GA no. 312111

Biowaste4SP
Turning Biowaste into Sustainable Products:
Development of appropriate Conversion Technologies
Applicable in Developing Countries

Project Final Report – Publishable summary

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1 Executive summary

In this project, we have focused on finding the shortest and most efficient (simplest) way of converting African biowaste (in this context from food waste and waste from agriculture) into value added products. A key focus was on pinpointing and using the right technology for the most significant raw materials identified in each of the participating five African countries - Ghana, Egypt, Kenya, Morocco, and South Africa - for the production of bioethanol, biogas, biofertilizer, lactic acid, protein and amino acids.

The project was based on the premises that:

1. The biowaste contents of carbohydrates, both starchy and lignocellulosic based were considered and evaluated as potential fermentation substrates for bioenergy carriers, chemicals, food/feed ingredient (e.g. amino acids, and protein) and compost.
2. The biowaste ash content was considered as a potential source for plant nutrients that could be used in fertilizers.
3. Proteins can be produced from biowaste sources.
4. Biowaste proteins were seen as a potential source for amino acids and proteins to be used in new food and feed applications.

These mentioned products can substitute fossil-based chemicals and energy products and turn a waste problem (biowaste) onto a wide range of valuable products, thereby reducing Greenhouse gas emission with benefit to the climate.

Emphasis was placed on biowaste streams that are produced in significant quantities in the participating five African countries.

The key results of the project were:

- Sugar based and nutrient based biowaste streams have been identified and characterized in selected African countries: Morocco, Egypt, South Africa, Kenya and Ghana.
- A feedstock catalogue based on actual analysis data has been prepared and made public.
- Sources of nutrient element based biowaste were identified and characterized; cotton straw and sugar cane bagasse were used for demonstration and proof of concept in the participating African countries in Egypt South Africa.

- Biofertilizers (microbes for assimilation of nitrogen and release of phosphorus as well as mycoriza fungi) were produced from sugar fermentation and supplied to the compost.
- Pre-treatment processes for an efficient conversion of biowaste feedstock into fermentable substrates and their upgrade into polysaccharide fractions (sugar platform) have been tested and evaluated.
- Bio-conversion methods for converting pretreated sugar solutions from biowaste into ethanol, lactic and amino acids have been developed.
- DDGS (Dried Distillers Grains with Solubles), i.e. protein fraction from ethanol and lactic acid production) have been recovered.
- Methods for down streaming and recovery of oligo- and polysaccharide fractions have been developed and optimized.
- Unconverted waste streams have been converted to biogas and lignin based biofertilizer.
- The sustainability and economic viability of the whole process chain of producing biobased energy carriers, chemical amino acids, proteins, and fertilizer from biowaste have been evaluated.
- Project results have been disseminate to industry and stakeholders in Africa, Asia and Europe at different international conferences and at the final project conference organized by theBiowaste4SP consortium and held in Morocco in September 2015.

2 Context and main objectives

The modern global society faces great challenges in supply of energy, feed, food, and other products in a sustainable way. One way to mitigate the negative effects of providing these local eco-services is to convert biomass – instead of petroleum or natural gas – into a variety of food, feed, biomaterials, energy and fertilizer, maximizing the value of the biomass and minimising the waste. This integrated approach corresponds to the biorefinery concept and is gaining attention in many parts of the world. Similar to oil-based refineries, where many energy and chemical products are produced from crude oil, biorefineries can produce many different industrial products from biomass. Energy, food and feed production is the driver for development in this area. However, as biorefineries become more and more sophisticated with time other products can be developed. Today, almost all organic chemicals, including fertilizers, are produced from crude oil, petroleum, and technologies driven by fossil energy, thus referred to as petro-chemicals and fossil fertilizer. It is generally anticipated that the white biotechnology, the use of fermentation and enzymatic processes, will play a key role for future cleaner production of bulk chemicals, energy carriers as well as fertilizer from biomass sources by saving resources and reducing negative environmental impacts from chemical production.

In order to replace fossil-based energy carriers, chemicals and fertilizer, cost is the critical challenge for success. Thus, easily accessible and low cost biomass feedstock is a prerequisite for making biobased production economically feasible. Industrial, agriculture and municipal biowastes have the potential to be that resource. However, it is of great importance to be aware of how to utilise the different sources of biowaste and for which purpose. In order to do this in the best possible way, one has to know about chemical composition.

Specifically, these include the biowaste content of:

1) Carbohydrates that can serve as potential fermentation substrates for bioenergy carriers, chemicals, and food/feed ingredient (e.g. amino acids). Both starchy and lignocellulosic based feedstock types should be considered.
2) Inorganic ashes that could serve as potential plant nutrients as in fertilizer.
3) Proteins, which are important ingredients in food and feed applications as well as fertilizer.

With these considerations in mind, the objective of the Biowaste4SP is to show and demonstrate the technical roadmap - a strategy - for efficient technological utilisation of selected significant biowaste in five African countries - Morocco, Egypt, Ghana, South Africa, and Kenya- derived from both the industrial and agricultural sector, thus, turning biowaste into a new resource for sustainable products.

As the world resources of oil are diminishing, the amounts of industrial and municipal waste are increasing, causing environmental problems and costs for its disposal. Typically, this is a problem for the industrialised world, but it is also an increasing problem in the developing countries. A large part of these municipal and industrial waste streams contain biodegradable components of sugar polymers, being mixtures of both starch and lignocellulose, proteins and fats, a so called biowaste, which, when disposed of in landfills will degrade to greenhouse gases. Landfilling of biowaste is reported to be one of the major sources of methane emissions in Europe, contributing to 2% of GHG emissions in 2007 in the European Union (EU). Moreover, according to the EC Landfill directive (1999/31/EC), the amount of landfilled biodegradable waste should be reduced with 35% (of 1995 levels) in 2016. As a result, a lot of attention is paid on the treatment of biowaste, addressing cost-efficient handling and their direct utilization, and possible reduced output of polluting products regarding both CO_2 emission and heavy metals. Consequently, by utilizing the biowaste as regional feedstock for production of value-added products such as energy carriers, biobased chemicals, and if possible food, feed and fertilizer, several problems could be solved achieving both environmental and economic benefits.

The use of white biotechnology on plant based biomass has so far focused mainly on the production of biofuel energy-carriers such as bioethanol, biodiesel and biogas, and the concept of converting starch materials from food and feed production into ethanol is a proven technology and in industrial phase many places in the world. The technology for conversion of lignocellulosic biomass materials such as wood residues and agricultural waste as substrates for ethanol production is already in demo-phase and next generations technologies are developing around the world for upgrading such ethanol plants into more sophisticated biorefineries with production of chemicals and other biomaterials. One such plant is placed in France with a significant production of lactic acid from starch. Processes focusing on conversion of municipal and industrial biowaste into ethanol have also been investigated and are foreseen to be of great importance for future management of waste to value. Compared to using only agricultural residues as feedstock, municipal or industrial biowaste have the advantage of their abundance and the availability is rarely affected by seasonal changes and the collection systems are already well established in most places. However, biowaste has typically a diverse and complex composition, and even if a general process is known, each new biowaste material needs to be adapted in terms of optimizing the chain from hydrolyzing the biowaste material (starch, cellulose and hemicelluloses) into simple sugars (pre-processing), bio-converting and fermenting the sugar (up-stream processing), and separating and purifying the products (downstream processing).

The Biowaste4SP project has focused on the development and demonstration of a concept to use mixed biomass feedstock, rich in starch and lignocellulose, for value added products. The product portfolio were 3rd generation bioenergy carriers (bioethanol and biogas), biochemicals (lactic acid), in co-production with a food ingredient (amino acids), and feed supply (DDGS, a protein plant residue from ethanol and lactic acid fermentation) and biofertilizer.

Left over sugars were used for production of specialty bacteria and microbes, e.g. nitrogen fixating bacteria and mycoriza developed from local African strains, to be added to the final upgraded fertilizer and for fruit waste storage purposes and food conservation (ensiling by lactic acid bacteria). Furthermore, the whole process, from the identification of the biowaste streams, bioconversion of biowaste to products and their separation and purification, have been evaluated for its sustainable and economical aspects.

All products have been made on selected industrial and municipal biowaste feedstock identified in each of the five participating project countries in Africa: Ghana, Morocco, Egypt, Kenya, and South Africa. The processes have been used as examples for how to utilise other similar biowaste feedstock in the future. This project aims at developing biotechnological processes that are well designed for converting biodegradable fractions of identified African agricultural and industrial waste as well as fractions of municipal and animal solid waste.

General project goals have been to develop and demonstrate a “proof of concept” for “white” biotechnological processes to convert African biowaste from food industry and agriculture into sustainable bio-based products such as bioethanol, lactic acid, protein, amino acids, and biogas (methane) and biofertilizer. These products could substitute fossil based chemicals and energy products and turn a waste problem (biowaste) onto a wide range of valuable products.

Emphasis was placed on biowaste streams that were produced in significant quantities in the participating African countries. The overall strategy for technological approach and choice of methods and materials was to have a low energy input and a high value added output.

3 S&T results and foregrounds

The scientific and technological objectives of the Biowaste4SP project were:

1. Identification and characterization of significant industrial sugar based biowaste streams in five African countries: Morocco, Egypt, South Africa, Kenya and Ghana. Selected resources to be used for demonstration and proof of concept in the project.
2. Identification and characterization of significant and typical nutrient element based biowaste (e.g. manure, MSW and some lignocellulosics) and selection of raw materials to be used for demonstration proof of concept in African countries.
3. Development of suitable pre-treatment processes for an efficient conversion of the identified biowaste resources (feedstock) into fermentable substrates and upgraded polysaccharide fraction (sugar platform) by testing and evaluation.
4. Development of appropriate bioconversion methods for converting pretreated sugar solutions from biowaste into ethanol, lactic and amino acids.
5. Recovery and upgrading DDGS (protein fraction from ethanol and lactic acid production) by solid state fermentation.

6. Derivation of the best technologies for downstream processing in order to recover (and utilize) oligo-and polysaccharide fractions (beta-glucan, hemicellulose, proteins) to meet product specification in terms of purity and functionality required by industry.
7. Utilization of a biogas reactor for conversion of all unconverted waste streams to biogas and for co-production in a compost facility of a fully loaded (all 14 essential plant nutrients) lignin based biofertilizer from nutrient based feedstock.
8. Evaluation of the whole process chain of producing biobased energy carriers, chemical amino acids, proteins, and fertilizer from biowaste in terms of sustainability and economic viability.
9. Dissemination of the results to industry and stakeholders and providing guidelines for using biowaste as a resource for the production of bio-based sustainable products.

To achieve the objectives, the project has been following a clear strategy for their implementation as illustrated in Figure 1.

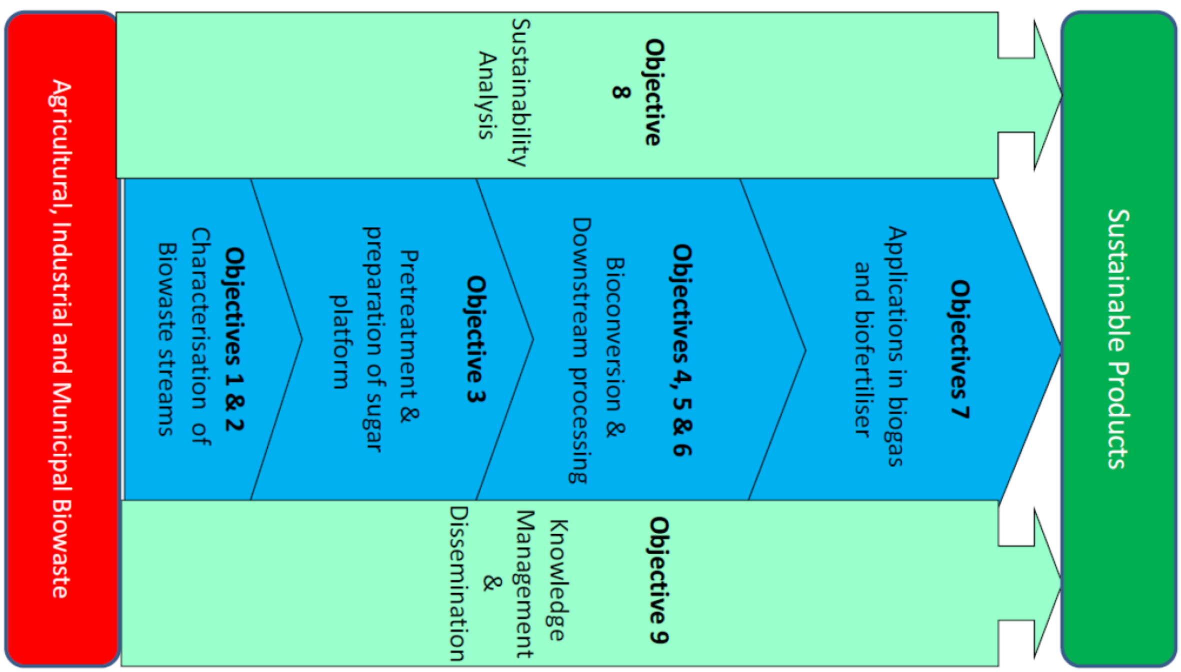


Figure 1. Strategy for implementation of the S&T objectives

The project was implemented through a combination of research and development activities comprising desk studies of available literature and previous projects as well as significant experimental work at laboratory scale. The experimental work was later in the project up-scaled to pilot plant size. In addition to the development of technological processes, considerable attention was paid on the validation and dissemination activities as well as sustainability assessments of the individual products and the entire system. Common procedures and protocols for experimental and field studies were drawn up. Knowledge-sharing and technology transfer to key stakeholders was emphasized during the various activities.

Biowaste comes from many sources and its composition can vary considerably, especially in waste streams such as municipal solid waste (MSW) and household waste. The project strategy took this into consideration and hence from the start efforts have been made to minimize the differences between biowaste streams selected by partners in order to make comparison of results possible, and to minimize the transfer of materials between partners.

Sugar and nutrient rich feedstock have been collected and characterized in a shared effort of the project partners in Biowaste4SP project. The different fields of application for sugar and nutrient rich feedstock are illustrated in Figure 2.

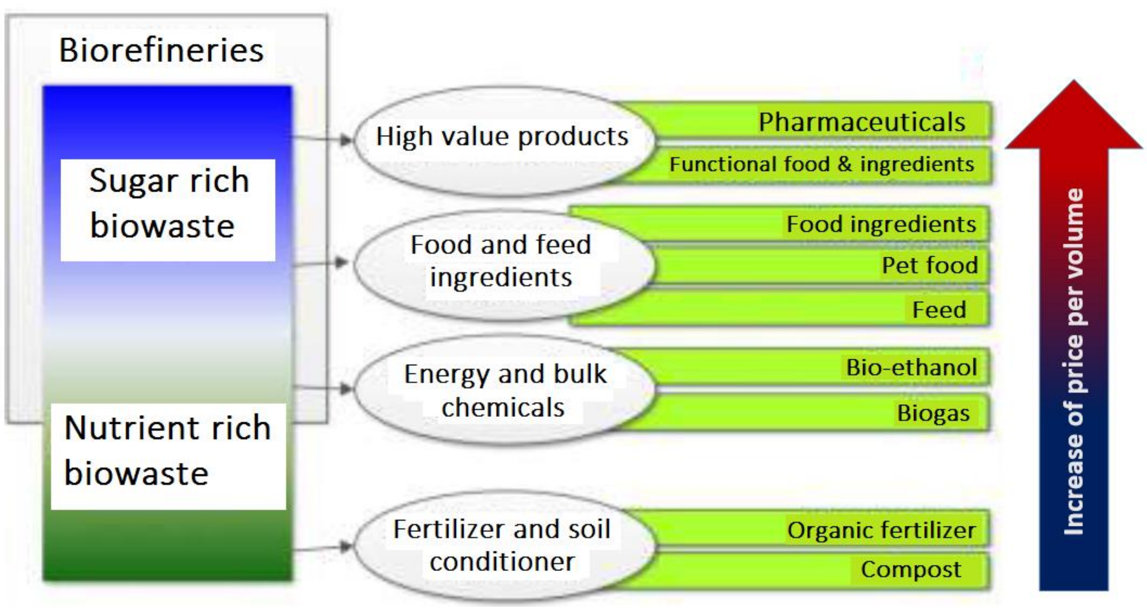


Figure 2. Biorefinery of sugar and nutrient rich feedstock

For purposes of easy implementation, the project was broken down into 10 interactive and iterative work packages (WPs) as shown in Figure 3. Each WP was further broken down into specific tasks. **WP1** and **WP2** delivered a selection of biowaste streams for pre-treatment and wet-fractionation in **WP3,** which included necessary steps of transferring solid biowaste streams into liquefied slurry containing available sugars for the subsequent bioconversion in **WP4.** Also in these work packages, different technologies at the different partners have been utilized and evaluated.

In **WP3,** not only different fractionation and technologies and methods have been evaluated but the potential for stripping value components from the substrates prior to fermentation steps have also been investigated. Included in the task was the evaluation and implementation of the needed separation technologies on the pre-treated suspensions that facilitate efficient downstream processing and provision of sugar rich and other fractions to **WP4** and on.

The major bioconversion tasks for production of bio-ethanol, lactic acid and amino acids from clean, hydrolysed carbohydrate streams (delivered from **WP3**) comprised **WP4**, which was a pivotal technological task at the hub of the project.

It was thus the aim of the experimental work in **WP3** to **WP4** to develop and demonstrate suitable processes for converting biowaste streams into a valuable biochemical and other components.

Main efforts in biogas development from nutrient rich feedstock (from **WP2**) and lignocellulosic waste streams (identified in WP 3) comprised **WP5. WP6** concentrated on development of bioorganic fertilizer, enriched with nutrients, utilizing solid and liquid output from **WP5** as composting media. The technical work packages were hence integrated in a logical sequence maximizing potential for optimal utilization of the original biowaste streams.

The overall production systems developed in the program need to be demonstrated as sustainable and environmentally sound. Hence, a range of rigorous life cycle and energy, economic and quantification studies was applied throughout the project period and this comprised **WP7**. A separate work package, **WP8**, was devoted to inter-partner knowledge sharing, dissemination and capacity building. Capacity building and knowledge sharing was a key target of the program and warranted such special attention. Scientific and technical management of project activities was covered by **WP9**, while project coordination and consortium management was likewise allocated a separate work-package, **WP10**: a project with such multi-partner, trans-continental and cross-disciplinary facets, as this one required focused and pro-active consortium management.

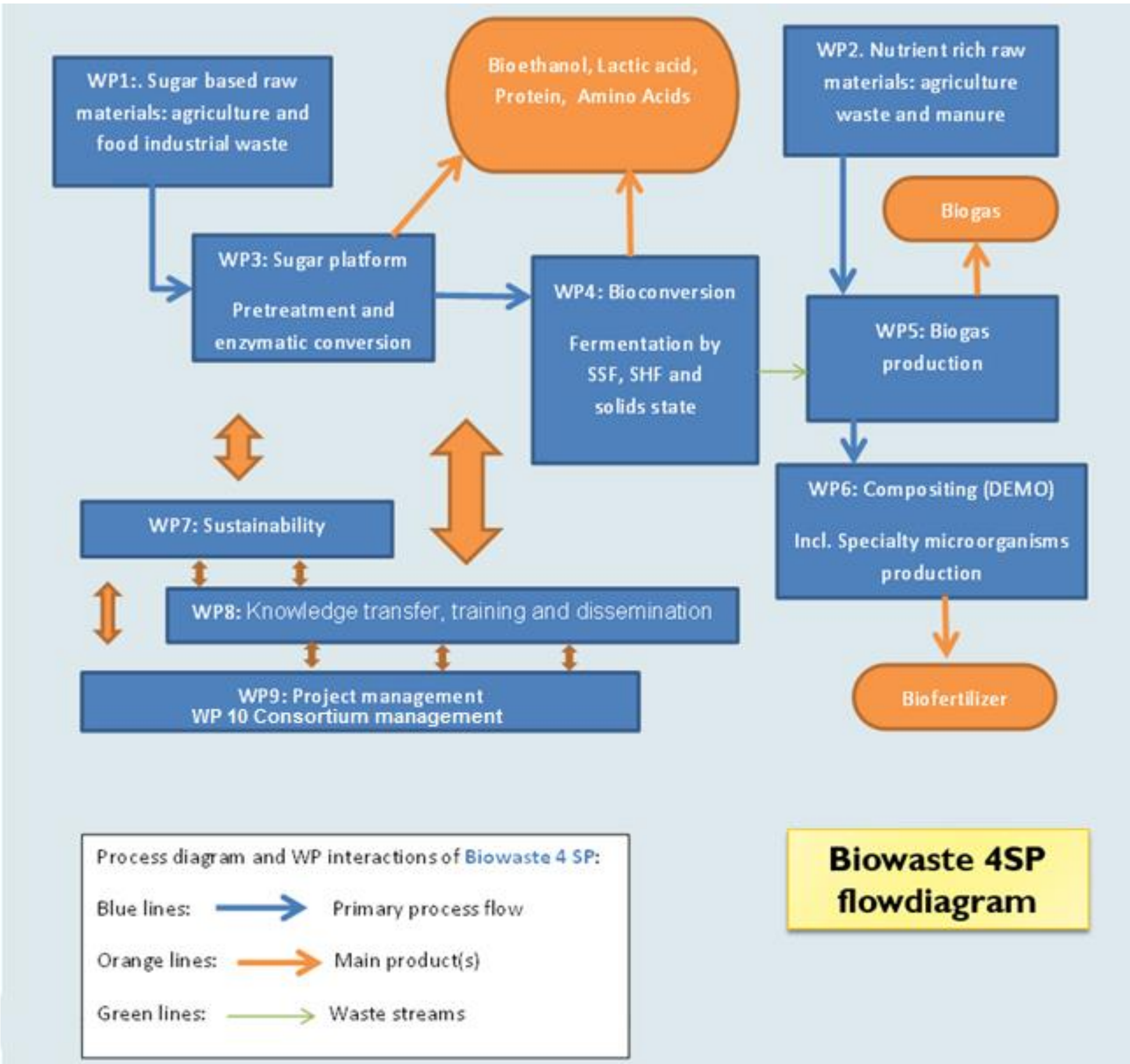


Figure 3. Process diagram and Work package interactions in Biowaste4SP project

3.1 WP 1 Identification and characterization of biowaste from food industry and agricultural sources

The objectives of WP1 (Figure 4) were to identify, characterize (and deliver) the most significant and suitable sugar based biowaste streams from the food industry and agriculture from the participating ICPC countries (e.g. banana biowaste, cassava biowaste, rice hulls, cotton stalk, olive biowaste or palm oil residuals). Five of the most significant, one from each participating country have been collected in sufficient amount, and for further conversion to fermentable sugar substrates (in WP3) and fermentation to ethanol, lactic acid, and amino acid production. Most suitable methods for storage have been identified for the selected feedstocks to be handled in the project.

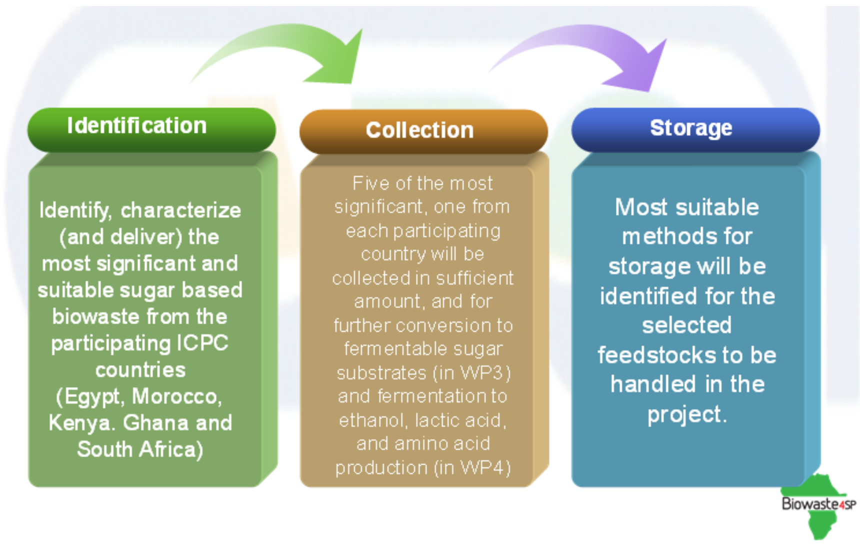


Figure 4. Strategy for identification, collection and storage of biowaste feedstocks in the five participating Africa countries (WP1 and WP2)

The most significant sugar based waste products from the food industry and agriculture were identified for targeted ICPC countries (Egypt, Morocco, Ghana, Kenya and South Africa). It is of importance that the biowaste contains both easily convertible sugar fractions (starch, amylopectins and hemicellulose), which have been converted to fermentable sugars in WP3 and further to bioethanol, lactic acid and protein and amino acids (in WP4). Some protein (obtained as DDGS as end product from bio-ethanol production) and to some extent, lignocellulose materials have been converted to biogas in WP5 and fertilizer in WP6. These waste streams were compiled and listed in a catalogue with information on their composition (starch, simple sugar, pectin and lignocellulose components), available quantities, distribution and logistics. In addition, local processers of fruit and vegetables, which have some basic infrastructure in place, were recruited as external collaborators for the remaining project activities. A plan for collection, storage and utilization was developed for five of the most promising feedstock in each country.

The summary of the activity of WP1 was:

- Development of protocols for sampling and storage of biomass residues in cooperation with WP2.
- Development of protocols for chemical analysis of biomass feedstock in cooperation with WP2.
- Training of PhD students from African countries in the developed methods and protocols so they can use and apply them on local biomass feedstock in their home countries.
- Identification of most significant sugar based biowaste resources from industry and agriculture. (A protocol for chemical analysis of identified biomass to be used in the project).
- Sample collection and chemical characterization (starch, simple sugars, pectin, lignocellulose (cellulose, hemicellulose, lignin, NCWM and ash) of significant sugar based feedstock in each partner from ICPC country using same protocol with internationally recognized analysis methods. (Methods for the selection and storage of biowaste feedstock for WP3, WP4 and WP6).
- Development of a catalogue with information on biowaste composition (starch, simple sugars, pectins, lignocellulose), locations, available quantities, distribution and logistics for each country.
- Collection and transportation of biowaste. Investigation and development of suitable and economical methods for collection and transportation of the most significant biowaste streams in each country.
- Report on biowaste management for the selected feedstock.

Key results of this work package have been compiled in a feedstock catalogue that is available on the project website.

The feedstock catalogue provided a systematic information on various typical biowastes and bio-residues found in large quantities in the partner countries (Figure 5). There are a total of 49 biomass samples that have been studied and are included in this catalogue. Twentynine of these are what could be labelled sugar rich and 20 nutrient rich. Many of the biomass samples studied are potential feedstock in processes requiring both nutrient rich and sugar rich feedstock.

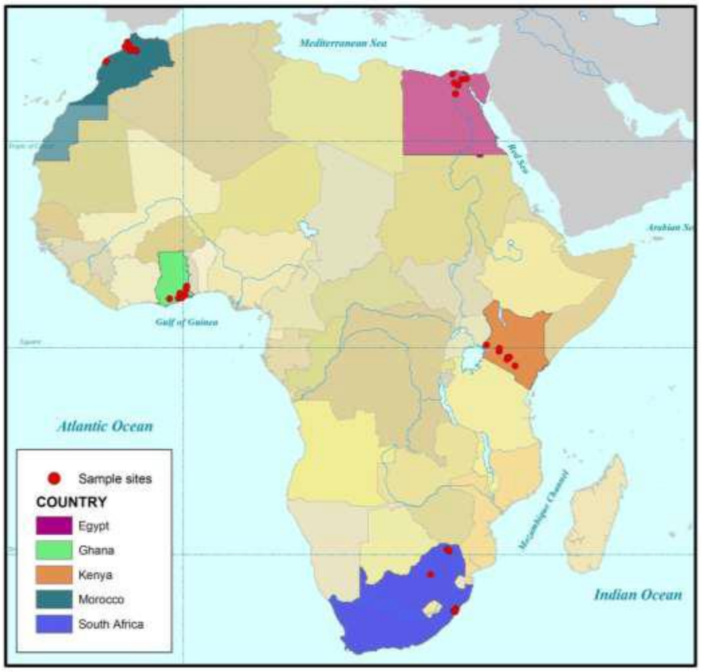


Figure 5. Sample sides for biowaste feedstock that have been included in the catalogue.

Identified sugar rich feedstock

The sugar rich feedstock identified and characterized in WP 1 are summarized in Table 1.

Table 1. Sugar rich biomass feedstock

SUGAR RICH FEEDSTOCK	Country	SUGARS			Nutrient rich**
		Rich in simple sugars	Starch rich	Ligno cellulo-sic*	
Cassava beer processing waste	Ghana		xx	xx	
Saw dust	South Africa			xxxx	
Sugarcane bagasse	Egypt			xxxx	
Coffee Husk	Kenya			xxxx	
Pomace from olive oil pro-cessing	Morocco	x	x	xx	
Sugarcane Vinasse (liquid)	Egypt	xxxx			
Cassava Peel, small scale	Ghana		xx	xx	x
Banana waste - whole ba-nana	Ghana		xxx		x
Green banana fruit	Egypt		xxx	x	x
Sugarcane Bagasse	South Africa			xxxx	x
Pineapple peels and used cores	Kenya	xx		xx	x
Maize Bran	South Africa		xx	xx	x
Rice bran	Egypt		xx	xx	x
Banana fruit	South Africa	xxx	x		x
Corn stover field residues	Egypt			xxxx	x
Rice husk	Egypt			xxxx	x
Crop residues of sugarcane	Morocco	x		xxx	x
Wheat bran	South Africa		xx	xx	x
Crop residues of maize	Morocco			xxxx	x
Cotton stalks field residue	Egypt			xxxx	x
Empty oil palm fruit bunch	Ghana				x
Olive pomace	Egypt	x	x	xx	x
Dried beet pulp	Morocco	x		xxx	x
Wood bark	South Africa			xx	x
Orange pulp	Morocco	x	x	xx	x
Cassava peels and trim-mings	Kenya		xx	xx	x
Crop residues of faba bean	Morocco			xxxx	x
Tomato pulp	Morocco	x		xxx	x
Flower waste - greenhouse	Kenya			xxxx	x
Sugarcane Bagasse	Kenya			xxxx	x

Main result per country from survey of identified biowaste resources in the five African countries are listed in ranging order below:

Egypt: The potential sugar based feedstock are available at both farm levels and at agro-processing units as follows:

1. Sugar cane vainness and bagasse
2. Yellow (mature) and green (immature) banana suckers and corms
3. Corn cobs
4. Cotton stalks
5. Olive vegetative water which was considered as the highest ranking of sugar based biomass or bio-waste

Ghana: The potential sugar based feedstock are available at both farm levels and at agro-processing units as follows:

1. Cassava peel and Cassava Stalk
2. Rice Bran
3. Cocoa Shell
4. Rice Straw
5. Maize Stalk
6. Sorghum Stalk

Morocco: Five top materials containing sugar detected as follow:

1. Banana crop residues
2. Corn residues
3. Head sugarcane
4. Olive pomace
5. Leaves and twigs of olive

Kenya: The top potential candidates from the inventory as potential sugar based feedstocks for bio-refinery processes include as follow:

1. Maize
2. Post-harvest losses Coffee
3. Pulp and wastewaters
4. Sugar molasses

5. Cassava processing
6. Pineapple wastes
7. Dairy processing waste

South Africa: Short list of candidates from the inventory as potential sugar based feedstock for bio-refinery processes are.

1. Sugarcane (field residues)
2. Bagasse
3. Pulp & Paper Industry (Black Liquor)
4. Bananas

3.2 WP 2 Identification and characterization of nutrient based biowaste

The objectives of WP2 were to identify, characterize and collect nutrient element based rich feedstock (e.g. manure, lignocellulosic waste) from the participating ICPC countries providing the main quantities of feedstock for co-production of biogas and biofertilizer. It is of importance that essential plant macro-nutrients (N, P, K, Mg, Ca, S) as well as micro-nutrients (Fe, Cu, Zn, Mo, B, Mn, Co, Na, Cl) are present in the feedstock together with significant amounts of carbohydrates for biogas production (in WP5) and lignin for biofertilizer (in WP6). This included:

1. Identification, characterization and delivery (some) of the most significant nutrient rich waste feedstock from municipal waste and manure for each ICPC country to be converted to biogas (in WP5) and fertilizer (in WP6).
2. Production of a catalogue with information on their composition, available quantities, distribution and logistics.
3. Development of a plan for collection, storage and utilization for the specific materials to be used within the project.

The nutrient rich feedstock identified and characterized in WP2 are summarized in Table 2. Based on these results, a catalogue was prepared in collaboration with WP1.

Table 2. Nutrient rich biomass feedstock identified in five African countries Ghana, Egypt, South Africa, Kenya, and Morocco.

NUTRIENT RICH FEEDSTOCK	Country	SUGARS			Nutrient rich ***
		Rich in simple sugars	Starch rich	Ligno cellulo-sic **	
Rice bran – not parboiled	Ghana		x	xxx	xxx
Banana peels	South Africa			xxxx	xxx
Cattle manure	Morocco			x	xxx
Crop residues of banana	Morocco			xxxx	xxx
Cattle Manure (collected pasture)	South Africa			x	xxx
Water hyacinth	South Africa			xx	xxx
Soya bean field residues	South Africa			xx	xxx
Farmyard manure (mixed with soil)	Egypt			x	xxx
Cow dung – sheds	Ghana			x	xxx
Pig manure from pig rearing farm	Ghana			x	xxx
Poultry droppings	Ghana			x	xxx
Cabbage packaging waste	Kenya	xx		xx	xxx
Open Market Agricultural Waste	Kenya	xx		xx	xxx
Rice straw	Egypt			xxxx	xx
Coffee Pulp	Kenya			xxxx	xx
Fruit & Vegetable Waste	South Africa	xx		xx	xx
Garden Waste	South Africa			xx	xx
Empty cocoa pods	Ghana			xxx	xx
Sisal processing waste	Kenya				xx

Main results per country from survey of identified nutrient rich-biowaste resources in the five African countries are listed in ranging order below:

Egypt: The potential nutrient rich feedstock are available at both the farm levels and agro-processing units as follow:

1. Animal husbandry droppings
2. Rice straw
3. Cotton stalks
4. Corn residues
5. Olive prune
6. Banana green residues

Ghana: The potential nutrient rich feedstock are available at both the farm levels and agro-processing units as follow:

1. Cattle dung
2. Poultry droppings
3. Pig dung
4. Goat droppings
5. Sheep droppings
6. Cocoa Pod
7. Ground nut stalk

Morocco: The potential nutrient rich feedstock are available at both the farm levels and agro-processing units as follow:

1. Manure of cattle
2. Sunflower cake
3. Sugar beet dry pulp
4. Legume residues

Kenya: The potential nutrient rich feedstock are available at both the farm levels and agro-processing units as follow:

1. Animal manures
2. Organic fraction of municipal solid wastes
3. Sisal waste
4. Maize combs
5. Sugar bagasse
6. Residues from cabbage production
7. Saw dust

South Africa: The potential nutrient rich feedstock are available at both the farm levels and agro-processing units as follow:

1. Chicken litter
2. Slaughterhouse blood
3. Forestry – Field residues
4. Pulp and paper industry sludge
5. Saw dust
6. Slaughterhouse fats
7. Slaughterhouse bones

3.3 WP 3 Pretreatment and development of a sugar-based platform

African Biowaste selected in this project was composed of mainly sugar component, which in their monosaccharide forms are substrates for fermentation processes. If used intelligently these are good feedstock that can serve as raw materials for biorefinery process i.e. separating and converting into value added energy-carriers, bio-chemicals (commodity and chemical building blocks), feed and food products (sugars as well as proteins) and fertilizer. However, efficient utilization with low energy input technologies accomplished with high yield and value-added product out-put requires development and application of novel as well as adapted known technologies for finding economically viable solutions. About 60 % of the cost in a biorefinery goes to pretreatment and fractionation of the biomass, and therefore WP3 in this project focused on the investigation and improvement of cost-effective pretreatment technologies for fractionating, sterilizing and hydrolyzing the selected biowaste feedstock, to provide suitable fermentation substrate for further production of bioethanol, lactic acid, amino acids, etc. The processes chosen were from already existing and proven technologies, however great efforts have been done for adjusting these to the selected feedstock (e.g. banana waste, cassava waste, and rice bran), and also to extracting (e.g. arabinoxylan, protein, etc.) and producing potential value-added products (e.g. ethanol, lactic acid, biogas, biofertilizer), to improve the overall process economy.

Wet-milling pretreatment

In WP3, an enzyme facilitated wet-milling, the pretreatment methodology originally developed from processing of cereal brans, was developed and adapted to seven different biowaste feedstock. The origins and composition of the seven feedstock were characterized and the pretreated substrates were tested for its potential of biofuel production i.e. ethanol. The results supported the developed enzyme facilitated wet-milling pretreatment method was promising to pretreat not only low-lignin content biomass (e.g. banana flesh, cassava, and rice bran), but also relatively high-lignin content biomass (e.g. banana peel and cassava peel), generating low or no inhibition to the following fermentation steps (bioethanol production). Satisfactory ethanol yields in the range of 80-95% theoretical yield were obtained from all the tested biowaste materials, with highest ethanol concentration of 53 g/l and 42 g/l obtained from fermentation of pretreated cassava peel and rice bran, respectively. Such high final ethanol concentration indicated the economic potential of realizing the industrial ethanol production from cassava waste, as 4-5% ethanol concentration after fermentation were considered as one of the crucial threshold for economic feasibility of bioethanol production.

Enzymatic hydrolysis

Different enzyme systems were developed based on the biomass compositions of different biowaste feedstock, for obtaining glucose-rich substrates for fermentation as well as recovering value-added products. A generic two-step enzymatic hydrolysis system, i.e. 1^{st} step starch hydrolysis and 2^{nd} step cellulose hydrolysis (SE+CE system), was designed and tested on hydrolyzing four different kinds of banana biomass, obtaining high glucose recovery up to 93.3%. The process for extracting water-soluble and fibre-bound arabinoxylans from rice bran was established by means of wet milling and enzymatic treatment followed by a sequential centrifugation for separating the bran fractions. Different enzymes were used for extracting water-soluble arabinoxylan (i.e. by using enzyme EC 3.2.1.1) and fibre-bound arabinoxylan (i.e. by using enzyme EC 3.2.1.8). The arabinose/xylose ratios (A/X) of water-soluble and fibre-bound arabinoxylan from rice bran were determined as 0.66 and 0.64, respectively. WP3 also developed and tested an enzyme immobilization system, as immobilized enzymes with functional efficiency and enhanced reproducibility have potential to decrease the demand usage of expensive enzymes and thus could play important roles in the bioprocess technology in economic terms. Iron oxide nanoparticles were synthesized as support materials for targeted enzymes. Chemical structure of nano-particles was confirmed by Fourier Transform Infrared Spectroscopy (FTIR) and the magnetic property of nanoparticles was tested with a simple magnet. The efficiency of binding and residual activity of immobilized amylase (which was bounded to the synthesized magnetic nanoparticles) were determined according to mass ratio of nanoparticle, carbodiimide, amylase, temperature, pH and time. The enhancement of the thermostabilities was observed after immobilization, as a nearly 1.5-fold increase at temperatures between 60-95°C.

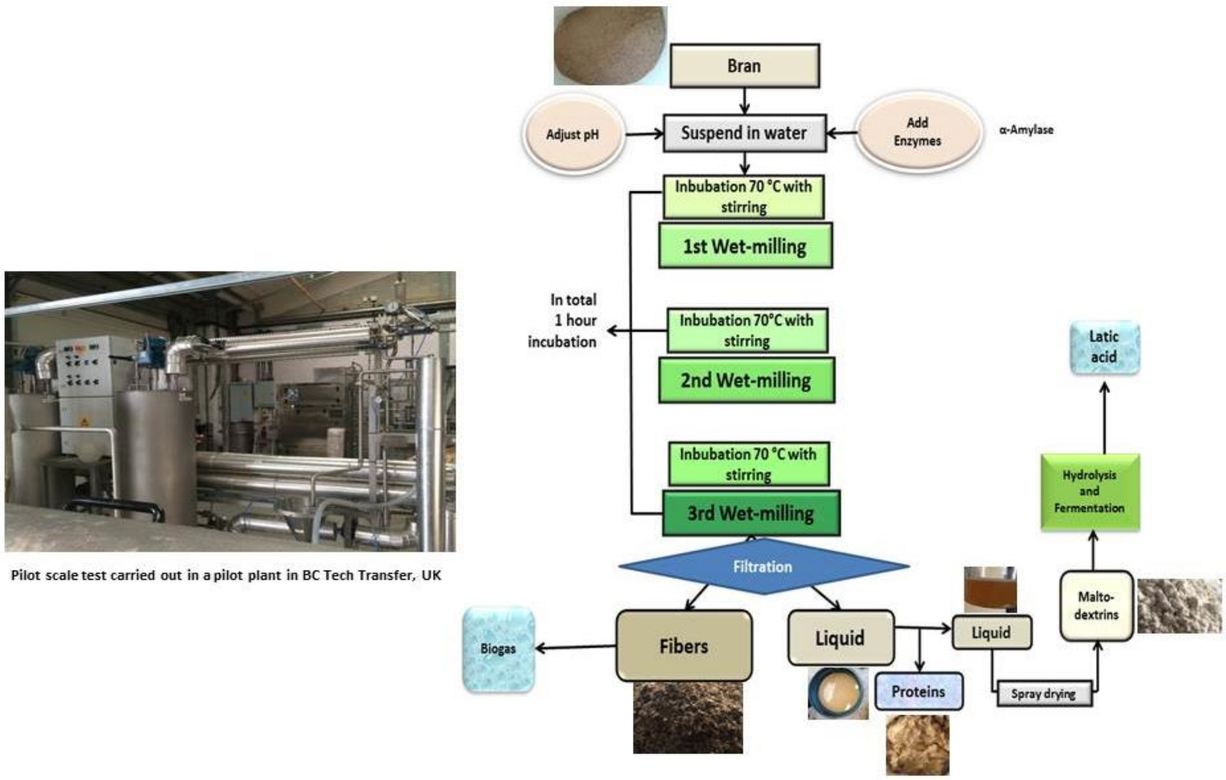


Figure 6. Pilot scale enzymatic facilitated wet-milling and fractionation of wheat bran biomass

Pilot scale trials

As a proof, a pilot scale demonstration of the developed generic biorefinery process was carried out at the final stage of this WP, on selected biomass feedstock i.e. wheat bran. 80% of sugars (glucose, xylose and arabinose) were recovered after wet-milling pretreatment. 71.4% of the recovered glucose was kept in the liquid fraction, while 75% of recovered xylose and 92.4% of recovered arabinose were stayed in the insoluble fraction of fibre. 27.2% of protein in the raw wheat bran stayed in the separated fibre fraction after wet-milling and majority of protein was released into the liquid fraction after wet-milling pretreatment, and can be further separated in the future process development. The separated insoluble fibre fractions were tested for its potential for biogas production. Such pretreated fibre contained high volatile solids (97% TS) and methanogenic potential reached at highest to 151 ml STP/ g VS. High percentage of biodegradability and a short retention time to be biodegraded were observed during the anaerobic digestion process. The lactic acid production by *Lactobacillus plantarum* fermentation on the pretreated sugar-rich liquid showed promising results, where 56% of wheat bran glucose was consumed and high lactic acid yield of 0.9 g/g-consumed glucose and productivity of 0.77 g/(l•h) were obtained.

Finally, WP3 was also involved in the training of three African PhD students during the work performed above, which helped for strengthening the research and development capacity of African partners.

3.4 WP 4 Bio-conversion for the production of bioethanol, lactic acid and amino acids

WP4 was designed to develop bioprocesses for the conversion of pre-treated African biowastes of cassava, banana and rice to value-added products such as ethanol, lactic acid and amino acids. DTU (Denmark) has been the lead beneficiary with close collaborations with four other partners, namely DTI - Denmark, TUBITAK - Turkey, CSIR-GH - Ghana and IAV - Morocco.

The results from WP4 are outlined in the following section. They have been divided into two parts. The first describes the deliverables, which deal with isolation of novel microorganisms, while the second part summarizes the deliverables concerned with fermentation of biowaste into value-added products.

Isolation and characterization of novel strains from environmental samples
An initial pre-treatment protocol for optimal hydrolysis of banana fruit and banana peel was developed followed by a screening protocol to isolate novel lactic acid bacteria (LAB) which could grow on the substrate and produce lactic acid. In parallel, the vast culture collection at DTU was systematically screened to identify the best candidate strains for efficient conversion of pre-treated banana waste to lactic acid while maintaining other desirable properties such as inhibitor tolerance and broad substrate specificity. Novel isolates of *Lactococcus* spp. and *Lactobacillus* spp. were isolated from environmental samples (primarily waste) as a result of this extensive screening work, while promising strains from the strain collection were also identified. Additionally novel LAB isolates from termite guts were screened for production of lactic acid using hydrolyzed cassava flour. Type strains of *L. lactis* and *Lb. plantarum* out-performed the gut-isolates and up to 16 mg/ml lactic acid could be produced from a cassava hydrolysate containing 10% glucose. With the high sugar concentrations, the medium needed to be supplied with a nitrogen source and beef extract was found to be the most effective and economical adjunct. The work outlined in the two deliverables indicates that there is a lot of potential for the African partners to develop processes based on candidates isolated in the respective partner countries. It should be possible to obtain relevant and interesting strains from many environments such as the waste already present.

Fermentation of biowaste to value-added products
Initial investigations focused on processed cassava flour from a commercial cassava plant, a cheap, abundant and renewable resource. The flour was progressively treated to produce a liquefied fraction that was further enzymatically hydrolyzed. The supernatant was used as a substrate for ethanol production using two strains of *S. cerevisiae* - NRRL-Y-12632 and BY4743. Fermentations were carried out both under aerobic and anaerobic conditions, and up to 23.8 g/l ethanol was successfully obtained. The yield of ethanol on cassava flour hydrolysed was lower than on defined media containing 5% glucose suggesting that the process can be further optimized for greater yields of alcohol.
In addition seven different kinds of African biowaste (un-matured banana peel and flesh from Egypt, flesh and peel from over-matured banana from South Africa, peel and flesh from cassava and rice bran from Ghana) were tested for ethanol production using the commercial yeast strain Quick Yeast. The pre-treatment regimes were varied depending on the compositional analysis of the biowastes and after 48h of fermentation very high ethanol yields were obtained, with the highest amounts produced from hydrolyzed cassava flesh (53.2 g/l with a range from 23.8 to 53.2 g/l). The remaining substrates produced approx. half- (immature- and overmatured banana fruit) or one third of the concentration from cassava flour (rice bran, over- and immature banana peel).

During this study, a low-tech enzymatic wet-milling process was successfully developed which would also be economically feasible in field trials. Further work was done to optimize the possible use of cassava peels as a feedstock for bioethanol production after appropriate pre-treatment and hydrolysis. Systematic wet milling coupled with SSF process yielded 46.52 g/l ethanol (98% of theoretical) which is comparable to industrial ethanol production requirement. This result is highly promising and demonstrates that cassava peel, a waste generated at cassava processing units has high potential of generating about 570.3 Million litres of bio-ethanol annually in Ghana alone.

Strains of LAB (*L. lactis*) were tested for their ability to utilize xylose to produce lactic acid and strains engineered with a plasmid carrying the xylose utilization genes were further adapted to the fermentation conditions to produce lactic acid as the sole by-product. The strains were also subjected to conditions of substrate starvation and high substrate concentration, both of which are experienced by the microorganisms during SSF fermentation. The results were promising but require further optimization. Since this work included genetically modified organisms (GMO), it would seem better to optimize this via alternative strategies.

The feasibility of producing lysine by fermenting hydrolyzed cassava peel was investigated. After wet-milling, cassava peel was progressively hydrolyzed enzymatically to produce a hydrolysate containing around 40 g/l glucose. A strain of *C. glutamicum*, which had been previously engineered to produce high yields of lysine, was used as the production organism. A minimal medium supplemented with hydrolyzed cassava peel as the carbohydrate source, was used for the fermentation trials and average yields of lysine of 76±8 mmol/mol glucose could be produced using the sugars available from hydrolyzed cassava peel. This study demonstrated the potential of utilizing cassava peel waste as a carbon source for production of amino acids via fermentation. Again, the organism used was an optimized lab. strain constructed by targeted engineering. However, industrial strains exist which have been developed using non-GMO methodology, which could easily be adapted for the processes investigated were to provide even better results. As an alternative (theoretical) for amino acid production the use of LAB were investigated and a strategy described. The theoretical assessment of the feasibility of producing amino acids using LAB as the production hosts was elucidated, and a strategy was designed to engineer *L. lactis* MG1363 for the production of lysine. Although not a part of the deliverable, the strain was further engineered with the *lysE* gene (lysine transporter) from *C. glutamicum* and lysine production was detected extra-cellularly via HPLC. The quantities of lysine produced need to be determined and improved to make this an economical reality, but this study provided a very promising strategy and the first step towards future strain development. The advantage would be a very robust process which could run anaerobically or semi- anaerobically depending on the optimized results.

Finally, WP4 was involved in the training of two African PhD students during the work performed in the above-mentioned deliverables. This paves the way for further improvements and future implementation of the processes outlined not only in WP4 but also from the entire BIOWASTE4SP project.

3.5 WP 5 Biogas production

The objectives of WP5 were to convert nutrient rich feedstock, as being identified and characterized in WP2, into biogas. The biowaste resources included all residues of lignocellolosic waste material and wastes separated from the starch material in WP3. The indigestible biomass components i.e. lignin and all inorganic nutrients for further processing in the compost facility for biofertilizer (in WP6). The partners involved in WP6 were AMADES at Biogas Team laboratory of Faculty of Sciences Ibn Tofail University Kenitra-Morocco, by CSIR-Ghana institute laboratory and by TUBITAK’s-Turkey institute laboratory.

Figure 7A (left photo): AMADES biogas research laboratory. From the left to right: Prof. Hassan El Bari (WP 5 leader), Prof. René Moletta, International biogas expert, during his recent visit to our lab), and Yassine Joute (AMADES PhD student) in Biowaste4SP project. Figure 7B (right photo). Lab scale digester used in AMADES tasks.

Lab-scale anaerobic digestion

Lab-scale anaerobic digestion were carried out in AMADES co-digestion experiments of cattle manure with three type of lignocellulosic biowaste i.e. banana waste, cassava peels and rice bran were performed respectively by A continuously stirred cylindrically shaped digester with domed cap was designed using anaerobic digestion properties of cassava peels (CP) and cow dung (CD) but also can be adapted for the co-digestion of banana or rice waste with cow dung. A maximum retention time of 70 days was selected with a digester volume of $0.6m^3$ to be fed intermittently at a rate of 1.87 kg/day in a CP:CD (both fresh) ratio of 1:5 and 1 part by weight of water on total weight of the CP:CD mixture resulting in TS equal to 8.5%.

Pilot scale trials

Pilot scale trials was used to carry out the anaerobic digestion of solid organic waste to produce biogas, and the indigestible component collected for biofertilizer production in WP6 and the results obtained during the entire experimental period indicated that the “two-stage” digester can be used for treatment of organic waste and can be optimized to produce high quality biogas (> 60% CH_4) and at the same time achieve greater than 75% volatile solids destruction. The last WP5 task concerning digested material to be composted in WP6, and the aim was to present results for the sample analysis of digested material from batch anaerobic co-digestion laboratory tests for vegetable waste and cattle manure to quantify certain parameters such as nutrient and heavy metal content for the material collected after anaerobic digestion tests. The results obtained in the laboratory scale experiments was used as preliminary results for designing pilot scale composting trials and show that the digestate material contains optimum nutrients and elements for addition to composting piles to improve compost quality.

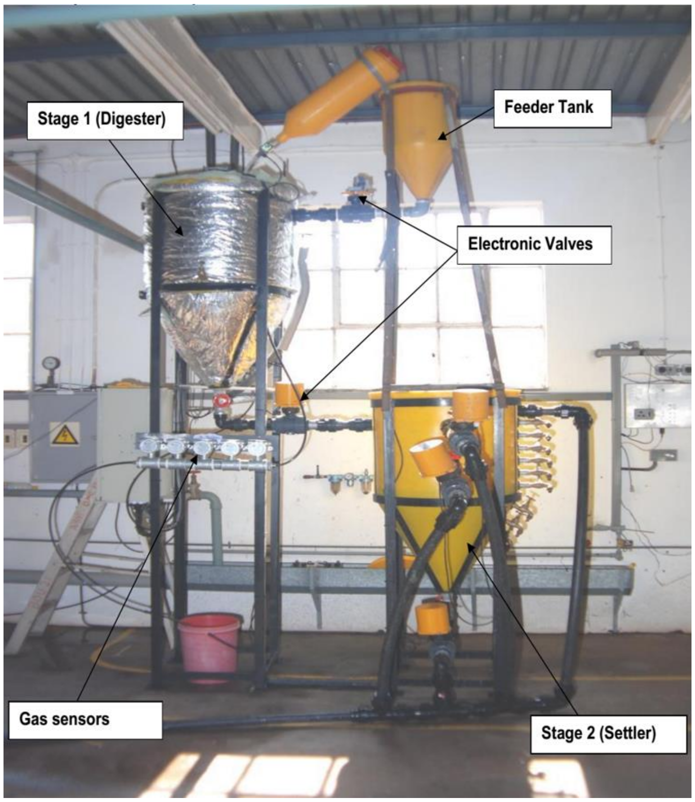


Figure 8.Pilot scale biogas reactor in South Africa

Finally, the effects of wet milling pre-treatment was studied on the biogas production and methane yield from mesophilic anaerobic digestion of solid fibres wheat bran residues. Wheat bran could be a suitable lignocellulosic bio-waste for anaerobic digestion, especially when it is pre-treated. Characterized by its high volatile solids content (97(% TS)), wheat bran gave an important methanogenic potential (151 ml STP/ g VS), high percentage of biodegradability and a short retention time to be biodegraded.

3.6 WP 6 Bio-fertilizer production

The objective in WP6 was to develop a bioorganic fertilizer that is enriched with nutrients; and with addition of premium microbial products and beneficial minerals that are essential for plant growth and development. Research and development (R&D) focuses on identification, characterization and processes for production of beneficial microorganisms that are suitable for African climate and soils. Biowastes are to be composted using microbes that are successfully isolated and propagated from the member countries. The compost has been enriched with beneficial microbes and nutrients and used in field trials to confirm its usefulness and functionality.

For reference, bio-fertilizers are substances that contain living microorganisms which, when applied to seed, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. For WP6, the end product which is compost plus bio-fertilizers is called bio-organic fertilizer.

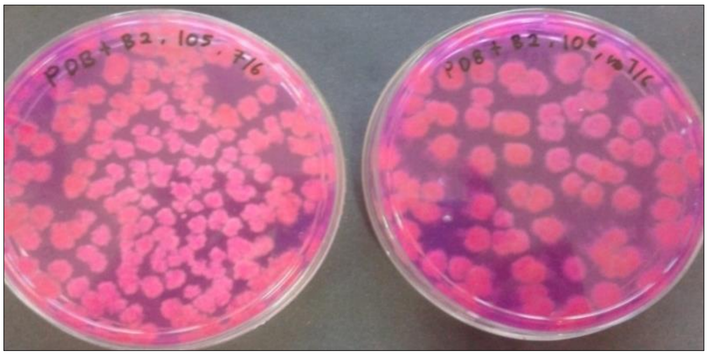
Microbes propagation

The Agriculture Research Centre (ARC) in Cairo, Egypt has provided microbial isolates to be used for this project. These samples were brought to Malaysia in April 2013 for SIRIM and Myagri to work on. Using the experts and equipments available at both organization, all six isolates were successfully cultured using several media and methodology that could be replicated by consortium partners in Africa. The guideline and protocols developed by SIRIM and Myagri can be used by stakeholders such as scientific & research centres and biotechnology companies in African countries to propagate local microbes with similar benefits and functionality. For this work package, this task to replicate and propagate the microbes was undertaken by the capable team of scientists at CSIR-ZA, South Africa.

Composting of biowastes

Based on studies carried out by WP1 and WP2, several potential biowastes were selected to be used in the composting experiments in this work package. They were banana fruit, peel & plant; rice straw; cassava fruit, peel & leaves; sugar cane bagasse and vegetables wastes from local markets. The initial experiments were done by Myagri and ARC where the results showed that those biowastes could be composted using the microbes provided by ARC. Using their data and methodology, a composting protocol was developed to be used by ETM in Durban, South Africa.

Based on Myagri's experience in Malaysia, the potential stakeholders that could undertake this task would be those that are involved in biowastes collection and management; or agriculture industry players that produce huge amount of biowastes and are looking to produce beneficial products from the wastes.



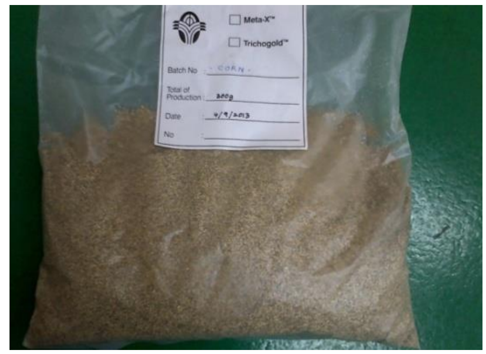


Figure 9. (Left) Colony Forming Units of Trichoderma sp; (Right) Bio-fertilizer formulation produced by Myagri.

Producing bio-organic fertilizer in South Africa

The tasks of testing and developing the relevant microbes for this work package were done in Egypt and Malaysia. The challenge for Myagri was to ensure our partners in South Africa, i.e. ETM and CSIR-ZA were able to receive and utilize these microbial isolates. Even though these microbes are generally recognized as safe for inter-country transportation, they were not commercial strains. After evaluation by DHL Malaysia, the bio-fertilizer formulation was accepted for delivery. However, the package was held for a long time by the South African Customs. Fortunately, it was released and CSIR-ZA was able to eventually isolate and propagate the microbes to fulfil their tasks.

The lesson learnt here was for future collaborators to either purchase commercial strains from microbial culture collection centres or locally identify and isolate microbes with similar functionality. It is also crucial for future technical teams to test the many biowastes and sugar substrates in order to formulate more suitable and cost effective media for propagating the bio-fertilizers on a larger scale.

Figure 10. (left) Composting microbe & Bio-fertilizer produced by CSIR-ZA; (right) Microbes inoculation

Figure 11. (left) Sugar cane bagasse heap; and (right) Vegetable + bagasse heap.

Bio-organic fertilizer trials

The final task for WP6 was to test the bioorganic fertilizer produced by Myagri, ARC and ETM on crops trial plots and in the field. Due to the delay in getting the microbes, ETM was not able to produce enough bioorganic fertilizer and start the trial on time. They have started a small-scale trial on vegetables and also distributed the bioorganic fertilizer to local communities to be used in their gardens. The farmers have given positive feedbacks on its use.

Myagri tested it on spinach planted in 100 plastic poly bags. The data collected has shown that the plants that were treated with the bioorganic fertilizers have significantly better growth; i.e. more biomass and more roots. For large-scale trials, the teams at ARC have used the bioorganic fertilizers on peanut, olive trees and cotton trial plots in Egypt. The data collected has shown significant growth and effects on the peanut plot and slightly less on the other two crops. The researchers were confident that results would improve with continuous use of the beneficial microbes in the fields.

Figure 12. Final product: Compost enriched with beneficial microbes – From ETM (left); from MYAGRI (middle); from ARC (right).

Figure 13. Trial on peanut

Figure 14. Trials on olive trees (left) and Cotton (right)

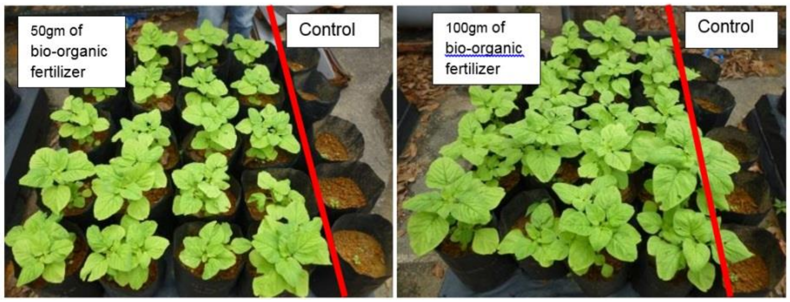


Figure 15. Trial on Spinach at Myagri, plants treated with bioorganic fertilizer (left side of test plot) vs control (right side of test plot)

3.7 WP 7 Sustainability studies

The sustainability studies of WP7 have concerned the implementation of sustainability assessment for systems that turn biowaste from agro-industrial sector into sustainable products such as bioethanol, bio-fertilizers, lactic acids, amino acids, biogas etc.

Based on data provided by the other partners of the project, a sustainability assessment of the entire production system has been performed. The tasks in the WP7 have been undertaken by University of Siena (Ecodynamics Group) in collaboration with IVL Swedish Environmental Research Institute (Sweden) and the African Institute for Capacity Development – AICAD (Kenya). In this regard, the University of Siena hosted two post-doctoral researchers (each for 12 months): Dr. Said A. Vuai from University of Dodoma (Tanzania) and Dr. Benard K. Langat from Moi University (Kenya), respectively.

The main objectives of WP7 were to:

- Characterize critical phases of the production chain from a sustainability point of view.
- Indicate the points that generate negative impacts on the surrounding environment.
- Improve the knowledge of sector operators on the factors determining the impacts on sustainability.
- Formulate guidelines to be applied for a sustainable management through scenario assessment.

The research activity of WP7 was focused on the sustainability assessment of two different technology routes, based on sugar and nutrient rich feedstocks, respectively. To this aim, we have used two different approaches that are Emergy evaluation and Life Cycle Assessment (LCA).

Emergy evaluation is an environmental accounting method based on thermodynamics principles. It is able to quantify the relationships between human-made systems and the biosphere and it is used to assess environmental sustainability of process and systems. Emergy is defined as the available solar energy previously used, directly and indirectly, in order to make a service or product. Emergy can be considered as an “emergy memory” that is the memory of all solar energy is needed to support a system, taking into account the work has been previously done by environment to produce a good. “The unit of solar emergy is the solar emergy joule (sej), to distinguish it from the regular joule (J) and point out a different quality assessment based on a donor-side point of view”.

LCA is defined as “the compilation and the evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its entire life cycle”. Thus, LCA is a tool for the analysis of the environmental burden of products at all stages in their life cycle – from the extraction of the resources, through the production of material, product parts and product itself, and the use of the product to the management after it is discarded, either by reuse, recycling or final disposal (therefore, ‘from the cradle to the grave’).

During the first part of the project we focused our attention on the production phase of biowaste (see Figure 16), carrying out a comparative evaluation of selected sugar and nutrient rich feedstocks. The sugar rich feedstocks have been compared on a common basis that was represented by their potential to produce bioethanol (given by their glucan contents), while the comparison among nutrient rich feedstocks was done on the basis of their potential to produce bio-fertilizers (given by their ash contents). The results of this evaluation are reported in an article entitled “Sustainability assessment of selected biowastes as feedstocks for biofuel and biomaterial production by emergy evaluation in five African countries”, recently accepted by the international journal Biomass & Bioenergy for publication.

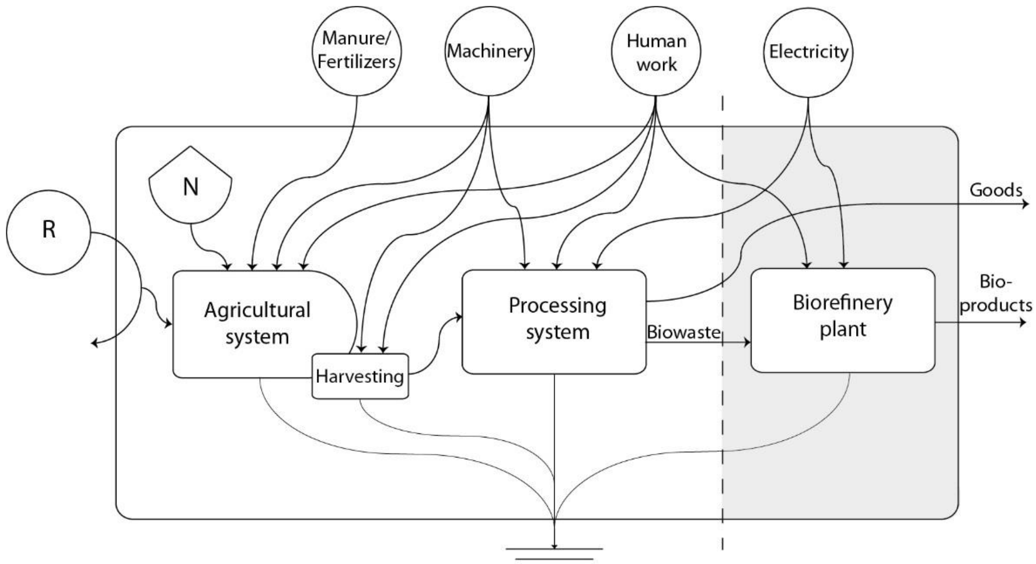


Figure 16. Energy system diagram of integrated agro-industrial production of goods and bio-products. Our study focused on the first part of the system (white section on left) that produces the main goods and related residues, keeping in mind the destination of the residues, i.e. the biorefinery plant (gray area).

Figure 17 gives an example, according to the Emergy evaluation, cassava peels (i.e. the by-product of cassava cultivation and processing), evaluated in Ghana, results the most promising sugar rich feedstocks from an emergy viewpoint, namely the one that combines high efficiency in terms of exploiting natural resources with a high degree of renewability. Manure from grazing cattle (i.e. co-product of milk in a dairy farming system), evaluated in Morocco was identified as the most promising feedstocks from a sustainability viewpoint, among nutrient rich ones. Indeed, it is the most efficient for what concern the exploitation of resources and it produces the lowest environmental impacts.

Finally, AICAD developed a guideline for sustainable management of biowaste, with the inputs of University of Siena and IVL. This document aims to be a valid support for those stakeholders that can be interested in implementing conversion processes of biowaste and bioresidues into value added products, in a context similar to that one evaluated within the Biowaste4SP project.

Guidelines in waste management focused on several aspects, including environmental and economic costs, collection and treatment methods, focus on specific waste materials or sources of materials, reducing the environmental impact such as emissions to air, land and water; adopting a market oriented approach with waste products, increasing social acceptability through public participation, formation of enforcing agencies, robust collection mechanisms, educating the public and establishment of central collection point where processing is economical throughout the year. The guidelines also cover aspects of availability, sustainability, economic viability, feedstock specifications, distance and location of biowaste feedstocks.

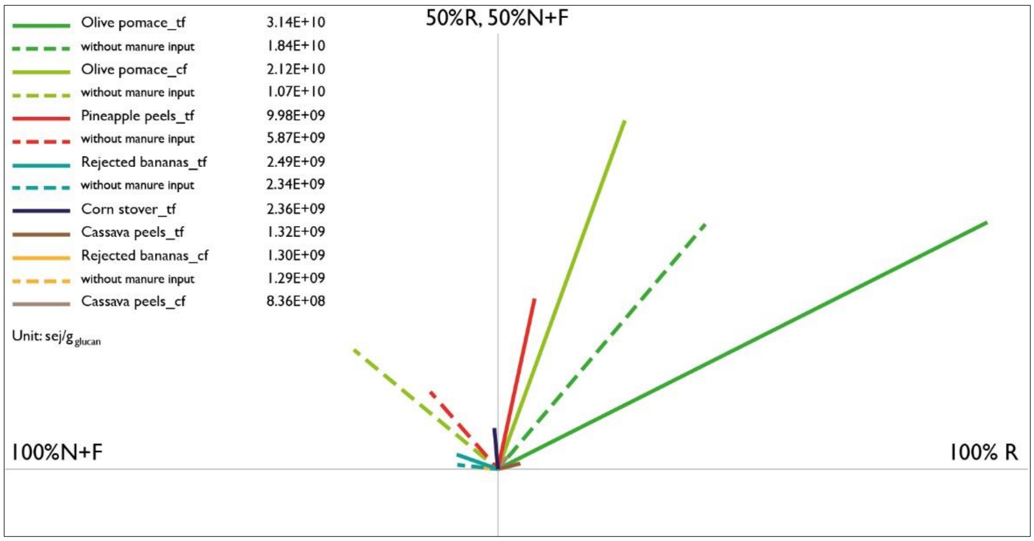


Figure17. Summary of Unit Emergy Values (i.e. the intensive expression of emergy) calculated for the sugar-rich feedstocks on the basis of glucan content, and related percentage renewability. Segment lengths are proportional to UEV (in sej/g_{glucan}) and slopes indicate the percentage renewability of the total emergy supporting the production system.

3.8 WP 8 Knowledge-sharing, dissemination, and capacity building (WAITRO)

Efficient communication among partners is a prerequisite for smooth project implementation and it was undertaken by the partner WAITRO. The Biowaste4SP placed high importance on communication efficiency among partners, project visibility and information dissemination, especially among the European and African scientific communities as well as in other regions.

The objectives of communication and dissemination were to:

- directly communicate with the researchers, main target groups and key actors, tailored and oriented to their requirements

- spread the knowledge and experience derived from the BIOWASTE4SP project to the scientific and small and medium enterprise (SME) communities of Europe and Africa as well as other regions of the world.

These objectives were met by:

- Undertaking a comprehensive review of current policies and development programs in African countries relating to biowaste conversion and assess challenges and opportunities.
- Reinforcing Research Capacity by implementing Hands-on training for PhD students that have been visiting different project partners for training purpose.
- Setting up stakeholder platforms in the main target countries.
- Distribution of project information through the WAITRO network in the African Region and Middle East North Africa Region as well as project partners' network.
- Implementing of a Project Webpage and Intranet site (workspace).
- Seminars, workshops and conference participation incl. the organization of the projects final conference.
- Identification of possibilities for developing IPR to protect the foreground generated by the project
- Publications

One major contribution to emphasize was the final conference organized by partner IAV and DTI in Morocco where all results were presented to a wide scientific community of about 80 participants (see Figure 18). The conference was covered by Moroccan television.

Figure 18: Panel discussion at the BIOWASTE4SP conference in Morocco, led by Prof. Amal Amber from ARC Egypt together with all PhD students in the project.

4 Potential impact and main dissemination activities and exploitation of results

The EU's Environmental Technologies Action Plan (ETAP) has three key dimensions, namely, 1) Getting from Research to Market, 2) Improving market conditions for the uptake of environmental technologies, and 3) Acting Globally to address environmental issues. The latter two of these were directly addressed by the outcome of this project.

Global partnership

The Biowaste4SP project contributed to the 8^{th} millennium development goals (MDGs), which seeks to "Develop a global partnership for development" by promoting international research cooperation across three continents and involving 10 countries and 16 institutions and several scientists. Scientific exchanges and networking events have enhanced long-term partnerships among the project participants.

The project brought together six leading research centres in Europe including Denmark, Sweden, Italy and Turkey. The participants included research centres, universities and SMEs operating in the biotechnological industry with proven expertise in the development of enzymes and downstream processing of chemicals and bioenergy products. The consortium also included four partners from African ACP countries (Ghana, Kenya and South Africa) as well as three partners from Mediterranean partner countries (Egypt and Morocco). The project involved the participation of three partners from Malaysia. The wide coverage of the consortium has led to a more efficient development of the bioconversion processes through a wider search for enzymes and microorganisms and the use of different substrates and operating in different environments.

The results obtained from the each work package was subjected to sustainability analysis in WP7 undertaken jointly by UNISI, IVL and AICAD, which was to ensure that the technologies developed in the project were adapted for use in Africa. The three established criteria and specifications to be met by the various processes in terms of resources input, potential environmental impacts, socio-economic suitability and long-term sustainability. For instance, it was recognised that the use of municipal biowaste, which fairly advanced in the EU17 countries, faces greater challenges in Africa due to collection and storage problems even though it may appear to present greater environmental problems, especially in urban areas. Hence, the technologies developed in this project relied primarily on other nutrient rich sources such as animal and human manure.

The inclusion of partners from Malaysia and Turkey has enhanced the project partners' ability to tailor the solutions to meet the conditions of the African and Mediterranean partner countries. Both Malaysia and Turkey have made great strides in conversion of their biowaste into useful products and some of the processes have reached commercialisation. Their experiences could be easily adapted for application in the African ACP countries where environmental conditions are similar to those in Malaysia and similarly for the Mediterranean countries where conditions resemble those in Turkey.

Impact on climate and environment

The project contributed directly to the 7th Goal of the Millennium Development Goals (MDGs), which is to "Ensure environmental sustainability". This should be done by among other things, reducing dependence on fossil fuels resources, combating climate change and mitigating its effects through a sustainable use of available food and energy resources. This goal is extremely critical to poor countries where less capacity exists to be able to combat the adverse impacts of environmental degradation. In Africa, over 60% of agricultural production is lost through waste due to poor infrastructure and food technologies. The results of this project provide the means to turn this waste into wealth by converting it into food, feed, chemicals and energy source.

A significant part of the goods and services that are available in the market in 2020 are yet unknown, but the main driving force behind their development will be the deployment of Key Enabling Technologies (KETs). The biomass industry based on new bioprocessing technologies is one of those identified as a KET for achieving Europe's industrial competitiveness.

The EU is in the forefront for promoting the achievement of several global goals and targets on climatic and environmental issues (Kyoto, Montreal, COPs, etc.). Taking the lead in developing sustainable technologies that support the biomass industry on a global scale is thus a key EU policy imperative. In order to attain a wider global impact in these efforts the EU must work in close collaboration with actors across the whole globe including from ICPC countries. Hence devoting the results of this project to achieve the improvement of the management of biowaste in Africa ACP and Mediterranean countries is seen as working towards achieving greater EU global environmental and development policies.

Impact Africa and Socio-Economics

The Biowaste4SP project clearly had a great awareness in the five participating African countries during the project time and hopefully will have impact also in the future. As illustrated by the following wordings from Prof. Hassan El Bari, AMADES, Morocco: "Thanks to the results provided by Biowaste4SP, local government and farmers in the five African countries that has participated in this project, have today a clear idea about the energy potential of their bio-wastes and the types of appropriate technologies which could be used to exploit this potential. "

The collaborative nature of this project allowed the consortium to exchange knowledge and experience among the 15 project partners from Europa, Asia and Africa. This enabled a positive impact on the quality of scientific results of the project at laboratory scale and pilot scale.

In general terms, Biowaste4SP project has contributed efficiently to:

- Identification and characterisation of African bio-waste for added-value compounds recovery.
- The transference of good practices in waste management and the opportunities of valorisations (energy, bio-chemicals, and/or agronomic e.g. protein) to the primary sectors in consortium countries, mainly to the five African countries.
- The transference of knowledge, expertise and management practices of agricultural feedstock from European countries to the African countries.

The project also contributes to meeting the 1st Goal of the Millennium Development Goals concerned with "Eradicating extreme poverty and hunger". According to some United Nations estimates, Africa is still the continent most unlikely to eradicate hunger in the first half of this century even though the continent is known to possess over half of the available global arable land. Much of this land remains unexploited due to poor soils and low agricultural input. Optimising the use of bio-fertilisers and the nutrient rich components from the biorefinery process has tremendous potential to improve most of these soils and increase agricultural output. This in turn should lead to improved food security and higher incomes for poor farmers. The results obtained by many Latin American and Southeast Asian countries through utilizing biotechnology to improve agricultural output provide best practices for African countries to emulate. This project shared some of the experiences gained from the production of biofertiliser to improve agricultural output in Malaysia and Turkey.

African countries lack appropriate policies and strategies to ensure proper environmental management. Even though most countries have environmental protection agencies (EPAs), they lack the corresponding legislative expertise to enforce good management practices. One reason for this is due to the lack of a science-based analysis of environmental issues. A systematic collection and analysis of data on waste and waste disposal is lacking to guide policy-making. This project contributed to solving this problem by providing baseline data on the characteristics of waste and how these could best be utilized. The catalogue developed from the results of WP1 and WP2, conversion technologies from WP3, WP4, WP5 and WP6, as well as the strategy guidelines developed in WP7 all contributed to achieving this goal.

The assumption for the achievement of the impacts of the project is that the development in the bioprocessing technology developed from WP3, WP4, WP5 and WP6 were sustained in spite of difficulties of industry making new investments suitable for the use of biowaste as a new feedstock. Only easy-to-handle methods were used throughout the project to ensure that the technological methods could all be implemented in developing countries.

The dominance of the petrochemical industry still determining investment patterns in industry, especially with new discoveries of fossil reserves in several African and Mediterranean countries has to be countered by deliberate incentives to assist the biomass industry to remain competitive, as is the case in many EU countries today. This can be achieved through various governmental schemes including tax incentives, national financial assistance programs targeting SMEs in the sector and additional support to research centres for technology development and transfer.

Another assumption is that greater attention will be given, at pan-African level, to assisting municipalities, regions and national governments in making more sustained efforts in promoting “green growth”, which is firmly anchored in recycling and the utilization of biowaste. This is more so as there are currently no stringent legislation towards enforcing proper environmental standards as obtains in the EU through its various directives that support the use of biowaste (e.g., Waste disposal directive, landfill, Greenhouse gas emissions directive), etc.

Impact Europe

The project results are of interest at the European level as they respond to key EU strategies on the economy and the environment. Key among these is the “Lead Market in Bio-based Products” derived from the Aho Report on "Creating an Innovative Europe". The project has contributed with improved knowledge on use of various substrates from the agricultural food sector as well as from non-European sources for the production of value-added products that are of importance in Europe. Europe is the world’s leading importer of food raw materials from Africa and knowing the detailed scientific characteristics of the waste from this source is important to the European biowaste industry.

During the project time, there has been a lot of attention to food loss in Denmark and Europe, which reflect a new tendency and could reflect some impact from the dissemination of the project to the public. To example, the projects results of the losses in the food production chain were presented in Danish television and in the Parliament Magazine. The problems with food losses and consequently negative effects to the climate has presented many times in Danish television during the last two years and there seems to be a public awareness and concern about this issue. As a follow-up to this, some supermarkets made campaigns about how to use out-date food products and in order to limit food loss, most supermarkets have now introduced “low price shelters” for out-date food products.

Dissemination

Dissemination of project results to a broad audience have been a key-element in Biowaste4SP project. Dissemination has been made in various forms of activities

The dissemination activities comprised:

- Public project website (www.biowaste4sp.eu)
- Project conference
- 14 peer reviewed scientific articles
- Conference presentations and posters
- National stakeholder platforms
- Popular articles
- Press releases
- Newsletters
- Public reports incl. public deliverables
- Videos

Overall aim of the dissemination activities have been to enlarge the impact of the project and attract as many different stakeholders as possible.

Table 3. Dissemination activities in Biowaste4SP

Peer-reviewed Journal papers
1. Bayitse, R., Hou, X., Bjerre, A.B., Saalia, F. K., (2015) Optimisation of enzymatic hydrolysis of cassava peel to produce fermentable sugars, AMB Express 5 : 1-7. 2. Bayitse, R. (2015) Lactic Acid Production from Biomass: Prospect for Bioresidue Utilization in Ghana: Technological Review. IJAST 5: 164-173 3. Bayitse, R., Laryea, G.N., Selormey, G., Oduro, W.O., Aggey, M., Mensah, B., Gustavsson, M. and Bjerre, A.B. (2014) Anaerobic Co-Digestion of Cassava Peels and Manure: A Technological Approach for Biogas Generation and Bio-Fertilizer Production – A Feature Article. JAST 19: 10 – 17 4. Saladini, F., Vuai, S., Langat, B., Gustavsson, M., Bayitse, R., Gidamis, A., Mohammed, B., Owis, A., Rashamuse, K., Sila, D. and Bastianoni, S. (2015) Sustainability assessment by means of emergy evaluation of selected biowastes as feedstocks for biofuels and biomaterials production in five African countries, Accepted by Biomass and Bioenergy, DOI: 10.1016/j.biombioe.2015.11.016 5. El Joute, Y., El Bari, H, Belhadj S.,, Karouach, F., Gradi, Y., Stelte, W., Bjerre, A.B. (2015), Semi-continuous anaerobic co-digestion of cow manure and banana waste: effects of mixture ratio, Submitted to Applied Ecology and Environmental Research 6. Bayitse, R., Hou, X., Laryea, G. and Bjerre, A.B. (2015) Protein enrichment of cassava waste using Trichoderma pseudokoningii (2015) Submitted to AMB-Express Journal

7. Bayitse R., Hansen, A.C. H., Dantoft, S. H., Wang, Z., Hou, X., Bjerre, A. B., Jensen, P., R., Production of lysine from cassava residue using Corynebacterium glutamicum (2015) Manuscript under preparation for Applied Microbiology and Biotechnology Journal
8. Isolation and characterization of lactic acid bacteria capable of converting agricultural food waste to value added products (2015) Manuscript under preparation
9. Investigation and development of prototrophic properties for selected strains of Lactococcus lactis for improved cultivation in chemically defined media (2015) Manuscript under preparation
10. Homolactic conversion of xylose and C6 sugars from selected agricultural and industrial food waste sources in African countries (2015) Manuscript under preparation
11. Tawona, N., Sithole, B., B, Parkin, J., Determining the biochemical methane potential (BMP) of fruit & vegetable waste in co-digestion with cattle manure at mesophilic conditions (2015) Manuscript under preparation for Bioresource Technology
12. Tawona, N., Sithole, B., B, Parkin, J., Identification & Characterisation of solid biowaste in South Africa: Potential feedstocks to waste to energy technologies (2015) Manuscript under preparation for Waste Management / Bioresource Technology
13. Hou, X., Bjerre AB., etc. ”Bioethanol production from banana waste feedstocks”, Manuscript under preparation
14. Bjerre, AB., Stelte, W., Hou, X. “African biowaste for Sustainable products: a review”, Manuscript under preparation

Conference Presentations

15. El Joute, Y., Gradi Y., El Bari, H., Stelte, W., Bjerre, A.B, Video :Biogas Research Team Laboratory - Ibn Tofail University - Morocco - Prof. Hassan El Bari (link: https://www.youtube.com/watch?v=7jE16vTpekg), presented in OPEN SCHOOL, 17th Apr 2014 in Oulad Said Settat, Morocco.
16. El Joute, Y., El Bari, H., Belhadj S., Turning biowaste into sustainable products: development of appropriate conversion technologies applicable in developing countries, Poster presented in Renewable Energy and Efficiency Fair 24th – 26th Sep 2013, in Chambre Francaise du Commerce et Industrie au Maroc, Casablanca, Morocco
17. Dantoft, S. H., Hansen A. C. H., Jensen P.R., Processing of biowaste for sustainable products in developing countries , poster presentation at the Conference for the National food Institute, DTU, 4th Sep 2015
18. Saladini F., Patrizi N., Vuai S.A., Langat B.K., Gustavsson M., Gidamis A.B., Bastianoni S., Analisi emergetica e LCA della produzione di biorifiuti e bioresidui in cinque Paesi africani, poster presentation at the “PhD student Day” organized by the Doctoral School in Chemistry of the University of Siena, 12th Nov 2014, Italy
19. Saladini F., Vuai S.A., Langat B.K., Gustavsson M., Bayitse R., Gidamis A., Mohammed B., Owis A.S., Rashamuse K., Ndaka D., Bastianoni S., Sustainability assessment of selected biowastes as feedstocks for biofuel and biomaterial production by emergy evaluation in five African countries, poster presentation at the “PhD student Day” organized by the Doctoral School in Chemistry of the University of Siena, 27th Nov 2015, Italy
20. Tawona N. Optimisation of a pilot scale anaerobic digester in developing countries: South Africa, Poster presented at the TAPPSA (Technical Association of the Pulp and Paper industry of South Africa) Conference – 2013, South Africa
21. Hou, X., Rashamuse, K., El Tahlawy, Y., Bayitse, R., Lawther, J.M., Owis, A., and Bjerre, A.B. Wet-milling, Hydrolysis, and Bio-ethanol Production of Banana Biomass from South Africa and Egypt, 22nd European Biomass Conference and Exhibition in Hamburg, 23rd Jun 2014, Germany

22. Tawona, N., Valorisation of biowaste: via production of biogas and compost, Oral presentation in international Conference on Chemical Thermodynamics (ICCT/SAIChE) – 2014, South Africa
23. Bjerre, A.B., Gustavsson, M., Biowaste conversion in Africa, Oral presentation of the Biowaste4SP project, Africa Innovation Network meeting at DTI, 20th Aug 2015, DTI Denmark
24. Gustavsson, M., Bioavfall i Afrika - en outnyttjad resurs? [eng: Biowaste in Africa – an unused resource?], Oral presentation in the conference of Avfall i nytt Focus [eng. Waste in new focus], Chalmers, Gothenburg, Sweden., 14th Sep 2014, Sweden
25. Stelte, W., Biowaste for sustainable products. Oral presentation at 3rd Mediterranean Workshop On “Organic Waste Recovery, Biomass And Renewable Energy”, February, 5th-8th,2013 Marrakech, Morocco.
26. Bjerre, A.B., (Biowaste for value added products: an overview, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
27. El Houssine, B., Biowaste characterization in Morocco, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
28. Gustavsson, M., Production of value added products, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
29. Hou, X., Biorefinery technologies used in an African context, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
30. El Bari, H., Biogas potentials from biowaste resources in Morocco, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
31. Hashim, S. M., Biofertilizer from Agricultural residues, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
32. Parkin, J., Biowaste utilization in African Municipalities – an Example from EThekwini municipality, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
33. Belmakki, M., Identification et caractérisation des déchets organiques au Maroc et leur valorization: Cas de valorization par la production de l’acide lactique, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
34. Tawona, N., Biowaste4SP – From an African Student Perspective, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
35. Saladini, F., Sustainability assessment of African Biowaste, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
36. El Joute, Y., Biogas production, oral presentation in African conference on – Biowaste for value-added products, 16th Sep 2015, Morocco.
37. Bastianoi, S., Sustainability of biowaste utilization in Africa, oral presentation in 17th Sep 2015, Morocco.
38. Kenny, L. , Agriculture Waste in Souss Massa: Current Situation and Prospect of Valorization through the Value Chain Approach, oral presentation in 17th Sep 2015, Morocco.
39. Gidamis, A., Agricultural Policies to facilitate biowaste use in Africa – getting business in field, oral presentation in 17th Sep 2015, Morocco.
40. Bjerre, A.B., Presentations of Biowaste4SP project, oral presentation and project flyer dissemination in The Bioeconomy Investment Summit, 10th Nov 2015, Belgium.

Other Publications

41. Tawona, N., MSc Thesis, Valorisation of Biowaste via Production of Biogas and Biofertlizer, Thesis accepted at the University of KwaZulu-Natal in July 2015
42. Bayitse, R., Supervisors: Saalia F. K., Amponsah Annor G., Jensen, P. R., Bjerre A.B., PhD Thesis: Bio-processing of cassava waste into lysine, on-going

43. Gustavsson, M., Newsletter, Potential New Feedstock of Nutrient-rich and Sugar-rich Biowaste in Africa for Future Bio-based Products. (2013) WAITRO News (December): 13
44. Amal Owis, Yasser El - Tahlawy, Long-list Report. Residues and Wastes Biomass in Egypt: Overview, potential and Challenges. January 31, 2014, LAP Lambert Academy publishing GmbH, Germany. eligible for voucher ISBN-13: 978-3-659-50869-1
45. Bartali, E. H. and M. Belmakki, Morocco country report. (2013) Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, Institut Agronomique et Vétérinaire Hassan II, Morocco - Biowaste4SP project, 1.0, 7 May, pp 61.
46. Bayitse, R., W. Oduro, M. Aggey, G. Selormey, B. Mensah and G. Laryea (2013) Ghana country report. Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, The Council for Scientific and Industrial Research (CSIR) in Ghana - Biowaste4SP project, 1.0, 7 May, pp 62
47. Sila, D. N. and N. F. Namu (2013) Kenya country report. Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, African Institute for Capacity Development (AICAD) - Biowaste4SP project, 1.0, 7 May, pp 38.
48. Owis, A. S. and Y. E. Tablawy (2013) Egypt country report. Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, Agriculture Research Center, Egypt - Biowaste4SP project, 1.0a, 7 May, pp 76.
49. Oelofse, S. and A. P. Muswema (2013) South Africa country report. Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, The Council for Scientific and Industrial Research (CSIR) in South Africa - Biowaste4SP project, 1.0, 7 May, pp 39.
50. Gustavsson, M. (2013) Summary report. Overview of potential biowaste and biobased residues for production of value added products. M. Gustavsson, Report, IVL Swedish Environmental Research Institute, 1.0, 8 May, pp 17.
51. Biowaste Public Deliverables. Report on biowaste management for the selected feedstock (D1.4)
52. Biowaste Public Deliverables. Report on biowaste management for the identified waste streams (D2.4)
53. Biowaste Public Deliverables. Report on generic process and specific variants of wet fractionation and hydrolysis of banana waste (D3.1)
54. Biowaste Public Deliverables. Report on generic process of wet fractionation and hydrolysis of cassava waste (D3.2)
55. Biowaste Public Deliverables. Report on generic process of wet fractionation and hydrolysis of rice bran and sample tests (D3.3)
56. Biowaste Public Deliverables. Final project review meeting and international conference (D9.5)
57. Press release: Italian online newspaper “greenreport.it”, on the launching of Biowaste4SP project (27th Nov 2012) http://greenreport.it/_archivio2011/index.php?page=default&id=19159
58. Simone Bastianoni e Fabrizio Saladini, La valorizzazione dei biorifiuti per una produzione sostenibile di energia in Africa. Italian magazine “Nigrizia”, on the contents of the Biowaste4SP project and the final conference in Rabat, submitted
59. Ecodynamics Group website “www.ecodynamics.unisi.it”, on the contents of Biowaste4SP project.
60. Bjerre, A.B. and M. Gustavsson (2015) New feedstocks of biowaste in Africa for development of sustainable products, The Parliament Magazine(404).
61. Bjerre, A. B., (2013) Vil genbruge Afrikas kasserede bananer [eng: How to reuse the African banana wastes], 15. AUG. 2013, Danish TV Program DR2

Conferences/Workshops

62. Biowaste4SP Project final conference: African conference on – Biowaste for value-added products. 16th and 17th September 2015 in Rabat, Morocco.

Stakeholder Engagement

Ghana

Stakeholder engagement on the national level has been fruitful. Ministry of food and Agricultural (MoFA), Energy Commission (EC), Council for Scientific and Industrial Research/ Animal Research Institute (CSIR-ARI) and Ministry of Environment Science, Technology and Innovation (MESTI) are the key stakeholders for collaboration.

Currently, Council for Scientific and Industrial Research/ Institute of Industrial Research (CSIR-IIR) (project designers and consultants), Cross Border Logistics Company Limited (project contractors), Vulpec Engineering Limited (supporting consultants and MESTI are collaborating to design and construct Anaerobic Bio-Reactors (ABRs) for the production of biogas from excreta at senior high school boarding houses in Ghana with an initial target of 30 ARBs at selected schools in three adjacent regions; Greater Accra, Central and Eastern regions. It is planned to convert the biogas produced into electricity for use in the schools thereby reducing dependency of these schools on the national grid for electricity. From May to September, 2015 up to ten (10) ABRs were constructed at seven (7) schools in the Greater Accra region.

Based on the Biowaste4SP results, CSIR-IIR is putting up proposals in collaboration with MoFA and CSIR-ARI to formulate poultry feed from cassava residue using Solid State Fermentation (SSF) for protein enrichment using Trichoderma pseudokoningii (ATCC 26801). The SSF process in the lab has been conducted on the Biowaste4SP Project. The results were encouraging and a journal article was published. When the proposal is finalised, the formulation will be done by CSIR-IIR and the trial conducted by CSIR-ARI with support from MoFA. Based on the outcome of the field trial, the quality of the feed will further be enhanced by lysine addition. This part of the work will be done in collaboration with DTI and DTU for technology enhancement.

Egypt

The handling and disposal of waste is an important topic in Egypt. A significant portion of todays' waste is disposed into canals, rivers, streets or open areas without any treatment or preventive measures. This causes water, soil and air pollution and spoils the landscape. It also poses a serious risk to public and animal health and negatively impacts the economy, especially the tourism sector. The public sector and private companies are becoming increasingly aware of this problem and can also see the business potential behind it. The Agricultural Research Center (ARC) has promoted the project within Egypt and gathered a group of stakeholders from the public sector, private companies and academic institutions that have been following the progress and results of the Biowaste4SP project. ARC has a broad network within the Egyptian public, private and academic sector and served as a hub to promote the project to different stakeholders. Key stakeholders have been private sector companies like ECARU - Solid waste recycling, El Gohary - Industrial and agricultural development and NGO partner “Protect the environment from pollution Central Association”

Morocco

The results of this project have a positive impact on the priority sectors of the Kingdom of Morocco. Indeed this project perfectly consistent with the priorities of the Government of Morocco in the development of technologies related to renewable energies as provided by law 13-09. By participating in this project, the partners from Morocco has once again confirmed its place in the African continent as a quality research institute. The Biowaste 4Sp project was an opportunity to develop new relationships with other research institutes in Africa, Asia and Europe.

In addition, the project was a great opportunity to work with well-reputed international institutions and there is a good chance to collaborate with in several scientific projects in the future. Furthermore, its demonstration activities had provided a useful information on new technology concepts that make recycling of African bio-waste economical sustainable and contribute to reducing environmental impact. The results of this project on the production of biogas by co-digestion (mixture of municipal and agricultural waste) has helped us to gain a clear vision on possible territorial approach about the development of biomass-waste recovery projects in Africa based on the optimization of the production of biogas by adequate mixing of the different types of organic substrates (scale economy effects). The stakeholders invited by the IAV have fulfilled their commitment and have participated in dissemination of the project results. The highly interesting results of this project in terms of biowaste will contribute undoubtedly to improve the current waste management especially with the presence of the Ministry of Environment at the dissemination conference.

Kenya

The Kenyan stakeholder platform comprises of a number of private companies from the fruit and vegetable processing industry such as Delmonte K Ltds, Njoro Canners and Mumias Sugar, public bodies such as Nairobi City Council and Kiambu County Government and R&D institutions such as University of Nairobi (UoN) and Kenya Industrial Research & Development Institute (KIRDI). The industrial stakeholders have vast amount of unutilized sidestreams such as pulps from juice and sugar production and residues from plantations and have been very interested in the project results. The

Kenyan project partner AICAD (African Institute for Capacity Development) has been a very active promoter of the project and gathered project stakeholders from in Kenya, Tanzania and Uganda.

Republic of South Africa

South African stakeholders comprise start-up companies in the area of waste conversion such as "Biowaste Technologies" and "Ibert - Converting Bio waste into green Energy" and public bodies such as the Department of Science & Technology. Both South African partners CSIR and Ethekwini municipality have promoted the project to their networks and recruited stakeholders from private and public sector.

Education

Research Capacities in Africa have been reinforced in multiple ways through the BIOWASTE4SP project. The project made it possible to train PhD students and contributed to capacity building in participating African countries. These PhD students with their respective advisors will pursue the momentum created by the project and will apply to new collaborative research calls, train new human resources, develop research capabilities, collaborate with professionals and stakeholders (such Elephant Vert in Morocco) to get more added-value products from biowaste. Such products include bio fertilizers and biofuels that will help reduce dependence on energy imports and related costs and will protect environment and increase resilience to climate changes in African countries.

Four PhD students, two Post Docs and a master student from the universities in Africa (Morocco, Ghana, Egypt and South Africa), were educated and given the opportunity to learn new laboratory techniques at training sessions held at the Danish Technological Institute (DTI) and at other European Institutions. These students are expected to apply the newly acquired knowledge at the respective organisations in their home countries. A training session on bio-fertilizer production was developed by partner MYAGRI Malaysia. The trial of this concept was tested at Ethekwini Municipality (ETM) in South Africa. The projects PhD students presented their research results also at the project final conference (Figure 19).

Figure 19. PhD students presenting their scientific work achieved in the Biowaste4SP project, left: Yassine El Joute from AMADES; middle: Richard Bayitse from CSIR-Ghana; right: Fabrizio Saladini from UNISI

Genders aspects

The Biowaste4SP project has made a successful effort to achieve a gender balance in the workforce. The ten work package leaders were five woman and five men, and the total workforce in the project was 60% men and 40% woman. The project management team consisted of two women and two men.

5 Address of the project's public website and relevant contact details

The BIOWASTE4SP project website (www.biowaste4sp.eu) was established at the beginning of the project by partner WAITRO. The site was well-designed and user-friendly and has served the needs of all user groups. It has regularly been updated with project news and events as well as when new deliverables were accomplished and with publications and conference presentations.

The Consortium also established an Online Workspace used for project management purposes. The Online Workspace was password-protected and has been used for storing all important project documents, essential European Union guidelines, project schedules and relevant literature. The Workspace has been accessible to partners as part of their project toolbox. An online forum for discussion among project partners was also available in the Online Workspace.

Project partners and relevant contact details

No.	Participant organization name	Country	Main contact	email
1	Danish Technological Institute	Denmark	Prof. Anne-Belinda Bjerre	anbj@dti.dk
2	Swedish Environmental Research Institute	Sweden	Dr. Mathias Gustavsson	mathias.gustavsson@ivl.se
3	TÜBİTAK Marmara Research Center	Turkey	Dr. Guldem Utkan	guldem.utkan@tubitak.gov.tr
4	SIRIM Berhad	Malaysia	Dr. Ahmad Hazri Bin Ab. Rashid	ahazri@sirim.my
5	Council for Scientific and Industrial Research Institute of Industrial Research (CSIR-IIR)	Ghana	Dr. Gabriel Nii Laryea	gabniilar@gmail.com
6	Council for Scientific and Industrial Research	South Africa	Dr. Konani (Koni) Rashamuse	JRashamuse@csir.co.za
7	Agricultural Research Centre	Egypt	Prof Dr. Amal Saber	amalsaber@yahoo.com
8	University of Siena	Italy	Prof. Simone Bastianoni	bastianoni@unisi.it
9	Hassan II Institute of Agronomy and Veterinary Medicine	Morocco	Prof Dr. El Houssine Bartali	bartali.h@gmail.com
10	Danish Technical University	Denmark	Prof Peter Ruhdal Jensen	prj@bio.dtu.dk
11	Ethekwini Municipality	South Africa	Mr. John Parkin	John.Parkin@durban.gov.za
12	Myagri Group of Companies	Malaysia	Ms. Salwa Md Hashim	salwa.myagri@gmail.com

13	Biovelop AB *(Merged into Tate and Lyle since 2014) – Biovelop has left consortium after M18*	Sweden	Henrik Schmidt - *Has left consortium*	*Not available*
14	Moroccan Association for Solid Waste	Morocco	Prof. Hassan El Bari	AMADES_morocco@yahoo.fr
15	African Institute for Capacity Development	Kenya	Prof Andrew Gidamis	gidamis@aicad.or.ke
	World Association of Industrial and Technological Research	Malaysia	Dr. Rohani Hashim	rohanih@sirim.my

Project logo

To create uniformity in communication a logo was developed in the beginning of the project with the African continent shown in green and with a banner across with the project title (Figure 20). It has been used throughout the project, e.g. in reports, power point presentations, posters or any kind of dissemination acitivitysuch as this one (top right corner) and by all partners to ensure project identification inside as well as outside the project.

Figure 20: Project logo, Biowaste4SP (Biowaste for Sustainable Products)