A NEW MOBILE KILN PROTOTYPE FOR CHARCOAL PRODUCTION

R. Picchio[1], L. Pari*[2], R. Venanzi[1], F. Latterini[2], A. Suardi[2], V. Alfano[2], S. Bergonzoli[3]
*Corresponding author: Luigi Pari, luigi.pari@crea.gov.it
[1]Rodolfo Picchio, Tuscia University, DAFNE Department, r.picchio@unitus.it
[2]Luigi Pari*, corresponding author, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Monterotondo (Rome-Italy) luigi.pari@crea.gov.it. Phone: +39 0690675249.
[1]Rachele Venanzi, Tuscia University, DAFNE Department, venanzi@unitus.it
[2]Francesco Latterini, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Monterotondo (Rome-Italy) francesco.latterini@crea.gov.it.
[2]Alessandro Suardi, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Monterotondo (Rome-Italy) alessandro.suardi@crea.gov.it. Phone: +39 0690675248.
[2]Vincenzo Alfano, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Monterotondo (Rome-Italy) vincenzo.alfano@crea.gov.it. Phone: +39 0690675315.
[3]Simone Bergonzoli, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Unità di ricerca per l'ingegneria agraria - Treviglio (Bergamo-Italy) simone.bergonzoli@crea.gov.it. Phone: +39 036349603.

ABSTRACT: One of the main problems of Central Italy forest sector is the low economical valorization of wood products and in particular of fuel wood. According to this there is the need of products diversification. In order to reach this goal it is fundamental the implementation of scientific research, not only to find new possible innovative solutions, but also for the recovering of traditional products which nowadays are abandoned, obviously trying to improve them with new technologies. A feasible example is wood charcoal, which years ago was the main product of Central Italy forests but today is completely disappeared from forest chain. This assortment could be rediscovered in order to improve forest value chain. According to this a new model of mobile charcoal kiln was tested evaluating the characteristics of the process and of the product. The results of the analysis showed that the process of carbonization with the new mobile charcoal kiln is very efficient and productive. This process could be very advantageous for local community, differentiating economically marginal productions and qualifying new operators.
Keywords: quality, charcoal, wood

1 INTRODUCTION

One of the main problems of Central Italy Forest sector is the low economic value of woody assortments, with particular reference to fuel wood [1]. Considering this Scientific research in the sector is trying to find solution to this problem, for example analyzing the possibility of products diversification. This challenging goal is reachable not only finding new innovative products but also rediscovering traditional products which, for various reasons, were abandoned. Obviously it needs to improve these products with new technologies nowadays available on market. A feasible example is wood charcoal, which years ago was the main product of Central Italy forests but today is completely disappeared from forest chain.

RICACCI project, funded by Rural Development Programme 2014-2020 of Tuscany Region, aimed properly to the improvement of a new charcoal value chain in Mount Amiata context.

Of course charcoal would be used for different aims than in the past, for example for barbecues or for other innovative applications linked with food and pharmaceutical industry but also for tree nursery sector [2–13].

The main problem in wood charcoal production is the need of performing production at landing sites, thus considerably reducing transport costs. The possibility of producing charcoal directly at landing sites could make the overall economic chain consistently more valuable. Considering this aspect mobile charcoal kilns are interesting instruments which allow to produce charcoal at landing sites, reducing process time and cost and optimizing yield.

Traditional charcoal production took place through the realization, in special pitches within the forests, of particular wood piles made up of small wooden logs, wisely built and the covered with soil (Figure 1).

Figure 1: traditional charcoal kiln

It needed skilled manpower in order to guarantee an anoxic environment and to regulate air fluxes. This was a very complex process with large and skilled manpower need and low work safety, moreover process duration was substantially long.

An evolution of the classic charcoal kiln is vertical charcoal kiln, which was very common in France but practically absent in Italy. This system consists in a series of metallic stackable cylinders within which fuel wood is positioned (Figure 2).

Figure 2: vertical charcoal kiln

A modern charcoal kiln, in particular the model used in the present study, that is a horizontal kiln of the Ukrainian enterprise Ugolkov, is made up of a metal structure brought on a sledge. In particular there is a loading space in which fuel wood has to be positioned, a little front space in which a fire shall be maintained and a rear chimney (Figure 3). This kiln can be loaded on trucks or tractors and located at landing site.

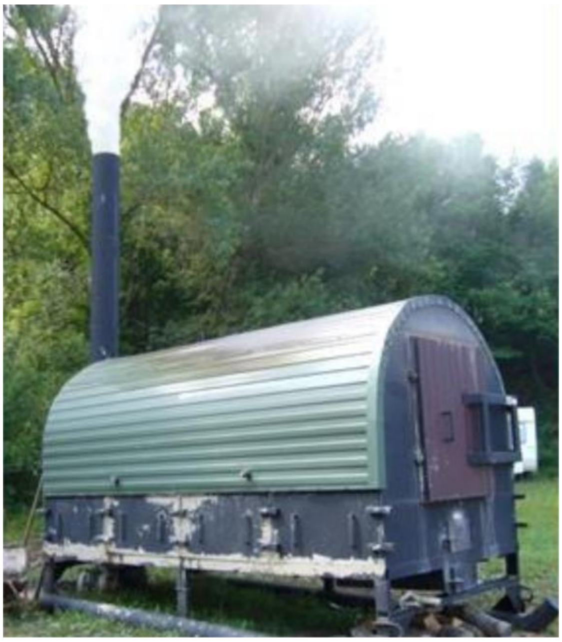

Figure 3: Ugolkov mobile horizontal charcoal kiln

The presence of the operator is needed, discontinously, from the kiln ignition to its shutdown. Oxigen flux can be set through the opening or the closing, total or partial, of dedicated side vents. Moreover it is possible to collect the liquid outputs of the process, which in traditional charcoal kiln are spilled in the soil.

The aim of the present work was testing the carbonization process of beech wood using a new model of mobile kiln, never used before in Italy and evaluating the characteristics of the product. Charcoal production was analyzed evaluating both the process characteristics (process duration, process yield, ergonomics) and the product's one (dimensions, moisture, bulk density, heating value, ash content, C content, N content, H content).

2 MATERIALS AND METHODS

Two different tests were conducted in two different yards consisting in old beech (*Fagus sylvatica* L.) coppices conversions into high stand. This aspect is central in this research because wooden material from forestry interventions like conversions, thinning and river maintenance are often characterized by low economic income [14,15].

2.1 Process analysis

Process duration and its development were analyzed. The overall process was divided in subsequent phases:

- Wood loading and sealing
- Drying
- Real Charbonization
- Cooling
- Charcoal unloading

The passage between one phase and the following one is identifiable by looking at the color of the emitted smokes and to the color and the consistency of the liquid outputs.
Moreover process yield was evaluated by the ratio between the weight of the charcoal and the weight of the fuel wood used for its production. Comparisons were made in relation to the other systems available for charcoal production (typical charcoal kiln and vertical charcoal kiln). Data for these other systems were taken to dedicated past scientific projects.

2.2 Products characterization

Investigated parameters for obtained charcoal characterization were the following:

- Bulk Density (kg/m^3): reference standard was CEN/TS 14779, 30 sub-samples of 0.5 kg each, charcoal was placed within a graduated recipient till reaching 400 ml volume without compressing the sample. The recipient was then weighed by a precision balance.
- Moisture content (%): reference standard was EN 14774-2:2009 (E). 30 sub-samples of 0.5 kg each were used. The process is the following. Weigh an empty clean drying container to the nearest 0,1 g, transfer the sample from the container or bag to the drying container. In case of moisture left on the inner surfaces of the bag or container, this amount of moisture shall be included in the calculation of the moisture content. Weigh the drying container with the sample and place it in the oven controlled at (105 ± 2) °C. Heat the container with the sample until constant in mass. Constancy in mass is defined as a change not exceeding 0,2 % of the total loss in mass during a further period of heating at (105 ± 2) °C over a period of 60 min. The drying time required will depend on the particle size of the sample, the rate of atmosphere change in oven, the thickness of the sample layer, etc. Dried solid biofuels are hygroscopic and the drying container with the sample shall be re-weighed to the nearest 0,1 g when still hot within 10 s to 15 s to avoid absorption of moisture. The total moisture content shall be calculated using Equation (1) and the result shall be given on a wet basis.

$$M_{ar} = ((M_2 - M_3) + M_4)/((M_2 - M_1) + M_4) \times 100 \quad (1)$$

Where

Mar is the moisture content in the biofuel, as received, expressed as a percentage by mass;
M_1 is the mass in g of the empty drying container;
M_2 is the mass in g of the drying container and sample before drying;
M_3 is the mass in g of the drying container and sample after drying;
M_4 is the mass in g of the moisture associated with the packing.
The result shall be calculated to two decimal places and rounded to the nearest 0,1 % for reporting.

- C, H, N, O content (%): reference standard was UNI EN 15104:2011. Analysis were conducted using a CHN Leco 1000 analyzer.
- Ash content (%): reference standard was UNI EN 14775:2010. A sub-sample of 200 g was milled by a rotating blade mill IkaWerke MF10B and a 1 mm sieve. The sub-sample was then put in the oven at 250 °C for 1 hour. Subsequently the oven temperature was raised to 550 °C with a speed of 0.083 °C/s. This temperature was maintained for 2 hours. Next step consisted in 5 minutes of air temperature cooling. Finally sub-sample was weighed for ash content determination.
- LHV (MJ/kg): reference standard was UNI EN 14918:2010. Determination was performed by a PARR 6200 calorimeter.

Comparisons were conducted in relation to commercial charcoal available on market, both low than high profile.

3 RESULTS AND DISCUSSION

Results of the process evaluation in comparison with the other systems for charcoal production are given in Table I.

Table I: process evaluation among different charcoal kiln systems

Parameter	Traditional Charcoal Kiln	Vertical Charcoal Kiln	Ugolkov Horizontal Charcoal kiln
Duration (h)	40-90	40-60	30-85
Mass Yield (%)	15-25	18-24	20-35
Smokes control	Not Available	Not Available	Available
Liquid outputs recover	Not Available	Not Available	Available

As it is possible to notice process duration is comparable among the three different systems but it is important to underline the substantially lower time needed for the load of both the mobile kilns compared to the traditional one.

Ugolkov kiln showed the best mass yield and moreover this system allows to control both smokes and liquid outputs, characteristics instead not available for the other systems.

For what concerning obtained charcoal quality results of the performed analysis are given in Table IITable .

Table II: charcoal characteristics among different charcoal production systems

Parameter	Commercial charcoal		Study's charcoal
	Low profile	High profile	
Bulk density (kg/m^3)	225	241	245
Moisture (%)	7	6	4.5
C content (%)	82	82	84
Volatile matter (%)	15	16	18
Ash content (%)	2.5	2	1.8
LHV (MJ/kg)	30.3	31.5	33

As reported in the above Table II charcoal obtained with this experiment showed optimum characteristics, even higher than high profile charcoal available on market. In particular it presented the best values for what concerning bulk density, moisture, carbon content, ash content and LHV.

4 CONCLUSIONS

The results of the analysis showed that the process of carbonization with the new mobile charcoal kiln is very efficient and productive. This process could be very advantageous for local community, differentiating economically marginal productions and qualifying new operators.

The product charcoal, even if it is wrongly considered "poor", has remarkable qualities that make it interesting under different aspects, alimentary, pharmaceutical, biologic, tree nursery sector. Moreover its properties seem to open new frontiers continuously. Charcoal produced in this reality could also appeals to the certification of Chain of Custody of PEFC reaching a more qualified market, both for products and for process of sustainable productions.

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