental degradation because it uses a huge quantity of wood and it produces gases which are not filtered in the chimney as it is done for improved earth mound kiln techniques. The tar produced through the chimney is a significant production of products of incomplete combustion (PIC). The PIC emitted during the charcoal making process include carbon monoxide (CO), methane (CH_4), total nonmethane organic compounds (TNMOP), and particulate matter. Nitrogen oxides (NO, NO_2, and N_2O) as well as CO_2, CH_4 are important greenhouse gases (GHG) emitted (David & Kilk, 2001).

The consistency and the quality of charcoal for casamance kiln (T3) and improved traditional earth mound kiln (T2) are also generally higher than traditional earth mound kiln. Casamance kiln (T3) was able to consistently deliver the yields in the range of 3.25 bags per $1m^3$ of wood used. The loss of charcoal in traditional method is caused by a higher air content entering the kiln and the long time of carbonization. The charcoals are also burnt completely and therefore, the quantity and quality of charcoal decreased. In addition, the moisture content in the wood has an impact on charcoal production. The quality of charcoal made from traditional earth mound kiln and improved earth mound kiln are significantly different in terms of time of carbonization and weight of charcoal. Improved charcoal making requires small quantity of wood to produce the same quantity of charcoal produced in the traditional method (Kokou, Nuto, & Atsri, 2009). The improved earth mound kiln reduces the emission of harmful volatile substances into the atmosphere up to about 75 % (Bill, 1981).

5. Conclusion

The traditional earth mound kiln is used to make charcoal and this technique persists in Southern Province of Rwanda mainly because it is flexible in use and cheap. However, they often produce very low yields (typically 1 or 2 bags of 30 Kg each of charcoal from $1m^3$ of wood), inconsistent quality (because it is difficult to maintain uniform carbonization) and environmental pollution from the released tar and poisonous gases. But the efforts can be made to improve the traditional charcoal making by equipping earth mound kilns with chimneys. With good practice, yield of 3 bags of 45 Kg or above of charcoal from 1 m^3 of air-dried wood was possible. The quantity of charcoal made by improved earth mound kiln is greater than the one produced by traditional earth mound kiln of the same size.

Acknowledgements

The authors acknowledge the contribution of Fabien Kayitare, Ir. Théogene Ndayambaje and Jeannette Mukamabano to the completion of this study.

References

Bill, S. (1981). *Improved wood, Waste and Charcoal burning stoves: A practitioner's manual, Netherlands*. p. 229.

CHAPOSA. (2002). *Charcoal potential in Southern Africa. Inco_Dev: International cooperation with developing countries (1998-2002)*. Final report. p. 88.

David, M. P., & Kilk, R. S. (2001). Emissions of greenhouse gases and other airborne pollutants from charcoal making in Kenya and Bresil. *Journal of Geophysical Research, 106*, 24-155.

Gerald, F. (1986). *Charcoal Making in Developing Countries* (17-76). London, UK.

Kaale, B. K. (2005). *Baseline study on biomass energy conservation in Tanzania, SADC Programme for Biomass Energy Conservation (ProBEC)* (p. 55).

Kammen, D. M., & Lew, D. J. (2005). *Renewable and Appropriate Energy Laboratory Report*.

Kokou, K., Nuto, Y., & Atsri, H. (2009). Impact of charcoal production on woody plant species in West Africa: A case study in Togo. *Scientific Research and Essays, 4*(9), 881-893.

MNRT. (2001). National Forestry Program in Tanzania. Ministry of Natural Resources and Tourism. United Republic of Tanzania.

Monela, G. C., Oktingáti, A., & Kiwele, P. M. (1993). Socioeconomic aspects of charcoal consumption and environmental consequences along Dar es Salaam - Morogoro highway, Tanzania. *Journal of Forest Ecology and Management, 58*, 249-258. http://dx.doi.org/10.1016/0378-1127(93)90148-G

Müller, N., Michaelowa, A., & Eschman, M. (2011). Proposal for a new standardized baseline for charcoal projects in the clean development mechanism. Zurich. p. 86.

O'Keefe, Phil, Raskin, Paul et Bernow, Steve (Ed.) Energy and Development in Kenya: Opportunities and Constraints. Uppsala – Stockholm, The Scandinavian Institute of African Studies – The Beijer Institute, Coll. Energy, Environment and Development in Africa, no. 1, 1984, p. 202.

Review of Technologies for the Production and Use of Charcoal. Energy and Resources Group & Goldman School of Public Policy. University of California, Berkeley, CA 94720-3050; National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, CO 80401-3393. p. 19.

Sander, K., Hyseni, B., & Haider, W. (2011). Wood-Based Biomass Energy Development for Sub-Saharan Africa, World Bank, Washington. Issues and approaches. p. 64.