Diversifying revenue in rural Africa through circular, sustainable and replicable biobased solutions and business models

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MAIN AUTHORS	
Name	**Organisation**
Patrick ROUSSET	CIRAD
Jean-Michel COMMANDRE	CIRAD
Evangelia Tsagaraki	QPLAN

QUALITY REVIEWERS	
Name	**Organisation**
Tracey O’ Connor	MTU
Moses Nganwani TIA	SAVANET

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1. EXECUTIVE SUMMARY

The current document represents the **initial version the Report on BIO4AFRICA pilot cases (D3.2)** of the BIO4AFRICA project which has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101000762. It provides meaningful details with respect to the **technologies piloted/ to be piloted** in Uganda, Ghana, Senegal and Côte d'Ivoire (flow diagrams, description, photos, operational considerations and feedstocks to be tested), about the **4 project pilot cases** (description and objectives, pilot sites, stakeholders involved, local team, trials) and **their operation and achievements until M24 (May 2023)**. It also includes updated information about planning of testing and monitoring activities (originally described in D3.1 Testing, monitoring and assessment plan (TMAP) submitted in May 2022), with detailed GANTT charts on pilot and validation activities, outline of **monitoring activities** common for all use cases and procedures about **monitoring and assessment of KPIs**. Updates of all information contained in the current report (including TMAP related information) will be presented in **D3.3 Report on BIO4AFRICA pilot cases- interim version (M34)** and in **D3.4 Report on BIO4AFRICA pilot cases-final version (M42).**

The first activity that was carried out within the framework of WP3 during the 1st period of the project was the understanding of the local contexts in each country in order to identify their needs with each partner. This activity required many hours of meetings and discussions as well as field missions carried out by the team from CIRAD and Grassa. Today, we can say that the majority of the technologies planned in the context of B4A have been identified, transferred or in the process of being transferred. The sites intended to receive the technologies as well as the tests have also been identified. Teams have been formed in each country for certain tasks and others will be as the technologies are installed.
Concerning the choice of technologies, the technical challenge was to match the selected biomasses and the technologies necessary for their transformation in the four countries concerned by the project. For example, the identified Brazilian pyrolysis technology has been retained in Côte d'Ivoire and Ghana, while the University of Ziguinchor in Senegal has opted for a technology developed on the African continent. We recall that CIRAD's role is not to impose a technology but to propose technical solutions which may or may not be

adopted by African partners. We had the same discussion with INP-HB on densification equipment. After several exchanges with RAGT, it turns out that the suggestion was to reduce the capacity of the pellet production line after taking stock of the equipment already existing in the University of Côte d'Ivoire. In the case of Uganda, we had to produce briquettesrom the by-products of the biorefinery and in particular the cake. KRC and Grassa decided that this option was not necessary because the cake was self-sufficient and did not need to be compacted for transport. We then proposed to work on the densification of local residues (vegetables, straw, hulls, etc.) in order to produce biochar brioquttes for cooking. This option has been approved by KRC.

All these examples show that during these 24 months, many exchanges took place between the different partners in order to adapt to local contexts and find the most suitable solution for each case study. After 24 months, some tasks have not yet been finalized but will be very soon. Some of them are mainly due to the alternation of dry and wet seasons which required the installation of covered structures.

2. INTRODUCTION

BIO4AFRICA sets off to support the deployment of the bioeconomy in rural Africa via the development of bio-based solutions and value chains with a circular approach to drive the cascading use of local resources and diversify the income of farmers. Our focus is on transferring simple, small-scale and robust bio-based techs adapted to local biomass, needs and contexts (green biorefinery, pyrolysis, hydrothermal carbonisation, briquetting, pelletising, bio-composites and bioplastics production). In doing so we aim at empowering farmers to sustainably produce a variety of higher value bio-based products and energy (animal feed, fertiliser, pollutant absorbents, construction materials, packaging, solid fuel for cooking and ingredients for biogas production), significantly improving the environmental, economic and social performance of their forage agri-food systems. A total of 4 pilot cases will be run during the project in Uganda, Ghana, Côte d'Ivoire and Senegal respectively, testing various technologies and technologies combinations in real productive conditions, using various feedstocks with regional specificities across different farming systems. A series of trials and experiments will enable us to assess and validate the added value and market potential of the generated bio-based products. An overview of our testing and validation activities is presented below (Table 1).

Table 1: Testing and validation activities

Country	Techs / processes	Inputs	Outputs	Validation tests
Uganda	- Green biorefinery - HTC - Briquetting	**Green biorefinery:** protein rich leguminous plants (Kalliandra, Tithuania, Blabla, Alfalfa, Mucuna beans, Butterfly Pea-Clitoria Ternatea, Lablab, Apios Americana), local Napier elephant grasses, cassava leaves - **HTC:** manure produced in cattle farms and deproteinized biorefinery whey stream **Briquetting:** biochar	-Animal feed: a) Press cake for dairy cattle, b) protein concentrate for pigs and poultry, c) whey as animal feed for pigs and for high value whey ingredients screening - Biochar briquettes for solid fuel - Biochar mixed with manure and struvite for soil improvement	- Animal feed trials (cows, pigs, piglets, poultry) - Field trials of soil amendments - Biochar briquettes to be used as cooking fuel - High value whey ingredients screening
Ghana	- Green biorefinery - Pyrolysis - Pelletizing	**Green biorefinery:** Cowpea leaves, soybean leaves, Cajanus leaves, itch grass, goat weed, gamba grass (single and mixtures) **Pyrolysis**: groundnut husk, rice husk, corn cobs, maize stalks **Pelletizing:** Cowpea husk, soybean husk, rice bran, cassava peals, cocoa husk, corn cobs, green biorefinery protein concentrate	- Animal feed: a) press cake for ruminants (dairy cows, bulls), b) protein concentrate for pigs and aquaculture, c) whey for piglets and for high value whey ingredients screening - Biochar for soil improvement - Protein concentrate pellets as aquaculture fish feed	- Animal feed trials (dairy cows, bulls, pigs, piglets) - Aquaculture feed trials (Tilapia, Catfish) - Soil amendment field trials (tomatoes, okra, chilli pepper) - High value materials screening in side streams
Côte d'Ivoire	- Pyrolysis -Bio-composites/ - Bioplastics - Pelletizing	**Pyrolysis:** cocoa pod shells, cashew nuts shells, millet husks/ stems **Pelletizing:** Cajanus cajan (pigeon pea), Leucaena leucocephala leaves, Stylosanthes guianensis (Stylo) leaves), rubber seed, cashew nuts **Bioplastics:** Cashew apple juice molasses mixtures **Biocomposites:** - Coconut fiber and palm tree branch fiber	- Biochar for soil amendment (tomato and maize crops) - Biochar for adsorption of water pollutants - Biomass pellets for animal feed - Bio-composites/ Bioplastics	-Soil amendment greenhouse trials (tomato and maize crops) - Tests of water filters using biochar -Animal feed trials with raw biomass pellets (sheep, rabbits, poultry)

Senegal	- HTC -Pyrolysis -Briquetting - Bio-composites	**HTC:** Typha, rice husk, cashew apple pulp, water hyacinth **Pyrolysis:** Peanut shells, cashew nut shells, millet stalks, rice husk, corn stalks **Briquetting:** Biochar from peanut shells, cashew shells, millet shells **Biocomposites:** Typha, rice husk, palm stalk	- Biochar briquettes for solid fuel - Biochar for addition to anaerobic digestion systems (or adsorbent of biogas pollutants) - Bio-composites	-Solid fuel (cooking fuel) trials with biochar -Anaerobic digestion tests adding biochar inside the reactor and as pollutants filter

With the above in mind, the current report is structured in **6 distinct chapters**, as follows:

Chapter 1 constitutes the executive summary of the report

Chapter 2 provides an overall presentation of the activities in the four pilots, as an introductory part of the report

Chapter 3 provides information about all technologies to be developed and/or adapted and transferred in the project (for each technology: short description and flow diagram, photos, operational considerations and feedstocks to be tested)

Chapter 4 provides information about the four BIO4AFRICA pilot cases in Uganda, Ghana, Côte d'Ivoire and Senegal (for each pilot case: overall description and objectives, pilot sites, stakeholders to be involved, local team, trials, GANTT chart on pilot and validation activities, activities and achievements in each pilot case until M24)

Chapter 5 describes monitoring activities common for all pilot cases

Chapter 6 provides information about KPIs monitoring and assessment (target values, hypotheses/ baselines, monitoring methodology, partners to be involved)

Chapter 7 concludes on the next steps foreseen in the framework of the project with respect to pilot activities as well as their monitoring and assessment plan.

In ANNEX 1, the Monthly Monitoring Template for each pilot case is presented.

Note that the current report will evolve during the lifespan of the project and will be **further elaborated and updated throughout the duration of BIO4AFRICA (i.e. as D3.3 and 3.4 at M34, M42)**, in order to include new data, better detail and/or reflect changes in the methodology or other aspects relevant to the technology transfer.

3. OVERALL DESCRIPTION OF TECHNOLOGIES IN BIO4AFRICA PILOTS

3.1 Small-scale green biorefinery

3.1.1 Flow diagram and short description

In BIO4AFRICA pilot cases, small-scale green biorefinery will be tested for processing local grasses and leguminous crops. The small-scale green biorefinery units of BIO4AFRICA are low cost units operated independently, with an initial processing capacity of 400kg/hr of fresh leaves, with possibility to increase up to 1,000 kg/hr during further optimisation activities under Task 2.3. Two main streams are produced: a press cake and a liquid (juice) fraction. The press cake fraction, albeit containing about half of the protein present in grass, can be used as improved silage for ruminants (cows, goats, sheep etc.). The juice fraction from the primary extrusion of the green biomass is rich in largely soluble protein, sugars and nutrients, constituting a green protein concentrate that can be used either in its original liquid form or in an easily storable and transferable condensed product, after coagulating, sedimentation and sun drying. Uses of the concentrate include animal feed for monogastrics (chicken, pigs etc.), serving as a suitable, home-grown soybean meal replacement and aquaculture feed. The liquid remaining residual stream after the green protein extraction is called whey and is rich in sugars, minerals (e.g. calcium, magnesium), amino-acids and carboxylic acids. It can be used as animal feed for piglets or biogas substrate. By depositing animal manure to crops, the nutrient loop closes at a farm level, as nitrogen, phosphorus and potassium are recycled back to land, diminishing the need of fertilizing. The use of legume crops will supplement the soil for the nitrogen going to green biorefinery protein products, further diminishing fertilizing needs.

The leaves are weighed before entering the washing cage. A weighing facility is necessary to be able to make mass balances and evaluate the overall performance of the biorefinery, and later for financial administration of feedstock). Next, the leaves are being washed in a washing cage, to remove dirt and sand and other impurities that may damage the refiner and have negative impact on product quality (higher ash content). By a conveyor belt, washed leaves are brought into the refiner.The refiner is an extruder that presses and squeezes the fresh green leaves, with as a press cake and a juice. The refiner has a weight of approximately 5 tonnes. The press cake is being collected and by a short conveyor belt feeding the baler. The baler presses and ensiles the press cake. This makes it storable and transportable. The juice is being collected and fed into a sedimentation container (to remove remaining sand particles) and then transported by worm pumps to the coagulation vessels. Protein coagulation and precipitation: Protein coagulation is done in two parallel primary precipitation vessels, and one secondary precipitation vessel.

After concentration, the wet protein is pumped by worm pumps to the drying house. A ventilator will be used on days with little wind/high humidity to ensure the drying process and prevent loss of product quality. Protein concentrate powdering is expected to be done manually. Packaging either in bags or small containers. The press cake will be baled in bales of approximately 50-60 kg. The whey from the coagulation/precipitation process will be stored in a 4 m3 stainless steel vessel. Possibly UV-light will be applied in the vessel to prevent microbiological contamination processes. In order to concentrate the sugar-rich whey after protein separation, a passive solar whey concentrator will be developed after the initial biorefinery is operational. The basic principle of the whey concentrator is to have small streams of whey flowing over a surface that is warmed by solar radiation. The whey is recirculated over the warm surface for a number of times, till a concentration of approximately 10 times has been achieved. It is expected that after 10-times concentration, the whey can be used as conservative in silage-preparation.

In Figure 1 and in Figure 2, the process of small-scale green biorefining is presented schematically. A detailed description of the small-scale green biorefinery technology to be adapted and tested in BIO4AFRICA is presented in Deliverable D2.3 Small-scale green biorefinery units – initial version.

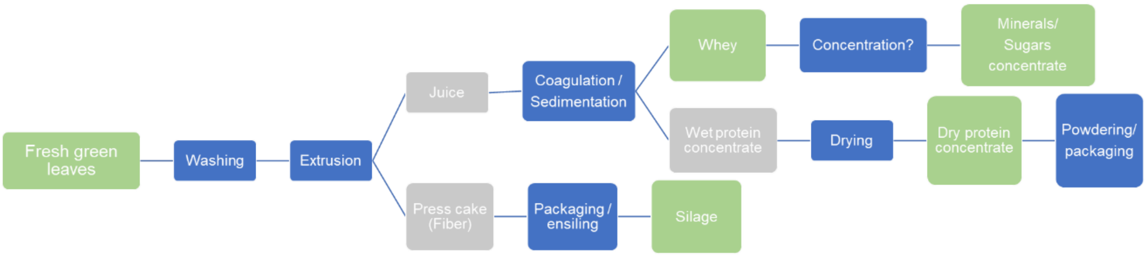


Figure 1: Flow chart of small-scale green biorefinery process

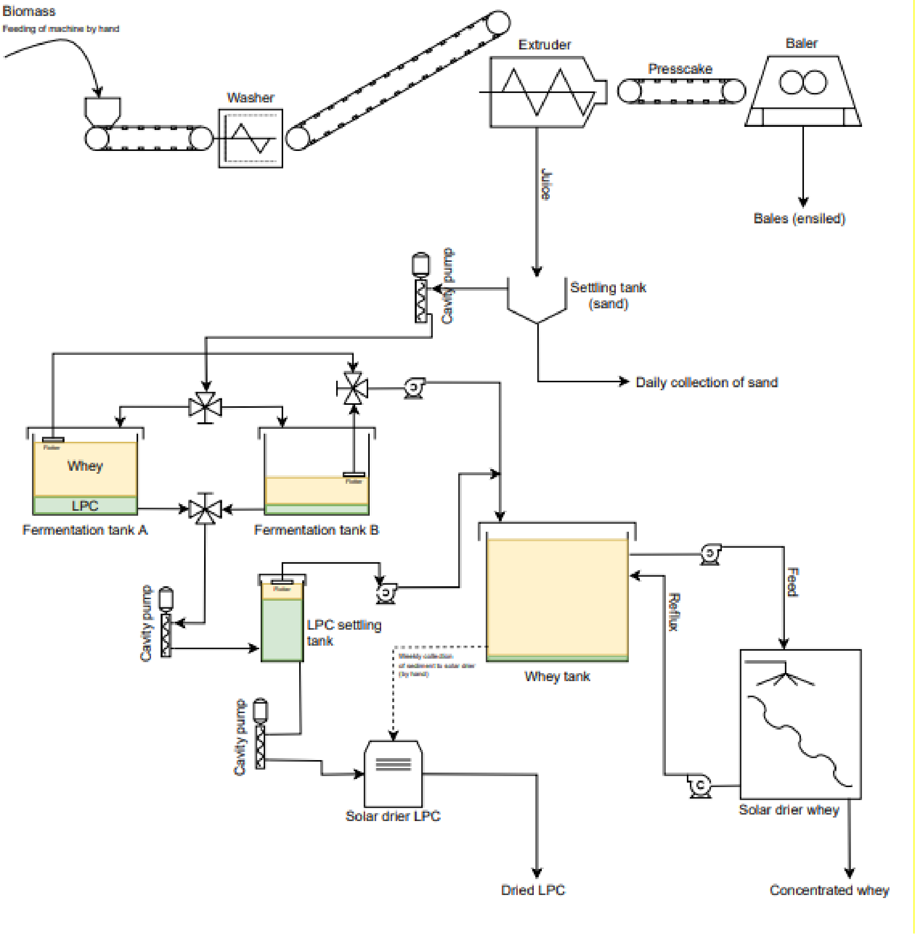


Figure 2: Process scheme of small-scale green biorefinery

Green biorefinery is a sustainable concept, using a combination of equipment to produce multiple products out of green leaves. Using a relatively simple technology, it is possible to enhance the agricultural output of a farming operation. To achieve this, fresh leafy biomass can be refined by mechanical means. This biomass is converted into high value protein concentrate feed, silage for ruminants, fertilizer and maybe even food in the future. The food grade protein yield will be 50%-200% higher per hectare compared to regular agricultural practices (animal-based protein). The small-scale green biorefinery is located close to where the feedstock is grown, in order to ensure the delivery of fresh feedstock. Short transport distances also minimize the related emissions and costs. The products from the biorefinery are well storable and easy to transport. This will enable the local distribution of the feed products powering a more decentralized economy and allowing local farmers economic independence and an additional source of income. Mineral cycles will be more efficient resulting in less pollution, both in the air and in the soil. Because of the higher agricultural efficiency, there will be less need to import feed and fertilisers from abroad. The environmental footprint using this system is lower compared to the agricultural practices today.

3.1.2 Photos

Figure 3: Photos of the small-scale green biorefinery pilot of BIO4AFRICA in Uganda

3.1.3 Operational considerations and feedstocks to be tested

Intake feedstock (storage): Depending on type, temperature and humidity of feedstock, refining should take place within 4 hours after harvesting. If transported/stored cool, this time period can be enhanced. Refrigerator truck: is advisable in case the transportation time from the fields to the biorefinery is more than 1hour.

Logistics: It is advisable to create a one way through routing through the biorefinery, entering the biorefinery with feedstock at one side of the refinery, and dried products leaving to the storage at the opposite side. The bulky products (whey and press cake) are more likely will leave from the same side as the feedstock as heavy transportation vehicles are necessary.

Platform, Roofing, noise control: Platform should be able to carry equipment with weights of 5 tonnes and a possibility to be easily cleaned. Roofing is necessary to protect the equipment but especially the operators against sunshine and rain. If noise sensitive receptors are present, it is advised to construct the necessary noise protection walls to ensure that no nuisance is caused in the neighborhood.

The following feedstocks, as single feedstocks or mixtures, will be tested with the small-scale green biorefinery technology in BIO4AFRICA pilot cases:

- Pakchong (local kind of Napier grass), Alfalfa, Mucuna beans, local species of Titonia and Clitoria, left over banana leaves, sweet potato leaves (Uganda)
- Cajanus, Soy, cow pea (Ghana)

3.2 Brazilian kiln pyrolysis technology (Ghana, Côte d’Ivoire)

The Brazilian technology was developed as part of a previous international program. The objective was to produce equipment that could produce good quality charcoal at the lowest possible production cost. The technology was aimed at local people. It had to be easy to replicate, easy to use, low maintenance and, above all, accessible to local communities. In addition, the technology had to be environmentally friendly, especially in terms of gas emissions. An incinerator was therefore added. The materials used to build the kilns are easily mobilized (mainly bricks and clay). Today, this technology has proven itself on the South American continent. In the frame of B4A, the challenge will be to adapt this technology to agriculture residues instead of woody biomass.

3.2.1 Flow diagram and short description

Concerning low pyrolysis technology, the only technology selected is originated from Brazil. It is used by small and medium rural producers to bring income gains, enabling them to produce higher quality biochar without the health and environmental issues of traditional kilns. The system consists of 4 circular ovens surface, connected by ducts to a masonry furnace. On the combustion chamber the furnace is built with a 3.5 m high chimney where the gases generated during the carbonization of the biomass are burnt (Figure 4, Figure 5). This tech was developed to pyrolyze mostly woody biomass with the capacity to hang approx. 9.5 stere of firewood per oven / cycle.

- The system works with 4 kilns connected to the furnace by means of 4 ducts.
- The drying process and the carbonization of the wood, which is transformed into coal, takes place inside the kilns.
- The ducts lead the gases from the kilns to the furnace.
- In the furnace combustion chamber, polluting gases are burnt.
- The carbonization cycle (cooling included) in this kiln system lasts from 6 to 7 days.

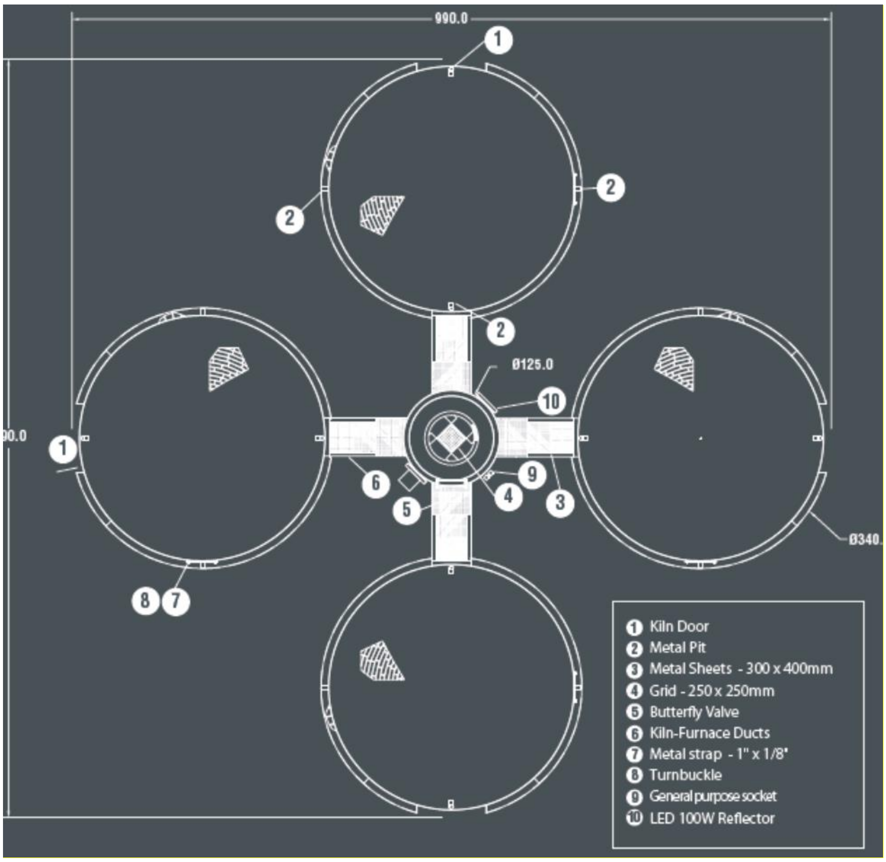


Figure 4: Brazilian kiln (top view)

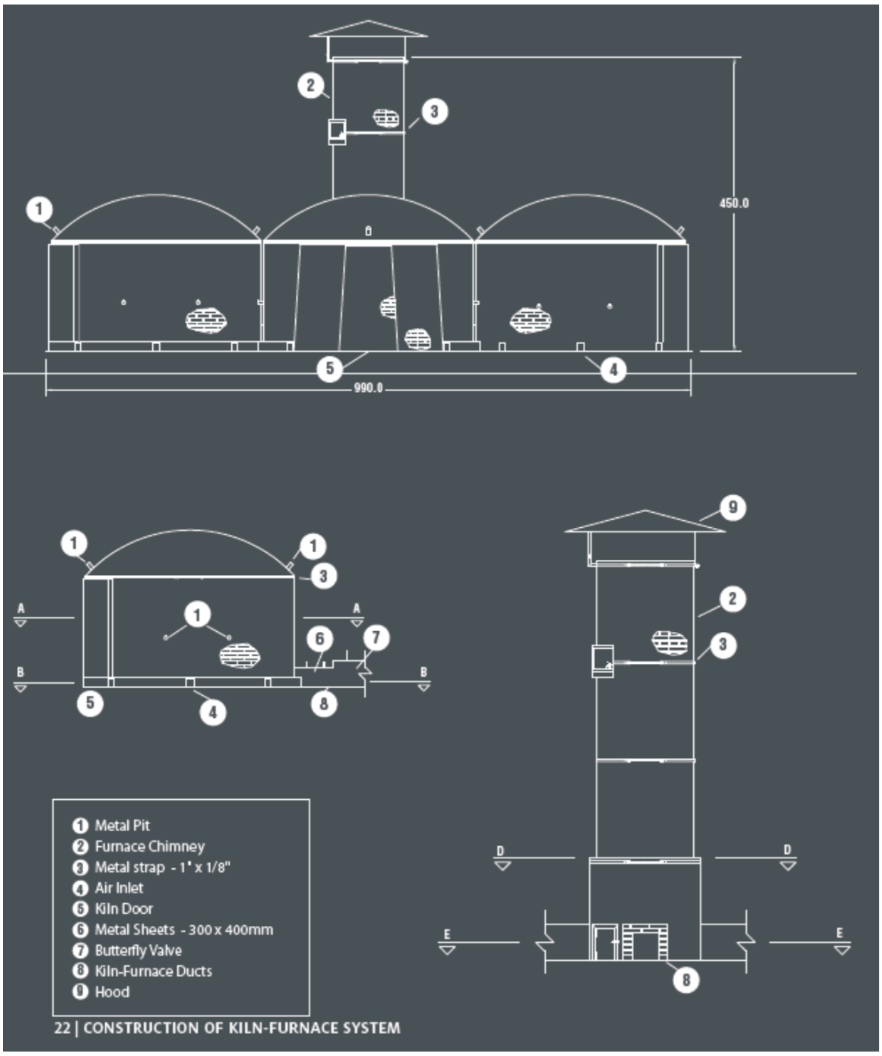


Figure 5: Brazilian kiln (front view)

3.2.2 Photos

Figure 7 shows the photo of the carbonization kilns to be transferred to the pilot sites in Ghana and Côte d'Ivoire.

Figure 6: Brazilian Kilns developed at the Federal Viçosa University

3.2.3 Operational considerations and feedstocks to be tested

The main parameters controlled during processing will be the type of biomass, the mass of biochar produced and the pyrolysis conditions like temperatures, heating rate and duration of the carbonization.

Raw material: Biomass compositional methods has been performed by Celignis in the WP2 to compare different lignocellulosic feedstocks, to measure component balances around unit operations and to determine process yields and therefore the economic viability of biomass-to-biofuel processes. These results will be used in the WP3.

Charcoal yield: Efficiency of carbonization is expressed as the yield of charcoal in gross terms (at the side of the retort or kiln) expressed as a percentage of the wood charged or used-up to produce it. Wood and charcoal must be measured using standardized methods. They need not be the same for both materials but they must be consistent so that results are comparable. In other words, a consistent methodology of measurement must be adhered to. Properly measured conversion efficiencies allow different charcoal making methods to be compared. Also, these measurements are essential in controlling charcoal making enterprises. The mass of the biomass loaded into each kiln can be figure out either by direct weighing or from the biomass volume The most accurate measuring system compares all quantities on a weight basis. To avoid complication due to differing moisture contents, the raw biomass used is expressed on a bone-dry basis and the biochar is weighed bone dry. where moisture is present it must be determined and allowed for. To apply such a system, equipment for weighing and determining moisture content of wood and charcoal must be available. A practical method which has been widely standardized in South America, uses volume measurement. The total mass of residues charged into the kiln will be estimated from the number of loads carried out by the front loader underuse, after a previous assessment of the average net weight of the individual loads. For this purpose, the gross weight of the front loader was measured a minimum of five times for each type of wood feedstocks and the respective tare weight was subtracted. The yields of solid products were obtained by dividing the total mass of each product by the total mass of dry wood feedstock charged into the kiln.

Temperatures control: Continuous temperature measurements will be done by several K-type thermocouples positioned at different locations in the kilns. One thermocouple will be placed inside the chimneys, at about 1 m from the outlet, to monitor the temperature of the carbonization flue gases. The positioning of the thermocouples inside the kiln was done with the help of stainless-steel tubes resting on the kiln floor, thus allowing the thermocouples to be inserted to the exact measuring points.

Data signals from the thermocouples will be read, visualized, and recorded through a data acquisition system. In addition, temperature dataloggers (Carboraad software) will be used to check and record temperatures in several kiln locations during the experiments, especially to control the cooling phase.

Biochar proximate analysis: Proximate analysis typically involves the determination of moisture content, volatile matter, fixed carbon, total carbon and ash content. The fixed carbon (FC), volatile matter (VM) and combined ash and moisture content of biochar dictate the heating value of the charcoal which is the amount of heat obtained when unit mass of biochar is completely burned under specified conditions.

FC is the solid carbon in the biomass that remains in the char in the pyrolysis process while the volatile matter distills off. It is determined from the following equation, where M, VM, and ASH stand for moisture, VM, and ash contents, respectively : $FC=1-M-VM-ASH$. Volatile matter is determined as the loss in mass, less that due to moisture, when a sample is heated according to the procedures outlined in European Standard EN15148-2009 ("Solid biofuels - Determination of the content of volatile matter").

3.3 Local pyrolysis technology (Senegal)

3.3.1 Flow diagram and short description

The widespread use of cylindrical transportable metal kilns for charcoal production in west Africa and more specifically in Senegal are originated in Europe in the 1930's. Charcoal can be also produced in kilns manufactured from standard 45 gallon oil drums. This method has been operated successfully using fast burning raw materials such as coconut palm timber, coconut shells and scrub wood. However, when operated with dense hardwoods, complete carbonization is difficult to achieve and the resulting charcoal is likely to have a high volatile content. Even with low density materials like agriculture residues, the volatile content of the charcoal produced is somewhat high, although this is not a major disadvantage for a local domestic fuel.

The main advantages of transportable metal kilns compared with the traditional earth pit or clamp method are:

- Raw material and product are in a sealed container giving maximum control of air supply and gas flows during the carbonization process.
- Unskilled personnel can be trained quickly and easily to operate these units.
- Loss of supervision of the process is required compared to the constant attendance necessary with pits and clamps.
- Mean conversion efficiencies of 24% including fines (dry weight basis) can be consistently achieved. Pits and clamps give erratic, often lower yields.
- All of the charcoal produced in the process can be recovered. With traditional methods (pits and mounds) some of the charcoal produced is lost in the ground and that which is recovered is often contaminated with earth and stones.
- With maximum control of the process a wider variety of raw materials can be carbonised. These include softwood, scrubwood, coconut palm timber and coconut shells.
- The total production cycle using metal kilns takes two to three days.

The disadvantages of using metal kilns compared with the traditional earth pit or clamp method are:

- Initial capital to cover the cost of the manufacture of the kilns must be obtained. Basic mechanical workshop skills and equipment must be available and the steel used in the kiln construction often has to be imported.
- For ease of packing and maximum efficiency some care is needed in the preparation of the raw material. The wood must be cut and/or split to size and seasoned for a period of at least three weeks.
- Transportable metal kilns may prove difficult to move in very hilly terrain, although more gentle slopes can be easily traversed.
- The life span of metal kilns is only two to three years.

Method to operate metalic kilns:

- Assembly and loading the kiln
- Lighting the kiln.
- Reducing the draught
- Control of charring
- Unloading the kiln
- Bagging of charcoal

Description of metalic kilns: as described by the FAO, the major features of the cylindrical transportable metal kilns (TPI) designed kiln are:

- 3 mm thick sheet steel is used for the fabrication of the bottom section of the kiln; 2 m thick sheet steel is used for the top section and cover.
- The two main sections of the kiln are cylindrical.
- 50 mm angle iron shelves are used to support the top section and cover. These are welded to the inside of the uppermost rims of the two main cylindrical sections.
- The eight inlet/outlet channels positioned under the bottom section of the kiln are open based. A collar is provided around the hole in the top face of each channel to support the chimney during the kiln's operation.

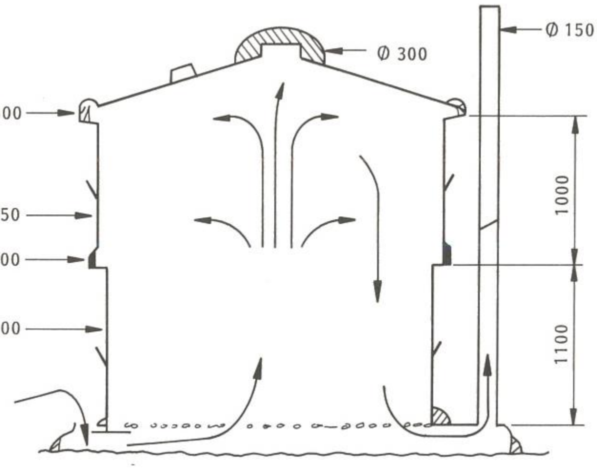


Figure 7: Schematic diagram of metallic pyrolysis kilns)(Shah, 1992)

To ensure the maximum working life of a kiln, especially when operated carelessly, the thickness and type of metal used in the kiln's construction is of prime importance. The lower section of the kiln is subjected to the greatest heat stresses and should be fabricated from 3 mm thick sheet steel. For the upper section and cover a thickness of 2 mm will suffice The process involves a carbonization period of about two to three hours, followed by a cooling period of about three hours. An experienced operator can cycle ten drums twice each day to produce a total output of up to 30 kg of charcoal from each drum. This means that a one man operation, using 10 kilns, can produce 1½ tons of charcoal per 5-day week, if supplied with adequate prepared wood.

3.3.2 Photos

Figure 8: Kilns manufactured from standard 45 gallon oil drums, Zinguinchor, Senegal

Figure 9: Cylindrical transportable metal kilns for charcoal production, Zinguinchor, Senegal

3.3.3 Operational considerations and feedstocks to be tested

The main parameters controlled during processing will be the type of biomass, the mass of biochar produced and the pyrolysis conditions like temperatures, heating rate and duration of the carbonization. The mass of the biomass loaded into each kiln will be figured out either by direct weighing in order to estimate the amount of biochar produced. According to the procedures outlined in European Standard EN15148-2009 we will determine the proximate analyses of biochars produced.

3.4 Local pyrolysis technology (Côte d’Ivoire)

3.4.1 Flow diagram and short description

The furnace used for pyrolysis was built on the North site of INP-HB. First, a metal skeleton was pre-designed (photo 1). Then mud bricks were mounted around the metal skeleton. Finally, the whole thing was sealed with clay in order to obtain the oven. Unlike the modern oven, this artisanal oven has two chambers: the feeding chamber and the pyrolysis chamber

- The supply chamber of the rectangular oven with a volume of 15000 cm^3 made it possible to supply the oven with firewood. Indeed, the activation of the oven required firewood. This material is essential because it represented the source of energy for the proper functioning of the oven. To do this, a good quantity of wood was needed to keep the oven powered for 5 hours. In addition, it was preferable to have large woods to maintain the ardor of the fire.
- The pyrolysis chamber, in conical form and with a volume of 10480 cm^3, received the material to be carbonized. The two chambers are separated by a metal plate. To obtain airtight conditions during carbonization, the upper chamber has been equipped with a closure.

The brick kiln used by INP-HB (Figure 12) is a traditional kiln that allows the production of biochar by indirect combustion. It is about 1m in diameter but does not have a chimney for gas recovery. The materials used may be similar to those of the Brazilian technology that will be transferred.

3.4.2 Photos

Figure 10: New furnace build at INP-HB with metallic skeleton and bricks

Figure 11: Traditional Bricks kiln tested in Yamoussoukro, Cote d 'Ivoire

3.4.3 Operational considerations and feedstocks to be tested

The main parameters controlled during processing will be the type of biomass, the mass of biochar produced and the pyrolysis conditions like temperatures, heating rate and duration of the carbonization.

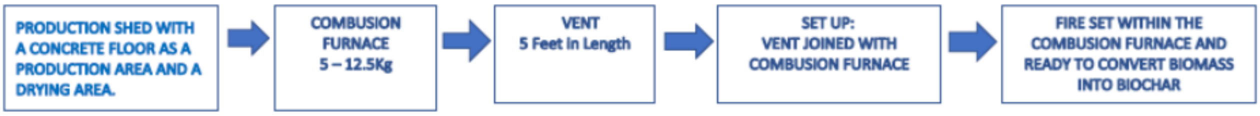
3.5 Local pyrolysis technology (Ghana)

3.5.1 Flow diagram and short description

The pyrolysis technology is made up of a combustion furnace and a vent for the efficient thermal decomposition of biomass at elevated temperature. The metal fabricated combustion furnace is designed with small air outlets around it to ensure sustainable combustion of biomass into biochar. The metal fabricated vent is designed to ensure that it is airtight when fitted with the combustion furnace. The vent provides an exit for gases during the combustion of biomass into biochar.

A production shed with a concreate floor and an open area is required for the production of clean biochar and to control the influence of the surrounding air during the combustion of biomass into biochar.

The technology is environmentally friendly designed to control the emission of thermal decomposed gases to reduce air pollution.


PRODUCTION SHED WITH A CONCRETE FLOOR AS A PRODUCTION AREA AND A DRYING AREA.
COMBUSTION FURNACE 5 – 12.5Kg
VENT 5 Feet in Length
SET UP: VENT JOINED WITH COMBUSTION FURNACE
FIRE SET WITHIN THE COMBUSTION FURNACE AND READY TO CONVERT BIOMASS INTO BIOCHAR

3.5.2 Photos

Figure 12: Pictures of biochar production using local pyrolysis technology in Ghana

3.5.3 *Operational considerations and feedstocks to be tested*

The combustion furnace is fabricated with metal at various sizes and weight ranging from 5kg – 12.5kg. The metal fabricated vent has an average length of 5feet and weight of 2kg – 5kg. The equipment can produce biochar with various biomass at an average volume of 5kg – 250kg depending on the size of the equipment. A concrete floor with a size of 5 – 10 square meters is required as the production area for the use of the equipment. The surrounding air direction need to be monitored before setting up the equipment with fire to produce biochar.

The mass of the biomass loaded into each kiln will be figured out either by direct weighing in order to estimate the amount of biochar produced. According to the procedures outlined in European Standard EN15148-2009 we will determine the proximate analyses of biochars produced.

The biomasses to be tested with the local pyrolysis technology in Ghana will be: cashew nut shell, palm kernel shells, coconut shells, roasted palm kernel shells

3.6 Pyrolysis technology (Senegal)

3.6.1 Flow diagram and short description

The rotary kiln selected works by processing material in a rotating drum at high temperatures for a specified retention time to cause a physical change or chemical reaction in the material being processed. The kiln is set at a slight slope to assist in moving material through the drum (fig 13). The kiln is fired by gas burners directly against the outer shell of the vessel. The temperature inside the kiln is controlled by adjusting the burner heat, varying concentration of O2.

Based on the material flow, a rotary kiln is usually divided into the following zones:

- Kiln inlet cone.
- Preheating zone.
- Calcining zone.
- Upper transition zone.
- Clinkering zone.
- Lower transition zone.
- Discharge area.

The size of the rotary kiln is 5meters and a diameter of 0.5m transforming 300kg/h of biomass in biochar. The heat is provided by an oil burner consuming 70l/h.

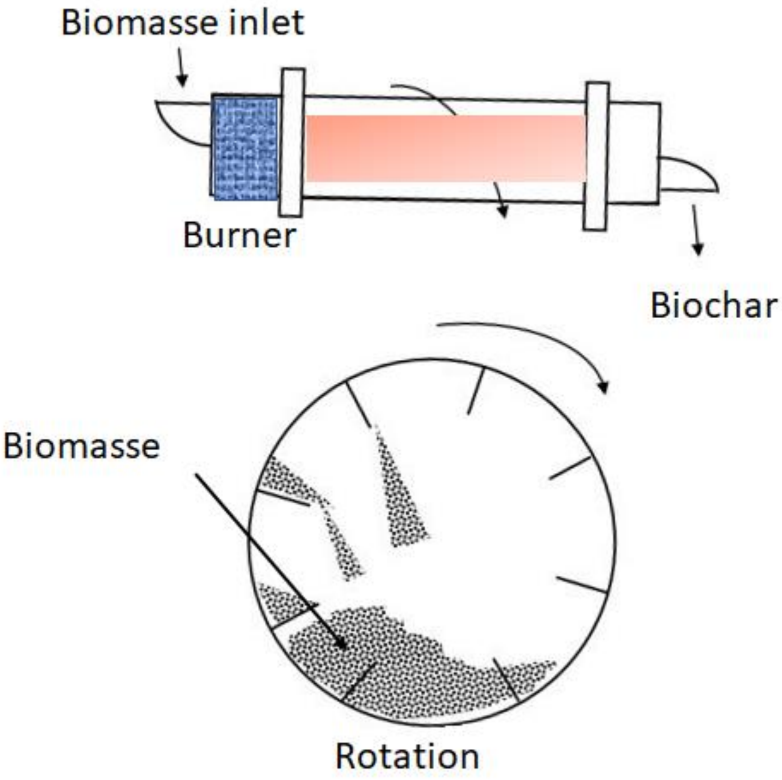


Figure 13: Principle of biomass pyrolysis in a rotary kiln

3.6.2 Photos

Figure 14 : Rotary kiln and burner running with used oil

3.6.3 Operational considerations and feedstocks to be tested

The main parameters controlled during processing will be the type of biomass, the mass of biochar produced and the pyrolysis conditions like temperatures, heating rate and duration of the carbonization.

The following feedstocks will be tested:

- Peanut shell, Cashew nuts shells, Corn stalks and palm nut shells

3.7 Hydrothermal carbonization technology

3.7.1 Flow diagram and short description

HTC is the most prospective process piloted in Bio4Africa, and as such, it will be tested as prototype (TRL 4-5). The development and construction of the pilot unit is part of WP2 Task2.5. All the details related will therefore be included in the deliverable D2.7 Small-scale hydrothermal carbonization units- initial version that will be submitted in M24 (May 2023).

Briefly, the idea is to build and test a 20L batch HTC unit for production of biochar to be used in WP3 for different applications depending on the country. The HTC unit will be based on the technology proposed by Robbiani (2013)[1] and illustrated in the figure hereafter.

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[1] Robbiani, Z. (2013), Hydrothermal carbonization of biowaste/fecal sludge: Conception and construction of a HTC prototype research unit for developing countries, Dept. of Mechanical Engineering ETHz, Master thesis, available at:

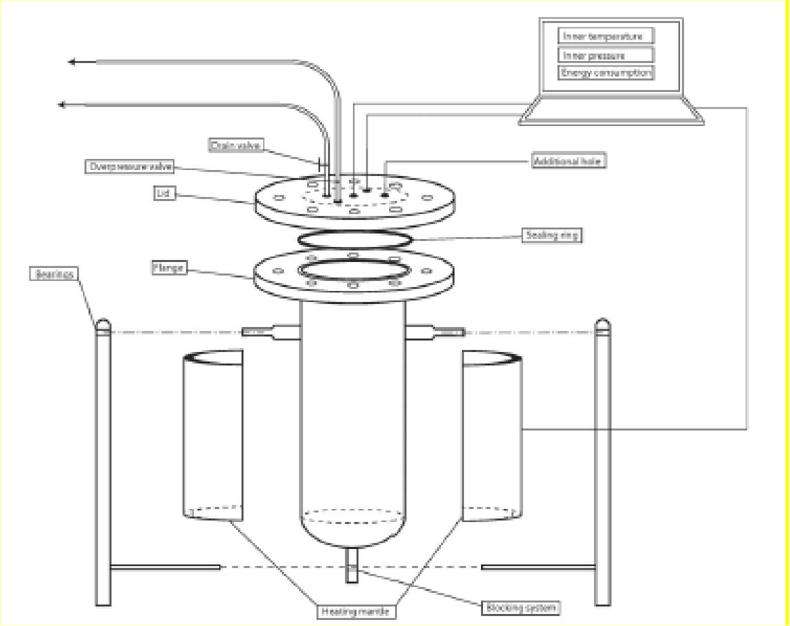

Figure 13: Schematic of the HTC technology to be adapted

One key aspect is the willingness to have it built and further adapted by an African company, using local materials, thus avoiding the future problems of spare-parts and contributing to the local economy as well as technology development in Africa. SCPL and Energeco, with the support of UASZ and IHE, are currently building the unit to be delivered in Senegal in M24 and will then replicate it for the second version to be implemented in Uganda in M30. Adaptations to the specificity of the pilot case in Uganda as well as improvements based on the experience gained with the first version tests will be considered.
Pretreatments/posttreatments needed and the utilities for each use case will also be described in D2.7, and summarized in D2.8 and D2.14, based on the results that will be obtained in WP2 related activities.

3.7.2 Photos

Figure 14: The HTC technology development for BIO4AFRICA

3.7.3 Operational considerations and feedstocks to be tested

The following parameters will be monitored: temperature, residence time, biomass/water ratios

The following feedstocks will be tested:

- Cow manure (Uganda)

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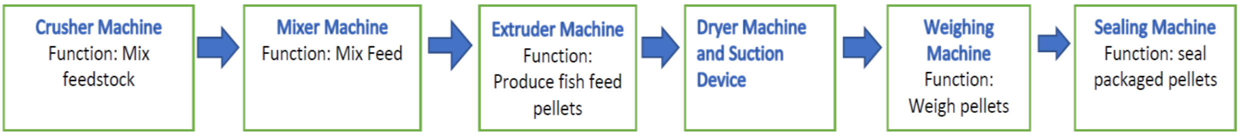
https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/Carbonization_of_Urban_Bio-waste/carbonization.pdf

- Typha, cashew apple (Senegal)

3.8 Pilot scale pelletizing technology (Ghana)

3.8.1 Flow diagram and short description

The flow diagram is described in then figure X :



Pelletizer, also called pellet mill, is composed of a die, rollers, and knives. Die is a steel matrix, which can be ring or flat, rotating or stationary, with a multiplicity of radial channels. A pellet mill die channel design is presented as example in Figure 15.

A die is specified by its surface area and distribution pattern of press channels in the die . The press channels are defined by length (L) / diameter (d) ratio but also its inlet angle and depth (l) and finish with a discharge side with does not affect the pelletizing process. Total size of the die, quantity of channels, size of open area of channels, the quantity, diameter, width and shape of rollers are also considered to affect the pelletizing process.

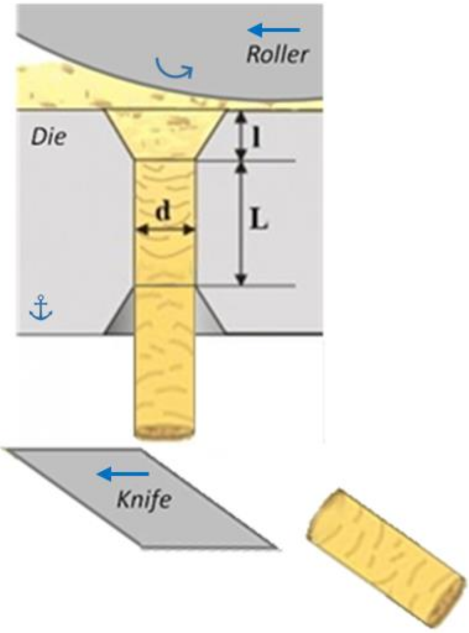


Figure 15. Cross section of a stationary pellet mill die channel

Pelletizing devices must be well-controlled during production because:

- It represents an important operating cost in a biomass pellet plant.
- Environmental analysis suggested that the drying and the pelletizing stages are the largest negative factors affecting the environmental performance of pellet production.

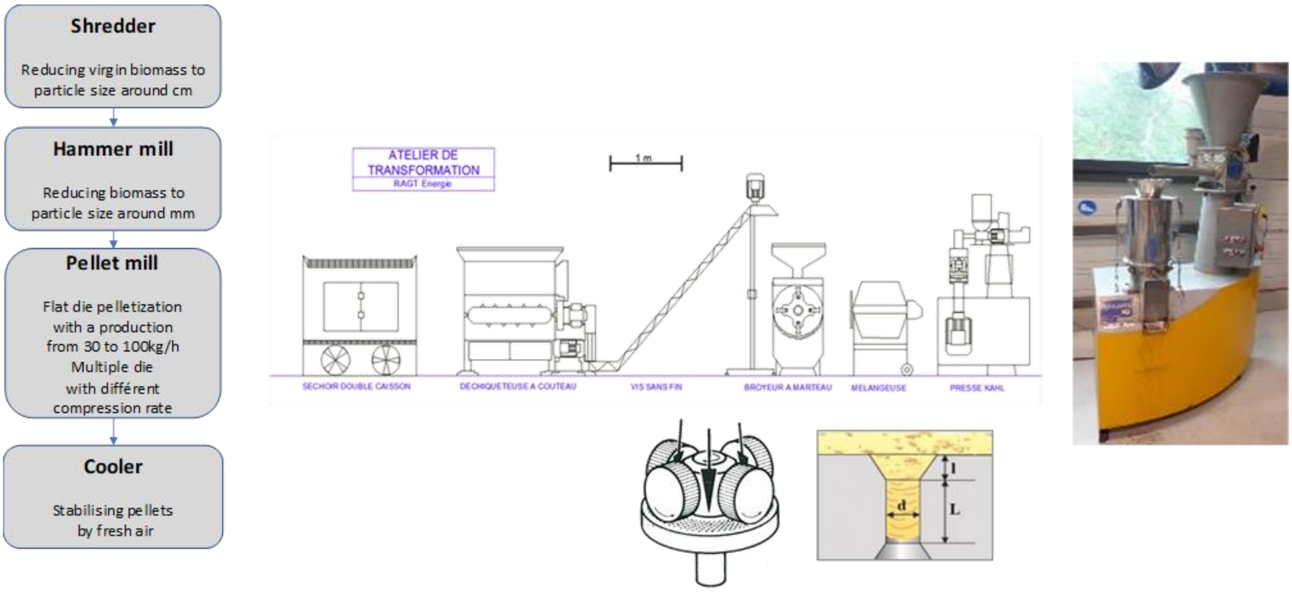


Figure 16: Overall densification process (RAGT, 2022)

3.8.2 Photos

Figure 17: Pilot scale pelletization technology in Ghana

3.8.3 Operational considerations and feedstocks to be tested

The feedstock that will be used for the production of floating pellets are Cowpea husk, Soybean husk, Rice bran, cassava peels, Cocoa husk, and Fermented corn cobs.

A pelletization extruder mill will be used to produce floating fish pellets for fish feed trials in Ghana. The machine is made up of the following:

1. Crusher machine. Output: 1-1.5T/h (3mm net), Output: 300-400kg (0.8-1mm net), Size: 770*460*600mm, Weight: 108kg, Motor: 7.5kw, and Voltage: 380v 50hz 3 phases.
2. Mixer Machine. Material: stainless steel, capacity: 50kg/batch, Motor: 7.5kw, Size: 1050*600*900mm, Weight: 180kg, Voltage: 380v 50hz 3 phases.
3. Floating fish feed pellets extruder machine: Model: LM-80, Capacity: 200-300kg/h, Voltage: 380v 50hz, 3 phases, power: 22kw, cutting power: 0.6kw, feeding power: 0.6kw, Feeding power: 0.6kw, Size: 1800* 1450*1300mm, Weight: 695kg.
4. Vertical Dryer Machine with a Suction device: Capacity: 200kg/batch, Diameter: 689cm, Electric power: 13kw, Fan power: 400w, Voltage: 380v 50hz 3 phases, Dimensions: 1200*750*1450mm, Weight: 140kg.
5. Weighing Machine: Size: 800*400*500mm, Power: 0.7kw, Capacity: 300kg, Weight: 15kg.
6. Sealing Machine: Size: 293*210*283mm, Power: 0.19kw, Capacity: 100bags/h, Weight: 15kg.
7. Spare parts: Moulds, Screw, Sleeves, Knife, Anti scalding gloves, and tools set.

3.9 Local pelletizing technology (Côte d’Ivoire)

3.9.1 Flow diagram and short description

1st installation

- Grinder-mixer
    - Hammer mill
    - 3 different screens : 2, 3 and 4 mm holes
    - Power: 7,5 kW
- Pellet mill
    - Ring-die pellet press
    - 3 different ring-die : 4, 6 and 10 mm holes
    - Power : 22 kW
    - Production rate : 100-200 kg/h depending on feedstock and die used

2nd installation

- Grinder-mixer : hammer millPelletizer-extruder
    - Single screw extruder
    - Electrical resistance for heating
    - 3 different dies : 1, 1,5 and 2 mm holes

3.9.2 Photos

Photos of the ring-die pellet press (top), pelletization chamber (bottom left) and different ring-die (bottom right) of the first installation at INP-HB.

3.9.3 Operational considerations and feedstocks to be tested

The following local feedstocks are going to be tested in pelletization pilot activities in Côte d’Ivoire: *Cajanus cajan* (pigeon pea), *Leucaena leucocephala* leaves, *Stylosanthes guianensis* (Stylo) leaves), rubber seed, cashew nuts

3.10 Pelletizing technology (Côte d’Ivoire)

3.10.1 Flow diagram and short description

Two options are still being considered regarding what densification equipment will be implemented in Côte d’Ivoire at INP-HB :

- 1st option : adapting existing equipment to have a continuous process
    - Connecting a grinder to the pellet press (with a conveyor for instance)
    - Solving the technical issues with the pelletizing screw and conditioner
    - Making an automatic output for pellets
    - Adding a pellet cooler/dryer
- 2nd option : having an entire new pelletization line entirely adapted to the needs of INP-HB and flexible to Côte d’Ivoire biomasses
    - Input silo
    - Hammer mill grinder

- Mixer
- Pellet press adapted to the uses
- Pellet cooler
- All connecting equipment required between each part

3.10.2 Operational considerations and feedstocks to be tested

The following local feedstocks are going to be tested in pelletization pilot activities in Côte d'Ivoire: *Cajanus cajan* (pigeon pea), *Leucaena leucocephala* leaves, *Stylosanthes guianensis* (Stylo) leaves), rubber seed, cashew nuts

3.11 Briquetting technology (Uganda)

3.11.1 Flow diagram and short description

Concerning briquetting technology, at this stage, the technologies are on investigation in each concerned use case: Uganda and Senegal. Some have been pre-selected and will be discussed in the next few months. The Figure 18 shows the classical flowchart for briquetting plant.

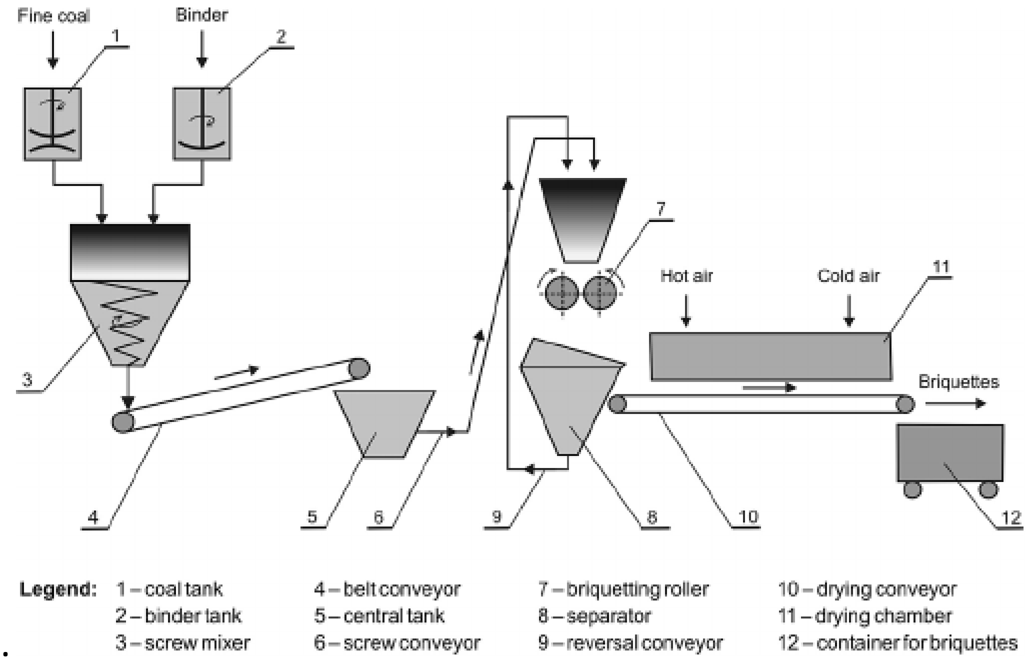


Figure 18 : Schematic of briquettes process.

The equipment that is being investigated for the densification of biochar in Uganda is a complete line of biochar grinding, mixing and briquetting. The grinder/crusher is capable of grinding 1t/h of biochar. The grinded material is then guided towards a mixer that works in batches of 250 kg and can mix them in 8 minutes. At this stage, the addition of densification binders and the adjustment of moisture content are done. Then, the densification machine is a briquetting equipment that works by extrusion : the material goes forward with a screw conveyor and is pushed onto a mold/die that will press the material into cylindrical briquettes.

3.11.2 Photos

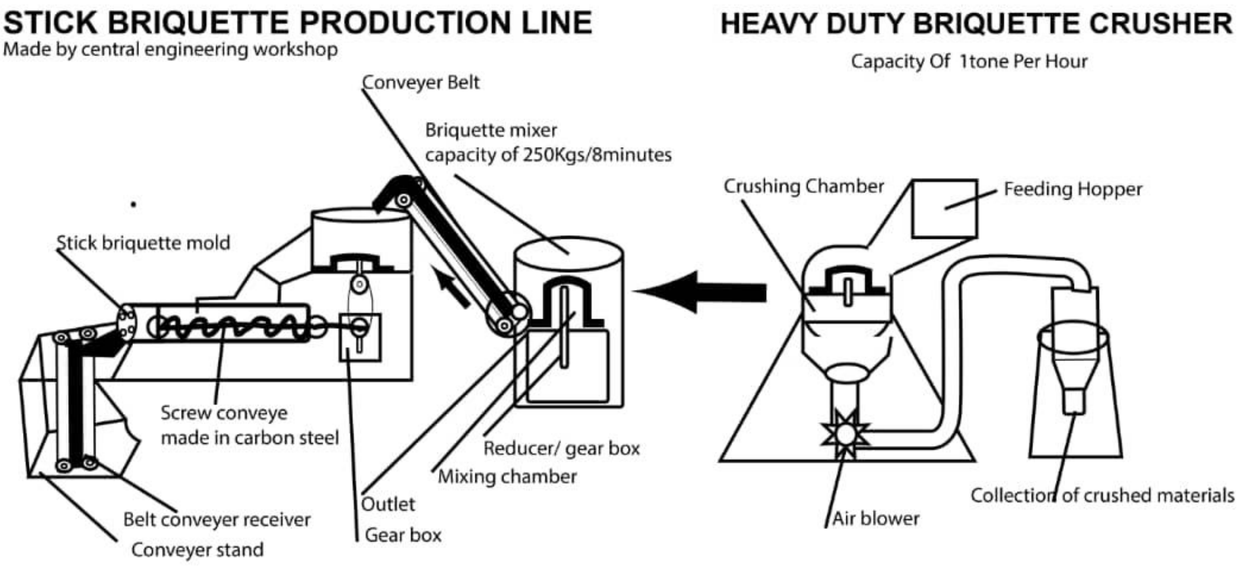


Figure 19: Schematic representation of briquetting line to be piloted in Uganda for biochar briquetting pilot activities

3.11.3 Operational considerations and feedstocks to be tested

Agricultural waste raw materials used in this project will be obtained from specific agricultural zones where each crop is grown in Uganda (selected leguminous plants and local Napier elephant grasses). Bio-chars obtained from the carbonization process will be grounded to particles sizes of less than 15 mm particles and sieved in order to increase their surface area for binding with starch. This was done to enhance the binding ability and eventual drop strength of the developed bio-composite briquette.

3.12 Briquetting technology (Senegal)

3.12.1 Flow diagram and short description

The equipment that is being investigated for the densification of biochar in Senegal is a sort of briquetting machine. The cylindrical roller has a pattern engraved on its surface. When the roller presses on the mixture of biochar and binder, an oval-shaped briquette is produced.

3.12.2 Photos

Figure 20: Photos of briquetting line to be piloted in Senegal for biochar briquetting pilot activities

3.12.3 Operational considerations and feedstocks to be tested

The following feedstocks will be tested in briquetting pilot activities of briquetting in Senegal: biochar from peanut shells, cashew shells, millet shells

3.13 Local water filtration technology

3.13.1 Flow diagram and short description

The pre-industrial prototype used for water filtration is an assembly of several elements. It contains 3 tanks. The first 1 m^3 tank was placed high up as a raw water tower. It is powered by a mechanical pump immersed in a borehole. This 3 m deep borehole was dug on the lake embankment. It is filled using an 8 m long PVC pipe connecting the lake to the well. The pre-industrial device also includes nine filters arranged in three series of three filters. Each of the series has a distributor to uniformly supply the filters with raw water. A second tank of 500 L which constitutes a support for the filters makes it possible to recover the treated water before its routing in the third storage tank. It is equipped with a water tap. Several valves make it possible to open or close the various water inlets and outlets. This pre-industrial prototype is mounted on a 1.5 m high concrete platform located above the borehole. An opening allows access to the borehole from the steps placed inside it. The photo hereafter presents the laboratory device before scaling-up.

3.13.2 Photos

Figure 21 : Laboratory device using Biochar as water filter, INP-HB, Côte d'Ivoire

3.13.3 Operational considerations and feedstocks to be tested

Biochar from cocoa pod shells, cashew nuts shells, millet husks and stems will be tested as water filtration media in Côte d'Ivoire pilot activities of BIO4AFRICA.

3.14 Biocomposites production process (Senegal and Côte d'Ivoire)

3.14.1 Flow diagram and short description

Several secondary biomass feedstocks have been collected in Senegal and Côte d'Ivoire and sent to CIRAD for biocomposites production. The selection of the specific biomass feedstocks has been made taking under consideration:

- The availability of several agro-wastes in Senegal and Côte d'Ivoire
- Their potentialities for composite applications.

Rice husk, typha, fruit bunch stalk from palm oil tree (palm stalks) and cocoa pods (husks) were selected. It must be underlined that they are all significant agro-wastes, except typha (*Typha australis*, also called cattail or bulrush). Typha is an invasive plant in the Senegal river, and, is largely represented in subtropical and tropical area. It is therefore an interesting costless raw material which has almost no valorization so far, except being used as biomass for combustion.

3.14.2 Photos

Rice husk	Peanut shells	Palm cobs	Millet stalks	Typha
				

Figure 22 : Local feedstocks for BIO4AFRICA pilot activities for biocomposites production

		
Mulching machine	Cutting mill	Sieving machine

Figure 23 : Laboratory equipment for biocomposites production (CIRAD)

3.14.3 Operational considerations and feedstocks to be tested

The table hereafter summarizes all the biomass residues collected in Senegal and sent to Montpellier (CIRAD) for the needs of the thesis in biomaterials and the pyrolysis tests to be carried out at CIRAD.

Biomasses	Rice husk	Peanut shells	Palm cobs	Millet stalks	Typha
Description	Residues from rice hulling.	Residues from the shelling of groundnut rice pods.	Residues resulting from the separation of fruits and palm oil bunch. It is on this diet that we find the fruits of the palm tree.	Millet harvest residues.	Invasive plant in rivers and swamps often used in building materials
Origin	These residues come from the SEDAB SARL factory, (Sahélienne d'entreprise de distribution en agrobusiness), located in Kougne department	These residues come from the Department of Bignona and at the Gambia and Diouloulou border (Senegal).	These residues come from the Department of Bignona, in Banbjikaki (commune of Kataba).	These residues come from Department of Bignona, in Macouda, commune of Kataba.	These residues were collected in a swamp located in Dongoro.

	of Goudomp, region of Ziguinchor.				

- Five biomasses will be tested:
    - Cocoa pods
    - Rice husk
    - Millets stalks
    - Typha
    - Fruit bunch stalk from palm oil tree
- Biomasses will be treated by dry fractionation process (milling and sieving)
- Biomasses will be incorporated in polymer resin in order to formulate a biocomposite compound and the shaping step will be carried out using a hydraulic thermal forming press.
- Characterization of the grounded biomass: density, chemical composition, biological stability and thermal stability
- Characterization of produced biocomposites: density, porosity, swelling, biological stability and mechanical and thermal properties

3.15 Bioplastics production process (Côte d'Ivoire)

3.15.1 *Flow diagram and short description*

Bioplastics are prepared by a fermentation process using a mixture of cashew apple juice and molasses as a substrate. Fermentation takes place in a biofermentor and parameters such as biomass and PHA level are monitored.

3.15.2 *Photos*

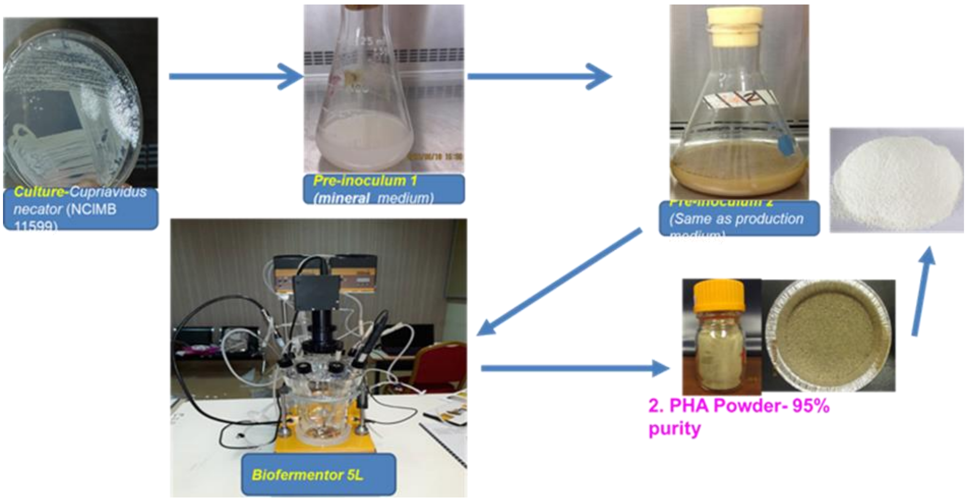


Figure 24 : Bioplastics production in Côte d'Ivoire

3.15.3 *Operational considerations and feedstocks to be tested*

Relative to biocomposites, the cocoa residues are delignified and transformed into cellulose triacetate then mixed with the PHA in variable proportions by two ways. The first concerns humid way by using a solvent and the second way concerns the thermal way by using thermopression. The materials thus obtained are afterwards characterized.

4. PILOT CASES

4.1 Pilot case in Uganda

4.1.1 Overall description and objectives

The pilot case in Uganda will test the potential of small-scale green biorefinery, HTC and briquetting techs. All steps of the biorefinery value chain will be tested from growing crops on the field and harvesting over to transporting the products to their final destination. The small-scale green biorefinery unit (200kg/hr) will be built and tested by KRC. Protein rich leguminous plants and local Napier elephant grasses will be processed in fibre/protein grass press cake, protein concentrate and protein whey. The fibre-rich protein press cake resulting from the biorefinery will be used as animal feed for cows by local farmers. The precipitated protein concentrate output stream will be transported to pig and poultry farmers to be assessed as animal feed. The biorefinery unit will be combined with a small-scale HTC unit to produce biochar by manure produced in participating cattle farms and by the deproteinized whey stream of the biorefinery. Biochar produced via HTC will be assessed for use as soil conditioner. The project will also test a pilot scale densification technology (briquetting) on local biomasses and biochar with a view to study the increasing products density as well as to reducing the environmental impact and cost of transportation.

The pilot case in Uganda could have a significant economic, environmental and social benefit for smallholder dairy farmers, as well as for the pigs and poultry industry, by offering the opportunity for on-farm production of rich proteinaceous animal feed by utilizing local crops and grasses instead of imported soy. As both the press cake and dried protein concentrate are storable and easily transportable feed products, this contributes to feed availability throughout the year even in locations with less favourable growing conditions, and makes it possible to bring animal feed to zero-grazing small dairy farmers near urban areas (like Kampala) where is a shortage of dairy cattle feed, in particular in the dry season. As these smallholder dairy farmers in urbanised areas are mainly women, BIO4AFRICA's bio-based solutions will also contribute to improving the socio-economic position of women and their families, helping them grow out of poverty. The diversification of products in farm level will increase economic options for farmers within the feed value chain, making stronger the local rural employment and green entrepreneurship.

4.1.2 Pilot sites

All technologies to be piloted in Uganda will be hosted in Fort Portal, Uganda (KRC).

4.1.3 Stakeholders to be involved

The leguminous feedstocks will be provided by local farmers, who will be supported in terms of crops selection, weed control mechanization and harvesting by KRC. The fibre-rich protein press cake resulting from the biorefinery will be used as animal feed for cows from local farmers. Biochar briquettes will be tested as solid fuel by local farmers. The precipitated protein concentrate output stream will be transported to pig and poultry farmers to be assessed as animal feed.

4.1.4 Local team

Name	Contact	Organization	Position	Responsibility	Location of activities
Mr. Mohammad A. Shariff	shariff@krcug.org	KRC Uganda	Executive Director	Coordinator of B4A trials in Uganda	Karabole, Uganda

Mr. Buwa Ronald	ronniebuwa@yahoo.com	KRC Uganda	Biorefinery Research Associate	Management of biorefinery production and feed trials	Karabole, Uganda
Ms. Medius Bihunirwa	bmedius@krcug.org	KRC Uganda	Head of FAGRIB Unit	Coordinator of WP3 and WP4 activities of KRC	Karabole, Uganda

4.1.5 Trials

Technology	Estimated outputs	Monitoring parameters
Small scale green biorefinery	Press cake: Protein concentrate: Protein whey:	Protein capacity of the machine per tone of leaves, energy consumption per ton of leaves/ material processed, energy consumption per amount of products, protein efficiency of the coagulation, overall protein efficiency, mass balance of the biorefinery, quality of press cake (dry matter, crude protein, water soluble carbohydrate, starch, neutral detergent fibre, acid detergent fibre, acid detergent lignin, mineral content, total ash), quality of protein concentrate (dry matter, crude protein, water soluble carbohydrates, starch, fibre, mineral content, total ash), whey (dry matter, crude protein, water soluble carbohydrates, starch, fibre, mineral content, total ash, pH, organic acids)
HTC	Biochar:	Charcoal yields, pyrolysis conditions (temperature, pressure, duration, biomass), Proximate and ultimate analysis of biochars (Fixed carbon, ash, CHNO%), porosity, pH.
Pilot scale briquetting technology	Biochar briquettes	Energetic, chemical and mechanical properties (HHV, compression tests, proximate analysis)

4.1.6 Activities until M24

Planting was done in March 2022 (M10) for all selected leguminous plants and local Napier elephant grasses at Rwebitaba ZARDI (NARO) to be tested as feedstocks for the small-scale green biorefinery. Farmers have also been mobilized and availed seeds to establish fields that will supplement feedstock production. The crops are showing vigor with Alfalfa ready for harvest, which will be done once the machine is completely installed.

The following preparatory constructions have been completed before installation of the small-scale green biorefinery: roof for the machine, house for office, laboratory and storage room and the solar drier.

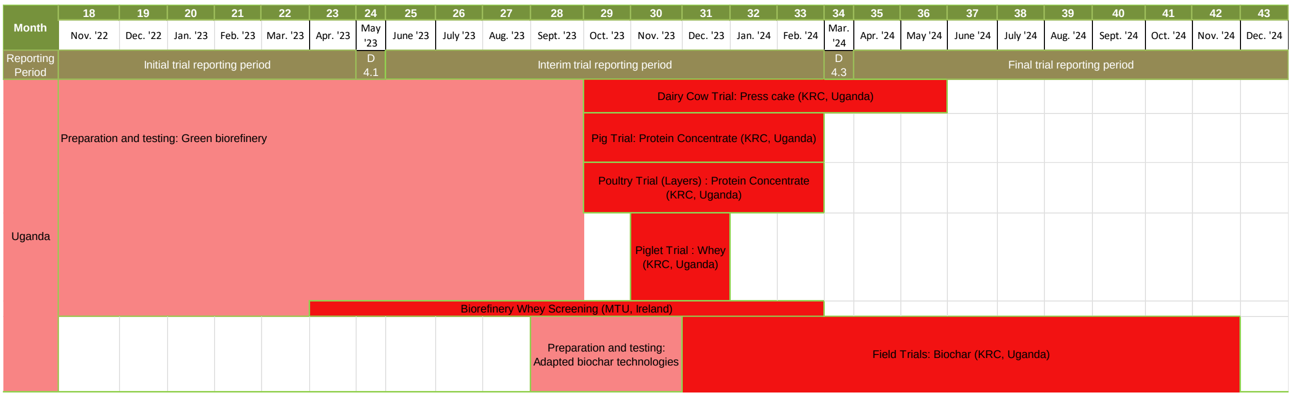
The initial version of the small- scale green biorefinery, as described in D2.3 Small- scale green biorefinery units- initial version has been established and is operational since May 2022. In months M13-M18, several optimisations have started, like improvements with washing of feedstock and recirculation of water, weighing, improved ventilation in the drying house. Parameters such as energy consumption per ton of leaves/ material processed, energy consumption per amount of products, mass balance of the biorefinery, quality of products (press cake, protein concentrate, whey) are monitored at a preliminary basis. 6 farmers are providing feedstock to the biorefinery, and 10 fieldworkers are (part-time) involved in harvesting feedstock. Four farmers, and the piggery of the nearby church are feeding biorefinery products to their animals, on a voluntary, non-commercial basis.

Regarding the development of the HTC technology, we are awaiting the finalization of the prototype under construction and validation in Senegal. When we ll get all the technical elements, we will transfer the plans to KRC in order to build the second reactor of the project. We hope to have the reactor built and validated by the end of 2023.

Concerning the dryer applied to dry the by-products from the biorefinery, we are planning, outside of the project, to couple a pyrolysis kiln with the bio-refinery equipment and to collect the energy-rich gaseous emissions. This activity should be first developed in Ghana before being transferred to Uganda.

Regarding densification, we finally favored the production of charcoal briquettes. The tool has been identified and tested by the KRC team. The supplier is Central Engineering Workshop which is already well known in the region for having developed and built similar equipment for other countries. The order is underway and will additionally include a pyrolyzer to produce the biochar.

4.1.7 GANTT chart on pilot and validation activities



Month	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
	Nov. '22	Dec. '22	Jan. '23	Feb. '23	Mar. '23	Apr. '23	May '23	June '23	July '23	Aug. '23	Sept. '23	Oct. '23	Nov. '23	Dec. '23	Jan. '24	Feb. '24	Mar. '24	Apr. '24	May '24	June '24	July '24	Aug. '24	Sept. '24	Oct. '24	Nov. '24	Dec. '24
Reporting Period	Initial trial reporting period						D 4.1	Interim trial reporting period									D 4.3	Final trial reporting period								
Uganda	Preparation and testing: Green biorefinery											Dairy Cow Trial: Press cake (KRC, Uganda)														
												Pig Trial: Protein Concentrate (KRC, Uganda)														
												Poultry Trial (Layers) : Protein Concentrate (KRC, Uganda)														
													Piglet Trial : Whey (KRC, Uganda)													
						Biorefinery Whey Screening (MTU, Ireland)																				
											Preparation and testing: Adapted biochar technologies			Field Trials: Biochar (KRC, Uganda)												

4.2 Pilot case in Ghana

4.2.1 Overall description and objectives

Livestock production is a major sector in agriculture in Sub-Sharan Africa (SSA) and very important in West Africa. It is an integral part of agricultural production system and predominantly practice by smallholder farmers in SSA. Livestock farming contributes significantly in the household's productivity pertaining to food security and income generation of the smallholder farmers in the sub-region. The most common economically viable livestock species in West Africa include; Cattle, sheep, Goats pigs and Poultry.

The productivity of these animals (cattle, sheep and goats) is constrained by numerous factors that are needed as inputs in their production. Among these factors, limited availability of feed is one of the most constraining factors, especially in the commercial level of producing animals. There is therefore a critical need for improving fodder/feed production and commercial processing of the available feed to improve its digestion efficiency and utilization in a sustainable manner. This will enhance farmers food security and income generation. To improve feed processing and utilization; BIO4Africa intend to process some forages into feed products and feed the animals and assess the performance of the animals fed with these products for scaling up the technology to enhance productivity. In intensive livestock production, as in the case of swine production, the cost feed range between 60% to 80 % of the entire production cost. Development of cheap and high-quality feed products from forage will lead to reduction in feed cost and cost of production in general.

The pilot case in Ghana will assess the potential of small-scale bio-based techs (green biorefinery, pyrolysis and densification) for meeting the livelihood and food security needs of a transhumance pastoralism livestock production system. A small-scale green biorefinery unit of around 600kg/hr of fresh leaves capacity will be installed to process local forage species and crop residues from legume crops to produce fibre/ protein grass press cake, protein concentrate and protein whey. The press cake will be tested as animal feed for dairy cows and bulls, the protein concentrate will be used as animal feed for piglets and will be used for the production for animal feed pellets for aquaculture. The protein whey will be used for piglets feed trials. Biorefinery side streams will be assessed/screened for their content and composition in high value components, with potential to be used in pharmaceutical and cosmetics applications.

A local pyrolysis technology and the Brazilian-kiln technology are included in Ghana pilots as well, in order to produce biochar from various crop residues (groundnut husk, rice husk, corn cobs, maize stalks). The biochar produced will be assessed for its use as soil amendment in Yagba region in tomatoes, okra and chili pepper crops.

A pelletizing line selected by SAVANET and RAGT will be implemented and operated locally. Biomass feedstocks along with protein concentrate resulting from the green biorefinery will be used for the production of animal feed pellets to be used as aquaculture feed from local communities that breed fish (Tilapia and cat fish).

4.2.2 Pilot sites

All equipment will be sited at the Experimental Station in Loagri in the North East Region of Ghana. The animal feed trial will take place in Sumburungu (Bolgatanga Technical University). The soil Amendment trial will be done in Sumburungu (Bolgatanga Technical University). The first fish feed trial will take place in Sogakopei.

4.2.3 Stakeholders to be involved

The local communities and farmers of Loagri in the North-East Region and the Savannah ecological belt of Ghana will take part in the pilot activities of BIO4AFRICA in Ghana, with the support of SAVANET and 0km.Nomads. The fibre rich press cake resulting from the biorefinery will be used as cattle feed with improved storage capacity and transport from local communities and nomads in Loagri. Protein concentrate and whey will be transported to pig farms by SAVANET and 0kmNOMADS to be used as animal feed substituting soya, whereas a quantity of the protein concentrate will be pelletized by SAVANET to be used as aquaculture feed from local communities that breed fish.

4.2.4 Local team

Name	Contact	Organization	Position	Responsibility	Location of activities
Ms. Selina Akologo	akologo@0kmnomads.org	0kmNomads.org	Project Manager	Biorefinery trials/ Management of livestock feed trials	Gbiligu, Ghana
Mr. Moses Nganwani Tia	gan_wani@hotmail.com	SAVANET	Country Director	Coordinator of B4A trials in Ghana	Gbiligu, Ghana
Dr. Solomon Konlan	kspigangsoa@yahoo.com	SAVANET	Lead researcher for animal feed trials	Livestock feed trials	Gbiligu, Ghana
Dr. Julius Yirzagla	Yirzagla2@yahoo.com	SAVANET	Lead researcher of soil	Soil amendment trials	Gbiligu, Ghana

			amendment trials		
Dr. Christian Ayisi Larbi	aclarbi@uesd.edu.gh	SAVANET	Lead researcher for fish feed trials	Fish feed trials	Gbiligu, Ghana
Prof. Elliot Haruna Alhassan	aelliot@uds.edu.gh	SAVANET	Researcher for fish feed trials	Fish feed trials	Gbiligu, Ghana

4.2.5 Trials

Technology	Estimated outputs	Monitoring parameters
Small scale green biorefinery	Press cake: Protein concentrate: Protein whey:	Protein capacity of the machine per tone of leaves, energy consumption per ton of leaves/ material processed, energy consumption per amount of products, protein efficiency of the coagulation, overall protein efficiency, mass balance of the biorefinery, quality of press cake (dry matter, ether extract, crude protein, water soluble carbohydrate, starch, neutral detergent fibre, acid detergent fibre, mineral content, fat, metabolizable energy), quality of protein concentrate (dry matter, crude protein, water soluble carbohydrates, starch, fibre, mineral content, total ash), whey (dry matter, crude protein, water soluble carbohydrates, starch, fibre, mineral content, total ash, pH, organic acids)
Local pyrolysis technology	Biochar:	**Biochar analysis**: Proximate analysis (fixed carbon, ash, volatile matter and moisture content), Biochar yield, pH. Cation Exchange Capacity, Anion Exchange Capacity, aromatic compounds, copper, iron, manganese, phosphorous, potassium, sodium, sulfur content, zinc, Scanning Electron Microscope, Specific Surface Area
Brazilian kiln technology	Biochar:	**Biochar analysis**: Proximate analysis (fixed carbon, ash, volatile matter and moisture content), Biochar yield, pH. Cation Exchange Capacity, Anion Exchange Capacity, aromatic compounds, copper, iron, manganese, phosphorous, potassium, sodium, sulfur content, zinc, Scanning Electron Microscope, Specific Surface Area) Yield, Bulk Density, pH, Electrical Conductivity, Cation Exchange Capacity, Anion Exchange Capacity, Ash Content, Volatile Matter,

		Carbon Content, Fixed Carbon, Oxygen, Hydrogen, Nitrogen (total and as %% of Carbon Content), Specific Surface Area, Aromatic Compounds, Mineral content: Copper, Iron, Manganese, Phosphorous, Potassium, Sodium, Sulphur, Zinc
Pelletizing line	Animal feed pellets	Protein concentrate yield, durability

4.2.6 Activities until M24

The design of the small-scale green bio-refinery for the Uganda pilot case is under development by GRASSA, using the experiences from its pilot implementation in Uganda, expected in M22. A refiner with higher capacity will be used for the Ghana pilot case, as the growing season in Ghana is quite short (Savannah climate), making it necessary to be able to produce more in shorter time period out of fresh green feedstock to be able to have enough feed products available for the feed trials in WP4.

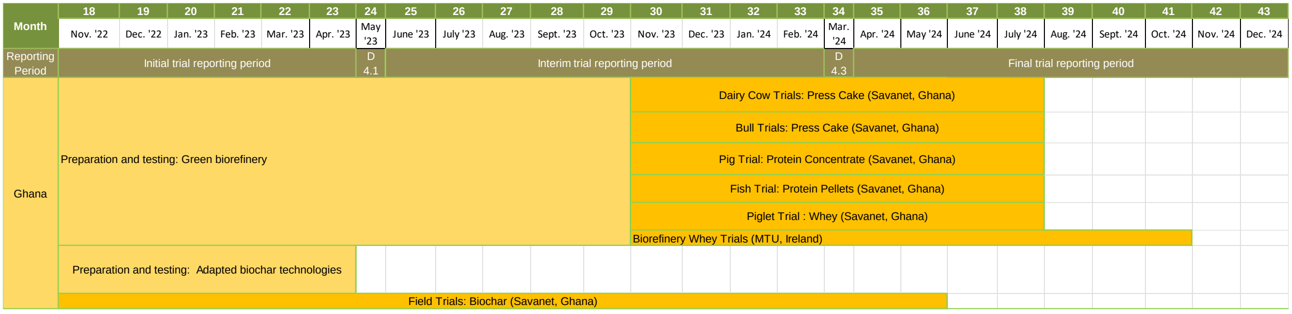
As per preparatory activities already conducted, SAVANET selected a suitable location for the biorefinery based on availability of power supply, water availability and distance for transferring the necessary feedstock. The pilot site where the Brazilian kiln pyrolysis technology will be established has been identified (SAVANET Agriculture Research Station in Gbiligu). Due to the raining season and the missing of roofed platform, we decided to delay the construction of the Brazilian kilns in September. During this time, a platform is under construction to accommodate all the equipment. SAVANET engaged additional construction workers to speed up the construction work. This should be operational in June 2023. An extension of electricity for supplying the Research Station was necessary. Hence an engagement with the Electricity service company (VRA) has been done to provide SAVANET with emergency electricity service.

In this time period before the Brazilian kiln pyrolysis technology implementation, (expected according to the timeplan described in Task 3.1 of the current report), SAVANET has been engaged in experimental production of biochar with a locally developed pyrolysis technology. Small quantities of biochar from sawdust and rice husks are being produced and used as soil amendment in preliminary greenhouse trials. Due to the small production capacity, several days were required to obtain enough biomass to perform field tests. To face the lack of irrigation system at the Research station in Loagri for Biochar soil amendment field trials in the dry season SAVANET decide to increase the number of days for biochar production and to develop an irrigation system at the SAVANET Research Station in Loagri for trials in the dry season.

2 local farmers are providing the necessary feedstocks for the biochar preliminary tests that are currently being conducted and 4 farmers take part in field activities with this biochar.

A pelletization line has been acquired for the production of pellets for fish feed trials, as described in Task 3.1. The pelletization mill is: cost efficient, adaptable to the local conditions in which the trials will be conducted, easy to operate, repair and maintain. The equipment can also be operated using various feedstock/biomass, efficient power (electricity) requirement, and can produce wide range of pellets (1-12mm). Other auxiliary equipment and infrastructure for the fish feed trials has also been acquired.

4.2.7 GANTT chart on pilot and validation activities



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Reporting Period	Initial trial reporting period						D 4.1	Interim trial reporting period									D 4.3	Final trial reporting period								
Ghana	Preparation and testing: Green biorefinery												Dairy Cow Trials: Press Cake (Savanet, Ghana)													
													Bull Trials: Press Cake (Savanet, Ghana)													
													Pig Trial: Protein Concentrate (Savanet, Ghana)													
													Fish Trial: Protein Pellets (Savanet, Ghana)													
													Piglet Trial : Whey (Savanet, Ghana)													
													Biorefinery Whey Trials (MTU, Ireland)													
	Preparation and testing: Adapted biochar technologies																									
	Field Trials: Biochar (Savanet, Ghana)																									

4.3 Pilot case in Côte d'Ivoire

4.3.1 Overall description and objectives

This Côte d'Ivoire pilot case will focus on women farmers and livestock producers, as they hold the present and future of agricultural transformation in the region. Traditional (rustic ovens) and the Brazilian kilns pyrolysis technology will be piloted in forest and savannah regions of the country, utilising the most abundant local food crops waste types. Biochar produced will be tested for its use as pollutants adsorbent in prototype water filtration units developed by INP-HB and as soil amendment in greenhouse and field trials. The production of bioplastics and biocomposites for packaging industry and for construction industry will also be explored. Last but not least, biomass pellets from local feedstocks will be produced by a local pelletizing technology in INP-HB and a commercial size pelletizing technology to be tested as animal feed for sheep and rabbits.

4.3.2 Pilot sites

- Local pyrolysis technology: INP-HB
- Brazilian kilns pyrolysis technology: INP-HB
- Local pelletizing technology: INP-HB
- Pelletizing technology (new equipments to purchase) : INP-HB
- Water filtration experiments: DJAHAKRO (closed to Yamoussoukro)
- Soil and plant experiments: INP-HB (greenhouse) and ZATTA, LOGBAKRO and SEMAN (Closed to Yamoussoukro : less than 20 km) (Field trials).
- Biocomposites experiments: INP-HB
- Bioplastics experiments: INP-HB
- Animal feed trials : INP-HB (the experimental farm of the Department of Agriculture and Production Farm of the Institute).

4.3.3 Stakeholders to be involved

The biomass feedstocks to be used in BIO4AFRICA pilot activities in Côte d'Ivoire will be provided by eight agricultural women cooperative groups. Farmers from three regions with different geographical and agro-climatic characteristics will use biochar produced by the pilot case at their fields, from which field experiments will be executed, to assess the potential of biochar as soil amendment. The selected pilot farmers will actively participate in other activities of the project (e.g. raising awareness campaigns of Task 6.1) in order to facilitate the adoption of the technologies. The adaptation of the technologies to the specific needs of the women cooperatives, training and knowledge transfer activities and monitoring of the pilot operation will be conducted by INP-HB. Students, PhD candidates and other pilot support personnel will be hosted in the participating villages by the traditional chiefdom, who will be responsible for the security of the testing sites. The water filtration units developed by INP-HB to test the biochar potential as water pollutants adsorbent will be installed in two villages in rural areas with no existing water purification system.

4.3.4 Local team

Name	Contact	Organization	Position	Responsibility	Location of activities
Mr. Fanou Guy Didier	guyfanou@inphb.ci	INP-HB	Assistant professor	Biochar production; biochar use for drinking water filtration	Yamoussoukro
Mr. Yao Kouassi Benjamin	benjamin.yao@inphb.ci	INP-HB	Professor	Coordinator of B4A trials in Côte d'Ivoire	Yamoussoukro
Mr. Kouakou N'goran David Vincent	david.kouakou@inphb.ci	INP-HB	Lecturer	Production of animal feed pellets; animal feed trials	Yamoussoukro
Mr. Yapi Yapo Magloire	magloire.yapi@inphb.ci	INP-HB	Lecturer	Production of animal feed pellets; animal feed trials	Yamoussoukro
Mr. Kouadio Kouakou Serge	serge1.kouakou@inphb.ci	INP-HB	PhD student	Animal feed trials	Yamoussoukro

4.3.5 Trials

Technology	Estimated outputs	Monitoring parameters
Local pyrolysis technology	Biochar for soil amendment	-Biochar yield -Biochar characterization: specific area, porosity, turbidity, Proximate analysis (fixed carbon, ash, volatile matter)
Brazilian kilns technology	-Biochar for soil amendment -Biochar for filtration	- Pyrolysis conditions (temperature, duration, type of biomass) - Biomass characterization: particle size, moisture content, proximate analysis - Biochar yield - Biochar characterization: specific area, porosity, turbidity, Proximate analysis (fixed carbon, ash, volatile matter)

Water filtration unit	Filtrated Water	Water potability tests: Bacteriological analysis of water (E.Coli, streptococci, GAM), physicochemical characterization (copper, lead, turbidity, SM)
Local pelletizing line	Biomass pellets for animal feed	Nutritional and physical quality of pellets
Commercial type pelletizing line	Biomass pellets for animal feed	Nutritional and physical quality of pellets

4.3.6 Activities until M24

While waiting for the Brazilian kiln pyrolysis technology implementation, according to the time plan described in Task 3.1 of the current report, INP-HB has constructed a traditional pyrolysis furnace to produce biochar in experimental quantities. Currently greenhouse tests with different doses of biochar as soil amendment are ongoing on tomato and maize grown in three different types of soils collected, representing three agricultural regions in Côte d'Ivoire. For this purpose, different agro-morphological parameters of the plants are being collected, to be statistically under WP4 activities. The results will be transferred to the farmers in the different geographical (agro-climatic) zones where these soils were collected to confirm and scale them up in real life.
Biochar as a medium for drinking water filtration
Regarding testing the potential of biochar as a water filtration media, biochar produced by the abovementioned traditional pyrolysis furnace has been used at a water filtration device that has been constructed for this purpose. Trials are currently in progress to calibrate the device. After obtaining biochar, we carried out tests on the evolution of the physicochemical parameters in the biochar washing water.
To complete this activity, a PhD student from Côte d'Ivoire arrived at CIRAD in Montpellier in September. He will work for 3 years on the production of activated carbons with biomasses selected by INP-HB. The student is supervised by Patrick Rousset WP3 leader and Jean Michel Commandré. Every month, technical meetings are held with Capucine Dupont from IHE (leader of WP2). The student has identified the pollutants that will be studied and the sites in Côte d'Ivoire where the activated charcoals produced will be tested.

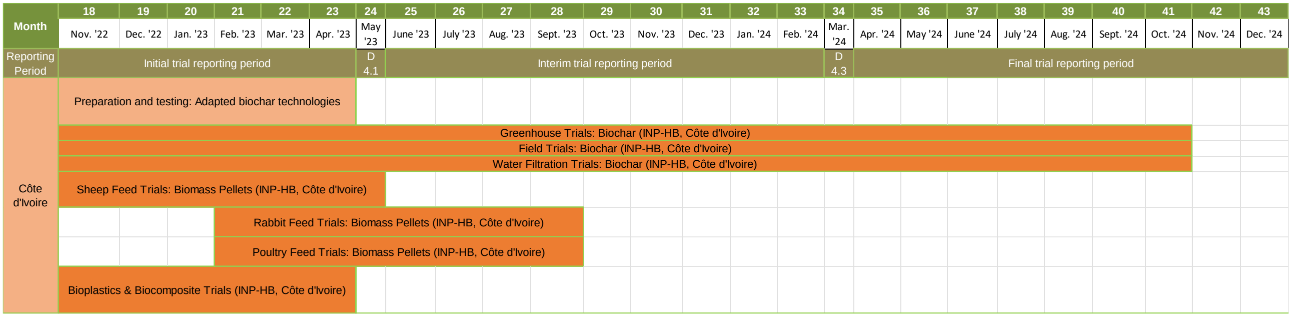
As far as bioplastics production is concerned, tests with cashew apple juice-molasses mixtures of varying composition have been conducted. The results obtained show that the presence of molasses seems to inhibit the growth of microorganisms and consequently the production of bioplastics. Tests are underway to understand the reasons for this observation. Regarding bio-composite production, two local plant fibres have been collected (coconut and palm branches). These plant fibres were chosen because they are available, undervalued and constitute agricultural waste. The lignocellulosic characterization of the different fibers local plants has been carried out. The results obtained showed that these plant fibers presented high contents of cellulose (greater than 50%) and relatively low contents of hemicellulose and lignin. These results make these fibers good candidates for the production of biocomposites. To complete this activity, a Lebanese doctoral student arrived at CIRAD in Montpellier in July. She will work for 3 years studying the production of bioplastic and biocomposite selected by the INP-HB and University of Ziguinchor.

As far as tests with densification technologies are concerned, apart from the pelletization line to be transferred and tested as described in Task 3.1 of the current report, preliminary tests with pellets produced by local tanning plants for sheep feeding have been conducted, using a local pelletization line available at INP-HB
The acquisition of a more efficient pelletizer should allow the production of pellets in large quantities for the breeders, during the real condition implementation phase. Discussions are underway between RAGT, CIRAD,

INP-HB and a supplier of densification equipment to clarify what the real needs of the INP-HB are. It seems that we are moving towards equipment with a lower production capacity.

20 women farmers are providing cassava peel and 10 women farmers are providing coconut fibres for tests regarding biocomposite production in Côte d'Ivoire. 18 farmers take part in animal feed testing activities.

4.3.7 GANTT chart on pilot and validation activities



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Reporting Period	Initial trial reporting period						D 4.1	Interim trial reporting period									D 4.3	Final trial reporting period								
Côte d'Ivoire	Preparation and testing: Adapted biochar technologies																									
	Greenhouse Trials: Biochar (INP-HB, Côte d'Ivoire)																									
	Field Trials: Biochar (INP-HB, Côte d'Ivoire)																									
	Water Filtration Trials: Biochar (INP-HB, Côte d'Ivoire)																									
	Sheep Feed Trials: Biomass Pellets (INP-HB, Côte d'Ivoire)																									
				Rabbit Feed Trials: Biomass Pellets (INP-HB, Côte d'Ivoire)																						
				Poultry Feed Trials: Biomass Pellets (INP-HB, Côte d'Ivoire)																						
	Bioplastics & Biocomposite Trials (INP-HB, Côte d'Ivoire)																									

4.4 Pilot case in Senegal

4.4.1 Overall description and objectives

The pilot case in Senegal will first of all assess the potential of HTC and pyrolysis techs for biochar applications. Three applications of biochar will be tested in the Senegal pilot case: solid fuel (cooking fuel), additive in anaerobic digestion systems (both as feedstock and a filter for H_2S) and soil amendment. In terms of pyrolysis techs to be tested, a local pyrolysis technology and another local African pyrolysis technology to be transferred (under confirmation) will be piloted. The pyrolysis technologies will be complemented by a pilot scale briquetting technology, for biochar briquettes and raw biomass briquettes to be tested for their potential as solid fuels. Other activities will concern on the biocomposite production tech developed by UASZ in cooperation with CIRAD, by assembling components, of different natures or not, making it possible to obtain mechanical, thermal and environmental performance superior to that of the components taken separately. These tests will focus on optimizing the production process considering the pre-treatment of feedstocks, the properties and performances of biocomposites, and the environmental and economic implications of production.

ASAPID and SCPL will be responsible for making available the quantities and logistics of feedstocks necessary for the smooth operation of the pilots in the testing sites. SCPL will also be responsible for the testing of biochar as solid fuel, and use as cooking fuel in improved cookstoves ("Jambar" stoves) and domestic cookers.

4.4.2 Pilot sites

- HTC: Ziguinchor (UASZ)
- Local pyrolysis technology: Koudioube, Ziguinchor (UASZ)
- Local African pyrolysis technology (still under confirmation): Ziguinchor (UASZ)
- Pilot scale briquetting technology: Diouloulou (ASAPID)
- Biogas experiments: Ziguinchor (UASZ)
- Soil and plant experiments: Ziguinchor (UASZ)
- Solid fuel experiments: Ziguinchor (UASZ)
- Feedstocks collection: Djiibonker

4.4.3 Stakeholders to be involved

Local farmers will provide the pilot sites with the feedstocks involved in the activities (millet stalks, peanut shells, rice husks) (villages in the surrounding area of Djibonker and Ziguinchor). Women from domestic population (of approximately nine villages in the areas of Ziguinchor and Diouloulou) will be provided with produced biochar and biomass briquettes to be tested as cooking fuel, from UASZ and ASAPID. The total number of local population in Diouloulou area to be involved in pilot activities of BIO4AFRICA is estimated to 500 people. The same number for the area of Djibonker and Ziguinchor accounts for around 450 people.

4.4.4 Local team

Name	Contact	Organization	Position	Responsibility	Location of activities
Prof. Lat Grand Ndiaye	lgndiaye@univ-zig.sn	UASZ	Lecturer	Coordinator of B4A trials in Senegal	Ziguinchor Diouloulou
Prof. Diouma Kobor	dkobor@univ-zig.sn	UASZ	Lecturer	Co-leader of B4A trials in Senegal	Ziguinchor Diouloulou
Mr. Philippe Bernard Himbane	p.b.himbane88@gmail.com	UASZ	Contractor	Biochar use for fuel and soil amendment trials, biomass briquettes for fuel	Ziguinchor Diouloulou
Mr. Georges Ambouor Diedhiou	g.diedhiou20140441@univ-zig.sn	UASZ	PhD student	Biochar use for fuel and soil amendment trials	Ziguinchor Diouloulou
Mr. Mamadou Seydou Ba	mamadouseydouba@gmail.com	UASZ	Contractor	Biochar use for fuel and soil amendment trials	Ziguinchor Diouloulou
Mr. Omar Kata Faye	Katafaye86@gmail.com	UASZ	PhD student	Biochar use for biogas systems trials	Ziguinchor Diouloulou
Mr. Paul Abib Sagna	asapidiouloulou@gmail.com	ASAPID	Partner	Biochar production (local and Brazilian kiln technologies) Biomass briquettes production	Ziguinchor
Mr. Elimane Drame	elybee70@hotmail.com	SCPL	Partner	Biochar production (local and Brazilian kiln technologies) Biomass briquettes use as cooking fuel	Ziguinchor
Mr. Abel Sagna	abel.ozomax@gmail.com	COUNTRY FARM	Partner	Biomass briquettes use as cooking fuel	Ziguinchor

4.4.5 Trials

Technology	Estimated outputs	Monitoring parameters
Local pyrolysis technology	Biochar for soil amendment Biochar and hydrochar as catalyst for biofermenter Biochar for fuel	**Operating parameters:** flow, temperature, the heating rate, residence time of the biomass in the oven **Biochar:** physicochemical characterization (total carbon, ash content, moisture content, lower heating value, total nitrogen, dry matter, organic matter)
Local African pyrolysis technology		
HTC	Hydrochar (biochar)	**Operating parameters:** flow, temperature, the heating rate, residence time of the biomass in the oven **Hydrochar:** physicochemical characterization (total carbon, ash content, moisture content, lower heating value, total nitrogen, dry matter, organic matter) Hydrochar:
Pilot scale briquetting technology	Biochar briquettes	**Solid fuel tests:** proximate analysis, lower heating value, bulk density, ease of ignition, moisture adsorption, impact resistance, compressive strength, emissions during combustion, CO2, CO, PM2,5

4.4.6 Activities until M24

Pilot sites for all technologies to be tested in Senegal have been selected and preparations and communication have been made about the supply and logistics of feedstocks necessary for the smooth operation of the pilots in the testing sites.

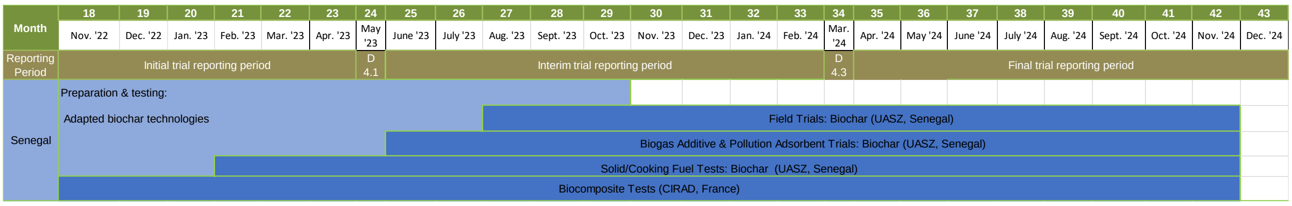
Technoeconomic enquiries are being made on the most suitable briquetting technology to be transferred for the Senegalese pilot case and adapted for the local context. Economic offers have been collected on the biogas reactor to be acquired and used for the tests of biochar as an additive in biogas production systems.

Regarding the production of biochar, the Brazilian technology was not retained by the University of Zinguinchor unlike the INP-HB and SAVANET. This decision was taken in January 2023 which delayed this task for this case study. UASZ has identified another technology (described above) developed in Cameroon. Several meetings between CIRAD, UASZ and the Cameroonian company Kemit Ecology have been held to assess the relevance of such technology. To date, the decision has not been taken because technical information is necessary. We are also planning a site visit to assess the production capacity of this tool and especially its potential to be disseminated to local communities in the region.

Regarding the HTC pilot, all the steps necessary for its construction have been carried out despite some delays due to manufacturing errors. At present, the teams in charge of its construction should complete the reactor in July 2023. We recall that all the experience acquired for the construction of this laboratory equipment will be useful to build similar equipment in Uganda. Preliminary laboratory tests are underway for the proper preparation of the HTC pilot activities in the country.

Densification trials will be limited to the production of biochar briquettes. Briquettes made from biomass are no longer the priority. The densification equipment was identified and tested by the university team. It would seem that this equipment corresponds to the requirements of the project. The supplier is the kappal company. The order has been made and the tool should be installed on the university premises during the summer of 2023.

4.4.7 GANTT chart on pilot and validation activities



<table>
<tr><td rowspan="2">Month</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td></tr>
<tr><td>Nov. '22</td><td>Dec. '22</td><td>Jan. '23</td><td>Feb. '23</td><td>Mar. '23</td><td>Apr. '23</td><td>May '23</td><td>June '23</td><td>July '23</td><td>Aug. '23</td><td>Sept. '23</td><td>Oct. '23</td><td>Nov. '23</td><td>Dec. '23</td><td>Jan. '24</td><td>Feb. '24</td><td>Mar. '24</td><td>Apr. '24</td><td>May '24</td><td>June '24</td><td>July '24</td><td>Aug. '24</td><td>Sept. '24</td><td>Oct. '24</td><td>Nov. '24</td><td>Dec. '24</td></tr>
<tr><td>Reporting Period</td><td colspan="6">Initial trial reporting period</td><td>D 4.1</td><td colspan="9">Interim trial reporting period</td><td>D 4.3</td><td colspan="9">Final trial reporting period</td></tr>
<tr><td rowspan="5">Senegal</td><td colspan="12">Preparation & testing:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Adapted biochar technologies</td><td colspan="16">Field Trials: Biochar (UASZ, Senegal)</td><td></td></tr>
<tr><td colspan="7"></td><td colspan="18">Biogas Additive & Pollution Adsorbent Trials: Biochar (UASZ, Senegal)</td><td></td></tr>
<tr><td colspan="3"></td><td colspan="22">Solid/Cooking Fuel Tests: Biochar (UASZ, Senegal)</td><td></td></tr>
<tr><td colspan="25">Biocomposite Tests (CIRAD, France)</td><td></td></tr>
</table>

5. Activities common for all pilot cases

Monitoring of activities of the pilot cases in BIO4AFRICA project is conducted through the following means:

a) Monthly joint WP3/WP4 meetings,
b) Monthly reporting, using the BIO4AFRICA Pilots Monthly Monitoring Template (ANNEX 1). Responsible partners for preparing the monthly report to be sent to WP3 leader are: KRC (Uganda), SAVANET (Ghana), INP-HB (Côte d'Ivoire) and UASZ (Senegal).
c) GANTT charts that are kept in Teams shared folder of the project and reviewed in each monthly joint meeting.

6. KPIs monitoring and assessment

In the following table, the project KPIs related to pilot activities are presented, along with respective target values, monitoring methodology to be followed, any related hypotheses/ baselines to be taken into account and partners to be involved. Updates on the current status towards reaching each KPI will be included in in **D3.3 Report on BIO4AFRICA pilot cases- interim version (M34)** and in **D3.4 Report on BIO4AFRICA pilot cases- final version** (M42).

	KPI	Target Value	Comments	Monitoring methodology	Hypothesis/ Baseline	What do we need from partners	Notes
KPI-5.	Increase in the exploitation of diverse side and waste streams, e.g. of Cashew shell, Cassava Shell, Coconut fiber	> 50% Increase in exploitation of side and waste streams of target biomass	Target biomasses such as Cashew shell, Cassava Shell and Coconut fiber are not used enough (animal feed, compost, energy source).	Results of a survey of producers to identify the types of use of these biomasses, quantities collected, quantities used & projected biomass uses, and quantities collected and used under pilot use scenarios	**Hypothesis** :Processing will allow for more efficient and increased use of these biomasses. **Baseline** : Use of these biomasses in their raw state without any transformation/existing biomass uses	Pilot partners: all feedstocks to be used ,survey of producers	
KPI-9.	Improvement in grass protein efficiency	40% per hectare, improved efficiency of grass protein (access, valorisation and utilization)		Determined via results of biorefinery performance (e.g. how much protein can be extracted from grass - a target is around 40%), and the performance of the different protein feeds in ruminant and monogastric trials (i.e. does presscake and protein concentrate provide a direct replacement compared to the control feeds) (JG-MTU)	Baseline scenario is a control scenario which assumes the the control feed is fed direct to ruminats (in fresh or silage form) without having undergone refining (this may need to be adapted for novel feedstocks) (JG - MTU)	GRASSA, KRC & Savanet - biorefinery performance, KRC & Savanet - performance of protein feeeds vs control feeds	Ghana, Uganda
KPI-10.	Decrease in N (NH3, N2O, NO3) and P emissions	25% decreasing emissions from animal excrements	CO2 & CH4 emissions added as an additional, separate KPI (26) (to cover pyrolysis tech etc too)	Analysis of faecal and urine samples resulting from trial and control feed diets to assess the presence of N and P within these samples (JG- MTU)	Direct comparison between animals on trial and control diets. Hypothesis is that biorefining can allow N and P content of feedstocks to be used more efficiently within the animals, with reduced losses (JG – MTU)	KRC & Savanet -analysis of faecal and urine samples of control and trial animals to assess N & P levels	Ghana, Uganda
KPI-11.	Reduction of logging in pilot sites	0.3	Is this to be applicable to UASZ and CIRAD only or all countries using HTC/pyrolysis? Baseline - assess how much wood needed for cooking at present + therefore how much deforestation necessary for that purpose, monitoring: how much wood needed for same amount of cooking with biochar, extrapolate to assess level of deforestation necessary with biochar - could be analysed in lab?	Efficiency of Brazilian pyrolysis kilns/HTC compared to traditional technology: amount of charcoal (PR - CIRAD - if all partners); how much wood needed for same amount of cooking with biochar, extrapolate to assess level of deforestation necessary with biochar	Mass yield of Brazilian kiln/HTCand traditional technology using woody biomass instead of agriculture residues (PR - CIRAD); assess how much wood needed for cooking at present + therefore how much deforestation necessary for that purpose	UASZ, CIRAD	Senegal
KPI-12.	Fuel needs for cooking/heating covered by biochar in pilot households	> 50%	HHV = High Heating Value	HHV of biochar produced comparing with current fuels used (PR – CIRAD)	HHV of wood (PR – CIRAD)	UASZ - current fuels used, CIRAD - HHV of biochar and current fuels used in Senegal?	Senegal
KPI-13.	Nutrient recycling achieved in pilot sites. Amélioration de la qualité de l'eau de surface habituellement consommée par la population rurale	> 80% re-introducing unused nutrients to the cycle as fertiliser and/or soil amendment. >90% de la population dispose d'eau potable. Réduction du taux de fréquentation du centre de santé.	Time period too short to realistically compare soil fertility influence of biochar amendment vs. existing soil amendment practices; could look at nutrient retention/availability/ other nutrient cycle parameters in range of soils, including poor soils as biochar has greater impact in poor soil conditions? One way that biochar influences soil fertility is through pH - is this something that can contribute to comparing nutrient retention capacity wit biochar amendments vs other amendments?	Suggestions 1)Amount of biochar substituting classical soil amendment according to soil texture; 2) % of C, N, P and K analysis from biochar & slurry recycled at pilot sites. 3) Physicochemical and microbiological analysis of the water according to the WHO standard.	**Suggestion 1: Hypothesis** : Soil amendment with biochar will improve aeration, fertility and biological activity of soil. Baseline : current practice for soil amendment based on the use of raw organic matter Suggestion 2: Hypothesis : Rural populations usually feed on water from often polluted rivers. Baseline: 80% of the population relies on non-potable water.; Suggestion 3: Hypothesis : biochar and slurry nutrient composition = %C, %N, %P, %%K - with value addition increased incorporation of nutrients beomes more attractive/feasible - need to know current soil management practices re. fertility **Baseline** : current practice for soil amendment/fertilisation based on the use of raw organic matter.	GRASSA, INP-HB, UASZ, KRC, SAVANET, CIRAD	Senegal, Cote D' Ivoire, Ghana, Uganda
KPI-26	Decrease in CO2 and Methane emissions	25% decreasing emissions from animal excrements	Pyrolysis releases very little CO2 and therefore the transformation of these biomasses by pyrolysis will generate very little	Analysis of gases emitted in the animal enclosure using gas analysers (CO2 and CH4) resulting from trial and	Direct comparison between animals on trial and control diets. Hypothesis is that feedstocks transformation by pyrolysis can allow CO2 and CH4	GRASSA, INP-HB, CIRAD, MTU	Ghana, Uganda, Cote D' Ivoire

7. CONCLUSION AND WAY FORWARD

The current report constitutes the initial report on BIO4AFRICA pilot cases (D3.2), presenting activities and progress until M24 and also including updated information of **Testing, Monitoring and Assessment Plan (TMAP)** of BIO4AFRICA project, originally presented in D3.1. To this end, the report provides meaningful details with respect to the pilots and their implementation, including information about the technologies to be piloted (flow diagrams, description, photos, operational considerations and feedstocks to be tested), about the 4 project pilot cases (description and objectives, pilot sites, stakeholders to be involved, local team, trials, activities and achievements, GANTT chart on pilot and validation activities), about the monitoring activities common for all pilot cases and about the monitoring and assessment of KPIs. Updates of information presented here will be submitted in **D3.3 Report on BIO4AFRICA pilot cases- interim version (M34)** and in **D3.4 Report on BIO4AFRICA pilot cases- final version (M42).**

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ANNEX 1- BIO4AFRICA Pilots Monthly Monitoring Template

a) Uganda

Experiment	Operation days	Description of activities	Is progress below timeplan?	Challenges identified	Type of challenge	Recommended action
Green biorefinery testing						
Dairy cow trial: press cake						
Pig trial: protein concentrate						
Poultry trial: protein concentrate						
Piglet trial: whey						
Biorefinery whey screening						
HTC testing						
Pyrolysis testing						
Briquetting testing						
Biochar field trials						
Biochar solid fuel trials						

b) Ghana

Experiment	Operation days	Description of activities	Is progress below timeplan?	Challenges identified	Type of challenge	Recommended action
Green biorefinery testing						
Local pyrolysis testing						
Brazilian kilns pyrolysis testing						
Pelletizing technology testing						
Dairy cow trials: press cake						
Bull trials: press cake						
Pig trial: protein concentrate						
Fish trial: protein pellets						
Piglet trial: whey						

c) Côte d’Ivoire

Experiment	Operation days	Description of activities	Is progress below timeplan?	Challenges identified	Type of challenge	Recommended action
Local pyrolysis testing						
Brazilian kilns pyrolysis testing						
Local pelletizing technology						
Pilot pelletizing technology						
Greenhouse trials: biochar						
Field trials: biochar						
Water filtration trials: biochar						
Sheep feed trials: biomass pellets						
Rabbit feed trials: biomass pellets						
Poultry feed trials: biomass pellets						
Bioplastics and biocomposites tests						

d) Senegal

Experiment	Operation days	Description of activities	Is progress below timeplan?	Challenges identified	Type of challenge	Recommended action
Local pyrolysis testing						
Pilot pyrolysis testing						
HTC testing						
Briquetting testing						
Biocomposites tests						
Field trials: biochar						
Biogas additive and pollution adsorbent trials: biochar						
Solid/ cooking fuel tests: biochar						