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Research Article

Highly Clean Biochar for Novel Applications in the Fields of Agronomy, Energy, Residential Housing

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ABSTRACT

Aside from imposing progressively tighter limits to the emissions, the issue of climate change due to increasing atmospheric carbon concentrations can be tackled by very few really practicable and effective counter-measures. Among these, the more viable appears that of removing excess carbon from the air by enhancing large-scale rapid-growth forestation and then sequestering it in the solid, carbon-rich residue of ad-hoc processes, notably, wood pyro-gasification. The paper, in its first part, presents a novel, simple, robust gasification technology that, when operated in intermittent mode, produces two highly clean products: a solid biochar and a gaseous syngas, without tars and condenses. If the modality is continuous operation (to be discussed in more detail in a companion paper), the syngas production is strongly enhanced, with just a few ashes as residue. The second part of the study addresses two main biochar utilization strategies, one in the agronomic field, highlighting its powerful effect particularly in fostering arboreal seeds' root taking process and the other, in the housing and construction sectors. In these latter cases, the addition of biochar finely ground into lime-based plasters (with and without cement) greatly enhances, as shown in a series of parametric experimental investigations, their performance in terms of thermal insulation and humidity control.

Key words: Wood gasification; Clean biochar production; Biochar uses; Ground biochar; Arboreal seeds' germination; Biochar-based plasters; Biochar-added mortar preparations

INTRODUCTION

After a period of high expectations, in the last 30 years or so, regarding a prompt, widespread penetration, particularly in rural areas, of cheap, standard-technology, small-scale biomass gasifiers, such as those which fall into the so-called downdraft and updraft typologies, actually a rather discouraging global picture of the real situation must be acknowledged. Indeed, it turns out that the number of really successful designs of small-size power plants, as attested by their market penetration, suitable to guarantee a fail-safe operation over extended time periods, is really limited [1]. However, if we look carefully at these latter technologies, they appear far from simple, rural-application, energy-conversion equipment, rather, they show up as complex, costly infrastructures (in particular if compared to power production capability), with sophisticated provisions and rigid operation requirements if continuous, adequate performance is to be achieved. Aside from environmental issues related to atmospheric emissions as well as solid and liquid pollutants' disposal, typically, a safe continuity of operation is not achievable in absence of costly abatement provisions, with the widespread need of progressively heavier maintenance provisions, especially related to the removal of sticky carbon-rich deposits and soot on the internal surfaces of the various plant components [2].

In order to tackle the above issues, while satisfying a strong constraint of always keeping investment and maintenance costs easily affordable and 'tuned' to a rural context, a series of innovative woodchips gasification equipment has recently been conceived, realized and thoroughly tested at Tecnoforest Ltd., an innovation-dedicated small enterprise [3], formerly an academic spin-off of the University of Genoa. Whilst the design and performance characteristics of Tecnoforest power plants, specifically conceived for cogeneration purposes, have been object of a recent webinar presentation [4], their extremely simple precursors, addressed to high quality biochar production, were presented in [5].

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Although the overall setups as well as the operational features of the said equipment appear rather differentiated in dependence of their various end-uses, in particular due to the need of continuous operation for the power plants whereas the biochar-producers are periodically intermittent machines, non the less, the basic physico-chemical processes taking place in all Tecnoforest gasification reactors are almost exactly the same.

A really unique feature characterizes their design, by virtue of which the reactors show an intrinsic capability of achieving an extremely clean wood gasification process, as attested by the analyses of their respective 'products', namely, the gaseous bio-syngas and the solid biochar. No liquid condenses, as well known highly toxic, are at all produced. To be noticed, when power generation is the target, no biochar is produced, rather, the output is just clean syngas and clean ashes, to the advantage of conversion process's thermodynamic efficiency [4].

One of the standard provisions, commonly found in both up-draft as well down-draft gasifiers, is the presence of a heavy column of piled-up woodchips weighing down upon the 'hearth' zone where air is sucked in. On the contrary, inside the novel syngas-generators here in object, the woodchip column is ignited from above, so that its upper 'free surface' becomes a kind of virtual hearth, where the 'embers front', a red-hot layer with a typical thickness of less than 10 cm, performs, while proceeding toward the bottom of the column, a rather efficient, clean, smoke-less wood-to-char conversion. The gaseous product of this process is, in its turn, a hot, tar-free syngas which, due to the local lack of oxygen, does not light up near the embers (in which case we would get a standard 'wood combustion'), but, instead, rises toward the reactor's empty upper volume and finally is discharged to the outside through an outlet nozzle [5].

The 'smart' gasification technology, which has been developed along the above guidelines, is now available on the market in three different typologies, addressed respectively to high-quality biochar production, thermal energy generation, electric and thermal cogeneration. In all cases, it features extreme simplicity (therefore, very low costs) and quite high environmental sustainability, is highly robust and shows great operational reliability.

BIOCHAR PRODUCTION TECHNOLOGY

Specifically in connection with biochar production, the proprietary Tecnoforest technology (gasifier SynChar) is based on a peculiar wood gasification process presented, in its thermo-dynamical, thermo-chemical and operational details, in [5]. As above said, the reactor design succeeds in achieving particularly clean solid (biochar) and gaseous (syngas) products: this is mostly due to two main provisions, namely, the 'free hearth' feature and a periodically intermittent operation, by which the biochar is discharged, allowing the reactor to be filled up with fresh woodchips. In this way, there is no operational phase in which the feedstock's column is looming upon the hearth, thus contrasting a situation conducive to pyrolytic pollutants' formation. It is exactly this provision, lacking in all known updraft and downdraft gasifiers of sort, which is deemed critically important toward the achievement of a high-quality biochar in terms of porosity and cleanliness.

In the following Figure 1, one of the several reactors SynChar so far produced is pictured in the shop, whereas Figure 2 shows a unit equipped with a top flare producing a premixed syngas-air flame: the gasifier is in actual operation, with the top flame which goes almost unnoticeable. Both the flame and the space around the unit appear quite clean, when usual biochar production activities are known for their 'smoky' visual impacts all around (Figure 3).

From an overall process perspective, Figure 4 presents the sequence of the phases presumably followed by the gasification process within SynChar reactor. A numerical tool, previously developed and applied to a downdraft gasifier [6], is now being used toward a theoretical prediction of the process here in object. However, due to the overwhelming presence of solid material, the task turns out difficult for the highly heterogeneous character of the chemical reactions to be modeled.

The high quality of the biochar as produced by above process was attested by a very detailed, certified analysis already presented in [3]. An excerpt from this official document, showing some relevant results, is here shown in Table 1. Notice the quite low presence of PAH contaminants without any abatement provision.

The corresponding syngas composition is presented in [5] : in this context, it is important to remark that the syngas's quality goes hand-in-hand with biochar's. This point is often overlooked when presenting biochar making equipment, particularly rotary-drum ones, which are by far the most used. By converse, it is sometimes discussed in connection with wood-gasification plants addressed to heat-and-power cogeneration, but in this case any biochar discharged from the reactor (which should turn out just ashes) would be symptom of a low thermodynamic efficiency of the conversion process.

Gasifier SynChar is available in different sizes: the standard one is 1200 mm (height) x 290 mm (dia). In it, as a rough estimate, a charge of about 50 kg of woodchips (average bulk density: 350 kg/m^3) is converted, in a process time of about 30 min, into 13 kg of cleanest biochar (average bulk density: 250 kg/m^3). If the input feedstock is virgin wood, the residue of the process is a biochar of nearly edible quality. Due to biochar high porosity, mass conversion efficiency is thus about 26%, whereas volume conversion efficiency, which is much more important for most applications, turns out around 71%.

As can be seen from Figure 4, the hot syngas, evolving from the embers, rises upwards due to thermal convection, 'creeping' through the biochar and thus undergoing a chemical reduction process which increases its heat value. A lifted-flame, partially premixed, of about 80 kW_{th} is released from the top flare, ready to be utilized for simple water-heaters connected to properly sized hot-water storage tanks. The flame is really clean, and hardly visible (Figure 2). Thermal power sizes up to 500 kW_{th} can be easily attained, by properly scaling-up the dimensions, without major changes in the overall design.

High-quality biochar is becoming a 'commodity' featuring an impressive range of applications: atmospheric carbon (centuries long) soil sequestration, air and water filtering, polluted land remediation, soil agronomic fertilization and water retention, gas absorption, pharmaceutical substrate, anti-crack additive for concrete, lime-based plasters with excellent thermal and acoustic insulation, electro-magnetic pollution shielding, indoor-air humidity and pollutants' control, and more (Schmidt HP et al., 2016). A few of these applications are discussed below.

Figure 1: Gasifier SynChar in the Shop

Figure 2: SynChar in operation

Figure 3: Gasifier Biochar from twigs (top) and from woodchips (down)

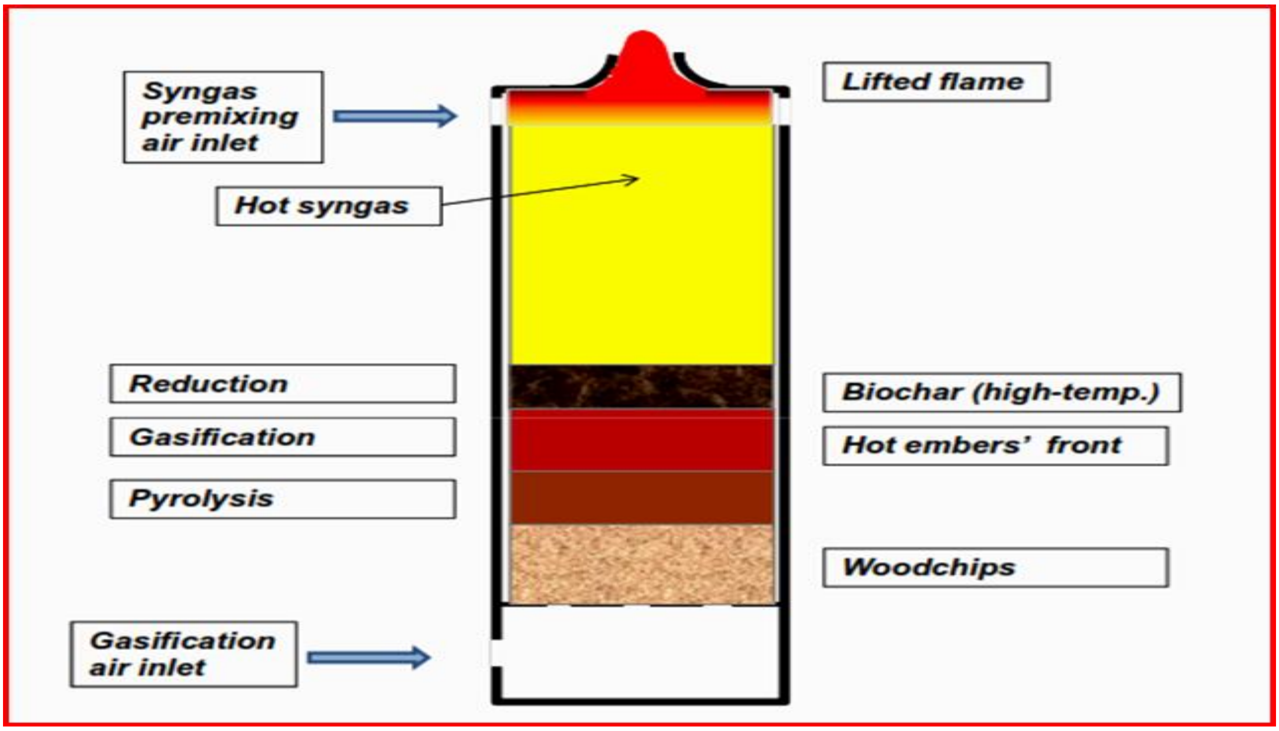

Figure 4: Sequential phases of gasification process inside SynChar reactor

Table 1: Some relevant results taken from a certified analysis performed on biochar as produced by SynChar reactor (Pittaluga F, 2019)

Parameters	Unit	Results	Method
Humidity @ 105°C	%	3.6	UNI 10780:1998
pH	pH unit	9.74	EPA 9045D 2004
Electric conductivity	µS/cm	3430	UNI 10780:1998 App. D
Organic matter	% d.m.	85.8	UNI 107B0: 1998 App. J
Organic carbon	% d.m.	76.1	UNI EN 13137: 2002 + UNI EN 15047: 2014
Ashes @ 600°C	% d.m.	14.2	CNR IRSA 2 Q 64 Vol 2 1984
H	%	1.63	UNI EN 15407: 2011
N (total)	% d.m.	1.006	UNI EN 10780: 1998
Water retention	%	62.0	UNI 10780:1998 App 1.5.
C/N	-	76	UNI EN 13137: 2002
P (total)	% d.m.	0.709	EPA 3050B 1996 + EPA 6010D 2014
K (total)	% d.m.	1,7833	EPA 3050B 1996 + EPA 6010D 2014
Ca	mg/kg d.m.	27393	EPA 3050B 1996 + EPA 6010D 2014
Mg	mg/kg d.m.	2970	EPA 3050B 1996 + EPA 6010D 2014
Na	mg/kg d.m.	434	EPA 3050B 1996 + EPA 6010D 2014
Cr (hexa-)	mg/kg d.m.	< 0.1	UNI 10780:1998 App B.4.7.
Hg	mg/kg d.m.	< 0.1	ANPA 15.3.4.2 Man 3 2001
PAH (total)	mg/kg d.m.	< 0.15	EPA 3550C 2007 + EPA 8270D 2007

AGRONOMIC AND ENVIRONMENTAL APPLICATIONS

Unfortunately, often under the term biochar fall many carbonaceous residues issuing from high-temperature thermo-chemical processes, applied to wood or biomass, which do not comply with the 'bio-' attribute, in particular they are far from 'clean' and thus represent a threat to biologic processes. Biochar is 'fixed carbon', mostly coming from the wood lignin content, but, in order to acquire its exceptional stability (up to several centuries) in sequestering atmospheric carbon, it must be of high quality, free of organic contaminants, which would induce its progressive degradation. On the other hand, in order to achieve an effective strategy for really contrasting climate change, extensive rapid-growth forestation of high lignin-content tree species should be pursued. As shown in [7] a so-called 'consociated forestry' technique, based on large-scale transplanting of up to 4000 hardwood trees per hectare, would be most suited to achieving that target. However, its unit costs would turn out prohibitive, up to 5000 €/hectare, actually preventing such extensive forestation campaigns.

Very recently, as reported in [5], a much cheaper technique has been conceived and actually pursued at Tecnoforest Ltd, which avoids both the very first growth-phase to be carried out in a tree nursery as well as the subsequent costly transplanting of the seedlings: on the contrary, according to this new strategy, the tree seeds, after being subjected to proper vernalization and germination, are directly sown in the field at destination. In this way, the costs per hectare turn out abated to 1/10 of the previous ones. In this context, it is really important to remark the crucial role played by limited amounts of biochar, finely ground, added to the soil surface in the immediate nearness of the germinating seed. In addition to stabilizing the local pH toward a neutral value, its presence guarantees the availability of a proper, continuous level of humidity in the soil, in addition to aid the nutrients' uptake by the radicles. The net effect is a great improvement of the root taking process, thus achieving plantation efficiencies (grown trees/sown holes) not far from those typical of transplanting operations (grown trees/transplanted seedlings). To increase the overall plantation efficiency, also in view of the low cost of germinating seeds, 2 or 3 of these latter are placed per 'sown hole', though just one seedling will be then kept if more grow up in that hole. The excess seedlings (if any) will be recovered to undergo standard transplanting [Figure 5&6].

Aside from the invaluable environmental benefits, the typical uses and the related agronomic advantages of pure biochar addition for agriculture and floriculture applications have been recently well documented [8] so that its acceptance and penetration into widespread practice begin to take foot. In our experience, a most proper modality of biochar utilization is to add it to the typical ingredients of an organic mixture, such as greens, vegetable residues, twigs, sawdust, woodchips, etc. during, and not after, its composting process. The outcome is an unparalleled biologic soil- fertilizer, with a unique capacity of soil nutrients' retention and humidity control at roots level.

Figure 5: Germinating seeds as sown in small holes. Darkish soil due to added biochar (ground).

Figure 6: Consociated-trees plantation 4 years after sowing (Tecnoforest Ltd)

BIOCHAR USES IN THE HOUSING SECTOR

In addition to the soil-related sectors, there are well known further uses of biochar, e.g. for pharmaceutical preparations as well as for filtering and pollutant abatement ('activated carbon'), and many others, which are not going to be discussed here. Rather, a novel application has the potential to achieving a so extensive and viable adoption to succeed in effectively counteracting climate change by taking advantage, as already mentioned, of the biochar's property of sequestering, for many hundreds of years, huge amounts of atmospheric carbon. Indeed, virgin wood biochar, clean of organic pollutants and finely ground, can be utilized in the residential housing sector as a smart alternative to the required inert additions (typically sand) to lime or cement admixtures for plaster or mortar preparations.

We have seen how soil addition of biochar can stabilize the storage of carbon in a chemically stable and inert form for extended period. On exactly the same ground, there comes the important perspective of biochar application also to the housing and building sectors: in this case, several further reasons point out biochar addition as an extremely interesting, cheap, simple, safe modality ready to provide the cement- or lime-based plasters and mortars with unique, novel performance. A really 'smart' addition indeed. As reported in the web site of 'Ithaka Institute' (see Refs.), biochar has been used to fully replace sand in lime plasters up to reach even 80% of mixture. Biochar has also been used to develop lightweight biochar-concrete panels, biochar-lime bricks, several plaster composites, and tile adhesives. Biochar-plaster composites provide excellent thermal and acoustic insulation (even electro-magnetic shielding), and are able to maintain the desired indoor humidity with an excellent 'buffer effect'. Molds and pollutants are abated. Thanks to this fully 'passive' provision, indoor air quality achieves an unrivalled level of comfort.

Recently, in order to characterize density, workability and performance of different lime-based plaster composites, a series of tests have been carried out at Tecnoforest lab. To that end, we have moulded small tiles of 100 x 70 mm area, 20 mm thick, with components in different proportions: in some of them, sand was added as the inert component, others, featured finely ground biochar. Compositions are given in Table 2 below [Figure 7-9].

Figure 7: The 4-tile mould (in Aluminum) resting upon its steel base

Figure 8: Different plasters as cast in the mould, undergoing curing.

Figure 9: The biochar grinder

Table 2: Compositions of the sample-tiles utilized for performance comparisons. (In the tile tags, L stands for Lime, S for Sand, B for Biochar; 1, 2, 3, stand for parts in volume)

Tile L1-S2	1 part of lime, 2 parts of sand
Tile L1-S3	1 part of lime, 3 parts of sand
Tile L1-B2	1 part of lime, 2 parts of biochar
Tile L1-B3	1 part of lime, 3 parts of biochar
Tile L1-B2/Lm	1 part of lime, 2 parts of biochar + 2 mm-thick 'lime-milk' coat

The first tests performed on the tiles were aimed at evaluating their respective thermal conductivities. To this end, they were placed on the flat cover of a pyrex pot, filled with boiling water, letting the temperature slowly go down, so to guarantee progressive attainment of a kind of sufficient equilibrium within the tile. Measurements were taken when the lid temperature reached 80 °C. Being the instrument a non-contact, infrared, quick-reading thermometer, the precision was not high, in the range of about 0.5 °C (+/-), but at all adequate in this case. Due the limited accuracy attainable, the readings, given in Table 3, are all rounded.

Conductivities ratios are evaluated with respect to the standard lime-based plaster with composition 'L1-S3', which corresponds to the most usual mixture. As easily verifiable, the conductivities ratios turn out inversely proportional to ΔT ratios, so that the former have been directly calculated from the available measurements of the latter [Figure 10-13].

Table 3: Comparisons of surface temperatures and conductivity ratios for the sample tiles
(In red, the decrease in conductivity of each tile with respect to 'L1-S3' assumed as reference)

Sample Tile	Bottom Face	Upper Face	ΔT	Conductivity Ratio $\lambda_1/\lambda_2 = \Delta T_2/\Delta T_1$ [%]
L1-S2	80° C	56° C	23° C	74 % (26 % Lower)
L1-S3	80° C	63° C	17 ° C	100 % (ref.)
L1-B2	80° C	52° C	28 ° C	61 % (39 % Lower)
L1-B2/LW	80° C	52° C	28 ° C	61 % (39 % Lower)
L1-B3	80° C	47° C	33 ° C	51 % (49 % Lower)

Figure 10: The IR radiation thermometer

Figure 11: Tile 'L1-B2' at left vs tile 'L1-B2/Lm' at right: this latter appears full-white, due to 'lime-milk' coat

RESULTS SAY THE FOLLOWING:

- higher percentage of sand increases heat transfer (sand is a good conductor)
- biochar presence is very effective in lowering conductivity: in tile 'L1-B3', λ gets down to nearly 50% of the standard (biochar is an excellent insulator)
- the dark color of a wall, with a biochar plaster on it, can be safely redeemed to white by a final surface treatment with 'lime-milk': no loss in thermal insulation is incurred.

After studying lime-based plasters, attention was directed toward the lime-cement based ones (cementitious plasters). Actually, due to the higher cohesion provided to the plaster by cement, some addition of the latter is standard practice. Typically, the mixture comes out made up by lime (3 parts), cement (1 part), and sand (10 parts). In this case too, we compared the characteristics shown by sample tiles of above composition with corresponding tiles wherein the sand was replaced by biochar. The new series of tiles, with exactly the same dimensions of the previous ones, was given the acronym 'L3-C1-S10' (C stands for cement) when sand was used, and 'L3-C1-B10' when the 10 parts of sand were replaced by 10 parts of biochar.
For comparison purposes, also a tile was tested made up of a recent high-technology plastic material typically used for thermal insulation of buildings' outside walls. Coming under the commercial name of Stiferite, its main component is expanded rigid polyurethane foam, usually covered on both sides with a protective coating: as such, it is not a plaster, rather it is used as the backbone of highly efficient insulating panels. Test results, ready to be directly cross compared among themselves (lime-cement based plasters) and with the previous ones (lime based) are given in Table 4 [Figure 14-15].

The said Table 4 shows rather interesting, somehow unexpected, results. In particular:

- Addition of cement to a standard lime-sand mixture improves thermal insulation, in spite of the higher cohesion of the plaster. This is probably due to a more efficient hydration process achieved during the curing of plaster. Notice that it is exactly the hydration process which provides the plaster with its 'hydraulic' properties.
- Addition of cement to a lime-biochar mixture brings about quite a remarkable outcome: plaster's thermal insulation achieves nearly that of Stiferite, one of the most performing high-technology plastic insulation materials, but, as such, by far less environmentally sustainable than biochar.

In order to complete the comparative scenario of the properties shown by all above plaster formulations, it is necessary to assess their respective performance in terms of indoor humidity control. To this end, the above tiles have also undergone a test of water vapor absorption as measured by the difference in weight before and after their placement into a steam pot, without contact with the boiling water. Notice that the absorption capacity of water vapor (gaseous phase, free molecules) is at all different from that of liquid water, wherein molecules are somehow 'lumped' together. The use of a steam pot, without liquid contact, strongly accelerates the former [Figure 16-17].

Figure 12 a: 'L1-B3' and 'L1-S3' on the hot pyrex lid; **Figure 12 b:** 'L1-B2/Lm' and 'L1-B2' on the hot pyrex lid **Figure 13 a:** T-reading on 'L1-B2' and 'L1-S2'; **Figure 13 b:** T-reading on 'L1-B3' and 'L1-S3'

Figure 14 a: Tiles 'L3-C1-S10' and 'C1-B10' on hot pot lid; **Figure 14 b:** Tile of Stiferite on hot pot lid; **Figure 15 a:** T-reading on tile 'L3-C1-S10'; **Figure 15 b:** T-reading on tile 'L3-C1-S10'

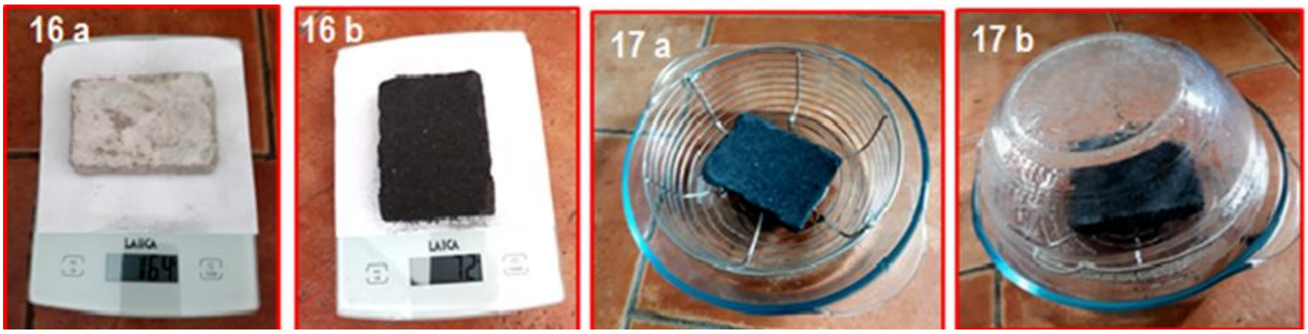

Figure 16 a: Tile 'L3-C1-S10' on the digital scale; **Figure 16 b:** Tile 'L3-C1-B10' on the digital scale; **Figure 17 a:** Tile 'L3-C1-B10' on steam pot's grate; **Figure 17 b:** Tile 'L3-C1-B10' during the steaming process

Table 4: Comparisons of surface temperatures and conductivity ratios for further sample tiles (In red, the decrease in conductivity of each tile with respect to 'L1-S3' assumed as reference)

Sample Tile	Bottom Face	Upper Face	ΔT	Conductivity Ratio $\lambda_1/\lambda_2 = \Delta T_2/\Delta T_1$ [%]
Stiferite	80° C	38° C	42° C	40 % (60 % Lower)
L1-S3	80° C	63° C	17 °C	100 % (ref.)
L3-C1-S10	80° C	56° C	24 °C	71 % (29 % Lower)
L3-C1-B10	80° C	39° C	41 °C	41 % (59 % Lower)

Table 5: Comparative scenario of the water vapor absorption capacity of the various tiles

Sample Tile	Dry Weight (W_d)	Wet Weight (W_w)	ΔW (W_w- W_d)	Absorption Capacity (ΔW / W_d) %
L1-S2	137 g	140 g	3 g	2 %
L1-B2	59 g	66 g	7 g	12 %
L3-C1-S10	164 g	166.5 g	2.5 g	1.5 %
L3-C1-B10	72 g	76 g	4 g	5 %
Stiferite	9 g	9 g	0 g	0 %

Above table [Table 5] gives a comparative scenario of the water vapor absorption capacity of the various tiles. It turns out that the sand-based plasters show a low such capacity. Very good performance is seen for lime-based 'L1-B2' tile (2 parts of biochar). Unfortunately, tile 'L1-B3' (3 parts of biochar) crumbled undergoing the quite severe steaming test, sign of an extremely high absorption capacity. The Tile 'L3-C1-B10', in spite of its high biochar content, safely sustained the steaming test, thanks to the cohesion properties provided by the cement addition, but at the expense of a lower absorption capacity with respect to the lime-biochar formulations. As expected, the vapor absorption was perfectly null for the tile in Stiferite: actually it is not a plaster, rather, a sort of impermeable wall 'panel', unsuitable to improve the indoor air quality by failing to control the ambient relative humidity and its uncomfortable swings.

The overall outcome, presented above, of the tests performed, clearly shows that incorporation of finely ground biochar as the inert component (sand substitute), within lime-based as well as lime-cement-based plasters, provides them with very interesting properties from the perspectives of improved thermal insulation and humidity control. It must be remarked that these benefits are brought about by addition of biochar which is a totally 'passive' component, safe, cheap, undegradable, fire-extinguishing, user-friendly as well as a powerful resource of environmental sustainability.

Actually, addition of biochar fine powder turns out useful not only for plaster and panel applications ('housing' sector) but also for concrete and reinforced concrete to be used for construction ('building' sector). Recently, very interesting investigations [9] confirm that incorporation of micronized virgin biochar to mortar preparations improve mechanical properties of cementitious composites, increasing flexural and compression strength, while hindering crack propagation. It can even be conceived that the presence of biochar, with its chemical reduction capacity, might contrast oxidation of the steel rods embedded in reinforced concrete, providing an invaluable contribution toward long term structural endurance and overall construction safety.

CONCLUSIONS

A novel, self-complementary set of small, but easily scalable, biomass gasifiers has been presented, all featuring a simple, rugged design and construction, and therefore also affordable costs in case of their wide territorial deployment. They show a unique capacity of achieving quite clean wood-to-biochar and wood-to-syngas conversion processes, making it possible to conceive a highly effective strategy of contrasting the threatening greenhouse effect: namely, that of using biochar as peculiar vehicle of atmospheric carbon massive sequestration. In doing so, a win-win outcome is achieved, because biochar remains undegraded for centuries not only in the case it is disposed of, say in dedicated underground sites, but also when its remarkable properties are put into use in the agricultural as well as in the housing and construction sectors.

In order to pursue such a wide-breadth, earth-rescuing strategy, based on a decentralized production of huge biochar amounts, the proposal conceived at Tecnoforest Ltd, as above discussed with some demonstration activities already performed, relies on local initiatives, pursued at a global level, of rapid-growth forestation carried out by directly sowing germinating arboreal seeds, in this way avoiding the costly nursery and transplanting phases. Notice that production of biochar via wood gasification processes provides significant amounts of free, carbon-neutral, clean thermal energy, a further advantage adding up to those already discussed.

As above seen with reference to agronomic applications, finely ground biochar, mixed with the top soil, greatly enhances the root taking process of germinating seeds while, if enriched with suitable nutrients, notably organic compost, it brings about distinctive and permanent improvements in soil quality, texture, humidity and overall vitality, to the advantage of a biologic and high-yield agriculture.

On the other hand, if incorporated into lime-based plaster formulations (either with or without addition of cement) as well as into cement-based mortar preparations, biochar would greatly improve their performance for the housing and building sectors. If this perspective, cheaply and easily practicable, would be actually and widely pursued, our future towns could become huge carbon sinks, ready to provide a formidable contribution toward climate preservation of our planet.

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