Sustainable utilization of agro-industrial wastes through integration of bio-energy and mushroom production

Amelia Kajumulo Kivaisi, Berhanu Assefa,
Suhaila Omar Hashim, Anthony Manoni Mshandete

October 2010
International Livestock Research Institute (ILRI)

ILRI
INTERNATIONAL
LIVESTOCK RESEARCH
INSTITUTE

ILRI works with partners worldwide to help poor people keep their farm animals alive and productive, increase and sustain their livestock and farm productivity, and find profitable markets for their animal products. ILRI's headquarters are in Nairobi, Kenya; we have a principal campus in Addis Ababa, Ethiopia, and 14 offices in other regions of Africa and Asia. ILRI is part of the Consultative Group on International Agricultural Research (www.cgiar.org), which works to reduce hunger, poverty and environmental degradation in developing countries by generating and sharing relevant agricultural knowledge, technologies and policies.

Citation: Kivaisi, A., Assefa B., Hashim S., Mshandete A. 2010. Sustainable utilization of agro-industrial wastes through integration of bio-energy and mushroom production. Nairobi, Kenya, ILRI.

International Livestock Research Institute

P O Box 30709, Nairobi 00100, Kenya
Phone + 254 20 422 3000
Email ILRI-Kenya@cgiar.org

P O Box 5689, Addis Ababa, Ethiopia
Phone + 251 11 617 2000
Email ILRI-Ethiopia@cgiar.org

www.ilri.org

Consortium Project Document - Project 04/2010

Principal investigator:

Professor Amelia Kajumulo Kivaisi
Department of Molecular Biology and Biotechnology
College of Natural and Applied Sciences (CoNAS)
University of Dar es Salaam
P. O. Box 35179, Dar es Salaam, Tanzania
E-mail: Amelia_kivaisi@yahoo.co.uk and akivaisi@amu.udsm.ac.tz

Co-Principal investigators:

Dr Berhanu Assefa
Chemical Engineering Department
Institute of Technology
Addis Ababa University
P. O. Box 385, Addis Ababa, Ethiopia
E-mail: hmberhanu@yahoo.com

Dr Suhaila Omar Hashim
Department of Biological sciences
Pwani University College
P.O. Box P. O. BOX 195 - 80108, Kilifi, Kenya
E-mail:sohashim@yahoo.com

Dr Anthony Manoni Mshandete
Department of Molecular Biology and Biotechnology
College of Natural and Applied Sciences (CoNAS)
University of Dar es Salaam
P. O. Box 35179, Dar es Salaam, Tanzania
E-mail: mshandete@amu.udsm.ac.tz

Amount Requested: **USD 1.2 M**

Duration: **2011-2013**

October 2010

2. Executive Summary

Sustainable use of renewable natural resources through value addition using biological life processes is an ideal transition in a petroleum based economy to bioresource economy, and in addressing climate change. The purpose of this project is to demonstrate innovative technologies with a potential to utilize agro-industrial wastes currently seen as low value materials as bioresource to produce value added products at the same time reducing environmental pollution burden. The project entitled: "Sustainable utilization of agro-industrial wastes through integration of bio-energy and mushroom production" proposes to integrate mushroom cultivation and bioenergy production from coffee processing and sisal wastes for more value addition. The project will establish techno-economic feasibility of the integrated technologies and disseminate to stakeholders. The direct potential benefits anticipated in this project include biogas for electricity production, high energy coffee waste briquettes, edible mushrooms, biofertilizer and public good. The project has a potential to benefit agro processing industries that will diversify their products through utilization of wastes to produce bioproducts with high economic value thus giving them a competitive advantage. Delivery of the project is feasible because it will be executed by a consortium made up of multidisciplinary development partners from Ethiopia, Kenya, Tanzania, Federal Republic of Germany and Denmark who will complement each other to deliver the expected outputs. The consortium is collabollating with private sector partners as a platform for future product commercialization. The project is anticipated to last 3 years and estimated to cost approx. USD 1.5 million.

3. Background and rationale for the proposed project

Biorefining of waste biomass involving the integrated production of chemicals, materials and bioenergy is a potential alternative for adding significant economic value to the waste as a bioresource. In the 21st century and beyond, bio-resource based economy is envisaged globally as a strategy towards achieving social, economic and environmental sustainability. Agriculture will be core to the bio-resource based economy, providing source of raw materials, which are sustainable, plentiful and inexpensive for utilization in bioprocesses for the production of bio-products. In the Eastern Africa's (EA) economy, agriculture is the mainstay and currently accounts for about 80% of the rural incomes, and coffee and sisal are among the important cash crops. EA is currently producing about 600,000 tons of coffee beans and about 100,000 tons of sisal fibre annually. Crop production and processing activities are generating huge quantities of organic waste.

Coffee processing done by wet and dry methods discard away 99% of the biomass generated by the coffee plants at different stages from harvesting to consumption. This includes cherry wastes, coffee parchment husks, sliver skin, coffee spent grounds, coffee leaves, and wastewater. Wet processing uses up to 15 m^3 of water to produce one ton of clean beans [1] and for every ton of beans produced, about one ton of husks are generated. It is estimated that coffee processing is generating about 9 million m^3 of wastewater, and 600,000 tons of husks annually in the EA region.

Production of sisal fibre from the sisal plant (*Agave sisalana*) is also a high waste industry currently using only about 2% of the sisal plant as fibre and the rest being various wastes, including decortications wastes (wastewater, sisal leaf decortications, sisal short fibres and sisal dusts) and post harvest waste (sisal stems or sisal boles). The traditional wet sisal leaf decortications process generates about 100 m^3 and 25 tons of wastewater and solid wastes, respectively, per ton of sisal fibres produced. In Tanzania and Kenya, about 20 million m^3 of sisal decortications wastewater and 5 million tons of solid sisal decortications wastes are generated annually [2]. Annual generation of post harvest sisal (stems) boles in both Kenya and Tanzania is significant and estimated at 4-8 million tons (Katani Ltd, Tanzania, personal Communication).

Agro-industrial wastes generated in EA are mostly underutilized, untreated and thus in most cases disposed off by burning, dumping or by unplanned landfilling. These practices are a wastage of bioresources apart from contributing to emission of green house gases (GHG) leading to climate change. At the same time, utilization of fossil fuels which is also contributing to GHG emissions has become a global concern thus necessitating the development of alternative cleaner, renewable bioenergy resources. Organic wastes despite being a menace to the environment, represent a potential bioresource for production of value added products such as food in the form of mushrooms, feed, bioenergy, biofertilizers and other biobased products [3].

Coffee waste contains high amounts of organic substrates including carbohydrates proteins, pectins, fibres and fat for bioconversion into value added bioproducts [4]. However, large-scale utilization and management of coffee wastes around the world still remains a challenge due to caffeine, free phenols and tannins (polyphenols) which are known to be very toxic to many life processes [5]. Previous studies have confirmed that toxic materials can be minimized by hot water pretreatment, microbial biodegradation and aerobic fermentation [6], [7]). To that effect, production of bioproducts such as silage, biogas, worms, animal feed, ethanol, vinegar, single-cell protein, enzymes, biopesticides, and probiotics have only been established at small scale thus demonstration of the technology at pilot scale is yet to be achieved. [8], [9]).

Production of oyster mushrooms using coffee husks for mushroom cultivation has been attempted in southern America [7]. However, utilization of the other coffee wastes for oyster mushroom cultivation is still in its infancy and not well documented [9]). One of the strategies to utilize other coffee wastes could be composting of fresh coffee wastes before growing oyster mushrooms. This will not only reduce the toxic nature, but also help in obtaining high mushroom yields on bulky cheaper coffee waste substrates, thus making the venture technically realistic and feasible at large scale.

Apart from growing oyster mushrooms to utilize coffee wastes holistically, another innovative approach is biogas production [8]. The biogas produced could be used for roasting of coffee processing solid wastes and the waste heat from the roasting unit could be used for pre-drying of the wastes. The roasted coffee waste would produce briquettes with 70 % less processing cost and 80 % more energy density than the ones made from raw biomass [10]. However, the feasibility of this concept is yet to be investigated and demonstrated at pilot scale in EA and elsewhere.

The sisal industry in EA is facing a number of challenges mainly caused by its failure to adopt new technologies to utilize other parts of the sisal plant apart from hard fibres. A holistic approach to utilize sisal decortications wastes and post harvest wastes presents a feasible future option for the survival of the sisal industry [11]. To that effect, efforts have recently been made to diversify bioproducts from sisal wastes. Mshandete and Cuff [12] reported oyster mushrooms cultivation on solid sisal decortications wastes only at laboratory scale. However, oyster mushroom production from sisal post harvest wastes has never been investigated. Furthermore laboratory investigations under the just ended BIO-EARN programme showed that anaerobic digestion of solid sisal decortications wastes to biogas is technically feasible and could be improved by various methods [13], [14]). However, production of biogas from post harvest sisal wastes is yet to be established and demonstrated at pilot scale.

Currently in Tanzania and Kenya, solid sisal decortications wastes are used as feedstock for large scale biogas production using stirred tank bioreactors (STBR), and conversion of the biogas to electricity. However, biogas production is limited by the lignocellulosic nature, and high carbon:nitrogen ratio of solid sisal wastes. Traditionally, hydrolysis of lignocellulosic materials for increased biogas production is achieved by pre-treatments. The C:N ratio can be manipulated conventionally by blending materials low in carbon content with those that are high in nitrogen content and vice versa. An innovative way of increasing nitrogen content of lignocelluloses and at the same time improving on hydrolysis of their fibre components is by fungi pretreatment, particularly white-rot prior to anaerobic digestion [15]). However, the potential of mixed sisal decortications wastes and post harvest sisal wastes as substrates for oyster mushroom cultivation and subsequent utilization of the spent substrates for biogas production is yet to be investigated.

Biogas manure (BgM) is a byproduct obtained from biogas plants after anaerobic digestion of organic matter. Anaerobic digestion reduces carbon: nitrogen ratio by removing some of the carbon thus increasing the fertilizing value. BgM is rich in organic matter, supplies essential nutrients, trace elements and other active substances. It is rich in humic acid that enhances water holding capacity, soil aeration, accelerates root growth and inhibits growth of weed seeds. The nitrogen released from organic matter during anaerobic digestion, becomes ammonium which is water soluble and thus readily available for plant uptake. Evaluation of fertilizer value of BgM resulting from anaerobic digestion of coffee and sisal wastes with integrated oyster mushroom cultivation has never been done. The proposed project therefore, intends to apply an innovative approach for the utilization of agro-industrial based organic waste for bioenergy production with integration of mushroom cultivation, thus adding more value to local bioresources in a sustainable manner, while at the same time minimising GHG emissions. Thus, this project fits within the BIO-INNOVATE priority areas of themes 1&2 with respect to climate change adaptability, food productivity and security, value addition to local bioresources in a sustainable manner and enhancing bioenergy recovery.

References

1. Hue N. V., Bittenbender H. C., and Ortiz-Escobar M. E., (2004). Managing coffee processing water in Hawaii, Department of Tropical Plant and Soil Sciences, College of Tropical Agriculture and Human Resources, University of Hawaii, Manoa, Honolulu, HI 96822, USA.
2. Muthangya, M., Mshandete, A.M., Kivaisi, A. K. (2009). J. Agricultural and Biological Science. 4(4): 66-73.
3. Okonko, I.O., Adeola,O.T., Aloysius,F.E., Damilola, A.O and Adewale, O.A (2009). 8 (4): 263-286.
4. Gathuo, B., Rantala, P. and Maatta, R., (1991). Water Sci Technol, 17(1).
5. 5.Fan L., Soccol A.T., Pandey A.and Soccol , C.R. (2003). Micologia Applicada International 15 (1):15-21.
6. Gaime-Perraud, I., S. Roussos and Martínez. Carrera, D (1993), *Micol. Neotrop. Appl*., 6**:** 95-103.
7. Martínez-Carrera, D., A. Aguilar, W. Martínez, M. Bonilla, P. Morales and M. Sobal, (2000). *In*: Sera, T., C. Soccol, A. Pandey & S. Roussos (Eds.). Kluwer Academic Publishers.
8. Neves, L., Oliveira,R. and Alves, M.M. (2006). 26 :176–181.
9. Murthy P.S. and Manonmani H.K. (2008). Research Jornal of Environmental Science. 2(2):145-150.
10. Bergman, P.C.A and Kiel, J.H.A (2005). Torrefaction for biomass upgrading, Proceeding of 14th European Biomass Conference & Exhibition, Paris, France.
11. Bisanda, E.T.N and Enock J. (2003). *Discovery and Innovation*. 15 (1/2): 17-27.
12. Mshandete, A.M and Cuff, J. (2008).. African J. Biotech. 7(24): 4551-4562.
13. Mshandete, A.M. (2005). Ph.D Thesis University of Dar es Salaam, Tanzania.
14. Muthangya M. (2008). M.Sc. Dissertation. University of Nairobi Kenya.
15. Mehta, V., Gupta, J.K. and Kaushal, S.C. (1990). *World J. microbial and Biotech.* 6:366-370
16. Muthangya, M., Mshandete, A.M., Kivaisi, A. K. (2009). Int. J. Mol. Sci. 10: 4805-4815.

4. Adding value to existing efforts

A number of efforts have been initiated at regional level to address problems of hunger and poverty via agricultural production, advocating for value addition to agricultural products and sustainability of food production. Some of these initiatives include the Forum for Agricultural Research in Africa (FARA), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the Comprehensive Africa Agriculture Development Programme (CAADP). The proposed project will complement these initiatives indirectly through utilization of agriculture-based waste for generation of renewable energy and food production in the form of protein-rich mushrooms. This approach will contribute to efforts towards sustainable agriculture in the region.

Initiatives have also been in place to address problems of pollution as a result of disposal of untreated agro-industrial and industrial wastes in East Africa for climate change mitigation. The largest of the initiatives was the Lake Victoria Environmental Management Project (LVEMP) and the just ended BIO-EARN programme. In Phase III of the latter programme, research focused on establishing improved technologies for the production of bioenergy and recovery of value added products from fish and sisal processing wastes. Pre-treatment of sisal waste with mycelia of a local fungus resulted in a significant improvement in biogas production [16]. These results raised another research question on the possibility of adding more value to the waste by first cultivating edible mushrooms and then using the spent mushroom substrates (SMS) as a feedstock for biogas production.

The chances of success of the proposed project are very high because it will build on sound knowledge, expertise and an experienced platform of partners with defined roles and commitment, with a large input of previous investments, experiences and achievements from the recently concluded Sida-supported BIO-EARN Program. Incentives and conducive policies present in the region also provide an enabling environment for the project objectives to be achieved. Besides, the proposed project has a big potential for replication in the region at small, medium and commercial scales, to produce mushrooms and bioenergy. This increases the chances of success.

5. Potential for economic and social impact

The project has a potential to stimulate economic growth and sustainable development in the region because there is evidence of demand for the proposed innovation. As mentioned above, the recently installed industrial plant producing biogas from sisal decortication waste in Tanzania is obtaining lower biogas yields than anticipated. This has been attributed to the fibrous nature and poor nutrient ratios of the feedstock. To improve on the nutrient rations of the waste, the industrial biogas plant for electricity generation recently installed at Kilifi, Kenya is co-digesting sisal waste with cow manure. The demand for technology to maximize biogas yields from sisal waste is hence evident. Worldwide it is well established that utilization of coffee wastes in production of bioproducts is impended by the toxic nature of the wastes. Reduction of toxic nature of the coffee wastes by growing mushrooms is an innovative approach towards alleviating the problem at the same time producing a valuable product. Utilization of biogas generated for improving the energy content of coffee solid wastes for briquettes is yet an attractive innovation. Additionally, BgM has a big potential in organic crop production which is currently a popular practice generating more revenue from the produce. Within the Eastern African region, production of edible mushrooms is at a small scale which is hardly satisfying the fast growing demand for fresh mushrooms locally and by the booming tourist industry. In Kenya, the current production is estimated at 500 tons per annum and the imports stand at 150 tons per annum. In Ethiopia, the current demand for fresh mushrooms by hotels and airlines is estimated at about 460 tons and being catered mostly through imports because the production is much lower. In Tanzania, production stands at 30 tons while the imports stand at about 150 tons. The local market for fresh mushrooms in Eastern Africa is guaranteed and needs to be satisfied. On the other hand, the global mushroom demand is more than 50 billion USD annually and is increasing every year by about 20%, hence there is also room for export markets. Additionally, there is also a growing demand for mushroom-based food supplements as health-enhancing additions by the local and external markets. Therefore the demand for large scale production is apparent with a huge impact potential.

The proposed project has a potential to impact on socio-economic development in the participating countries. First of all, energy from biomass is a sustainable and an environmentally sound means of producing modern energy. Currently, agro-processing industries depend mainly on thermal/hydro electricity which has been unrealiable and expensive. Utilization of the wastes that these industries generate for energy production in the form of heat and power will provide them with a more sustainable, realiable and cost-effective source of energy. Additionally, energy will be produced locally, thus stimulating local self employment.

Mushroom cultivation is a labour intensive activity and therefore has a potential to employment opportunities, particularly for villagers within the vicinity of agro-processing factories in order to improve their livelihood. Mushroom cultivation on a large scale will thus improve on their availability at affordable cost, and hence provide the people with an additional nutrient rich vegetable which can be of direct benefit to the human health. Mushroom cultivation is a profitable agri-business and mushrooms can be sold in local markets or exported to earn foreign revenue that will definitely contribute to sustainable economic development.

6. Regional and international collaboration

The execution of the proposed project will involve participation of partners in public and private sectors within the Eastern African region including, Kenya, Tanzania and Ethiopia and international partners from Germany and Denmark. A regional and international approach is more effective than a national one because it will broaden the field for the availability of technical know-how, providing a platform for the convergence and complementing competences and experiences of partners to foster strong linkages to address common regional developmental challenges such as environmental pollution emanating from agro-processing, climate change mitigation, and sustainable energy sources in an efficient manner. Additionally, in the wake of the East African common market, the chances for evaluation, incubation and eventual outlet for developed products is greater than in a national setting. Besides, the project intends to develop integrated technologies to utilize agro-industrial waste to generate energy and mushrooms that has a potential to benefit the entire region through adoption. A regional approach is a more rational way of utilizing funds because it will avoid duplication of efforts.

7. Project goal and purpose

The development goal of this project is that by 2013, the Eastern African region has in place, pilot scale plants demonstrating the utilization of agro-industrial wastes by applying an innovative biorefinery approach of integrating production of edible mushrooms and biogas, and its conversion to electricity thus adding more value to the bio-resource. Specifically, the project seeks to establish the feasibility of applying this concept in the utilization of sisal and coffee wastes to produce oyster mushrooms, and utilize the spent mushroom waste mixed with selected agro-industrial wastes as a feedstock for improved biogas production. Furthermore, the project aims at demonstrating the use of biogas for firing an infrared roaster for production of coffee waste briquettes. The purpose is to get this innovative technology adopted by respective agro-industries for cleaner production and hence climate change mitigation.

8. Objectives

In order to achieve the stated developmental goal, the following specific objectives must be achieved:

1. To establish technologies for integration of mushroom cultivation with biogas production from coffee and sisal processing, and sisal post-harvest waste.
2. To evaluate the suitability of coffee solid waste for the production of high energy briquettes utilizing a biogas fired infrared roaster.
3. To evaluate techno-economic feasibility of the developed technologies.
4. To assess the fertilizer value of the biogas manure.
5. To disseminate the results of the established technologies.

9. Outputs

The project will deliver the following major outputs:

a. Protocols for optimal formulations of substrates and parameters for mushroom cultivation using coffee and sisal wastes.
b. Laboratory protocols for biogas production from mushroom spent substrate mixtures in two stage and stirred tank bioreactors.
c. Commercial scale mushroom growing facilities (1000kg/month capacity) utilizing 2000 tons of wet substrates.
d. Ten (10) cubic meter digesters with a potential to produce a minimum of 5 cubic meters of biogas per day installed on site at collaborating sisal factories. Assuming a methane content of the gas to be produced is 60%, the gas to be produced is equivalent to about 9 kWh of electricity and 13.5 kWh of thermo energy. In the case of coffee waste, the pilot plant size is estimated to produce about 4 m^3 biogas/day under normal circumstance. The intended biogas generation volume is estimated from 8 hours gas consumption for firing infrared roaster assuming its consumption rate is equal to house hold biogas stove consumption, i.e. approximately 300 l biogas/hr.
e. Skilled employees in mushroom cultivation and biogas production at collaborating factories
f. Information on optimal logistics for the mushroom-bioenergy plants and markets for the products.
g. Data on performance of the scaled-up mushroom farm and biogas plants.
h. Information on composition of the upgraded biogas and its suitability for firing an infrared roaster
i. Infrared roaster and briquette making machine fabricated
j. Coffee waste briquettes and data on their energy density.
k. Information on performance of the power generator utilizing biogas
l. Data on fertilizer value of biogas manures.
m. Data on techno-economic feasibility of the integrated technologies

10. Outcomes

The proposed project intends to impact directly and indirectly on the environment and on the economies of the beneficiaries (starting with the partner factories) and the region at large. Within short and medium terms, the following outcomes are envisaged: 1) By 2013, a significant decrease in waste disposed off in the vicinity of the collaborating coffee and sisal-processing factories will have been realized 2) An increase in the number of employees at collaborating factories due to mushroom cultivation 3) An increase in availability of mushrooms and their consumption by communities in vicinities of the collaborating factories 4) The project partners that include Coffee Plantations Development Enterprise in Ethiopia, Kilifi Plantations Ltd in Kenya and Mohamed Enterprises in Tanzania, will be engaged in running and monitoring the demonstrated systems at their premises beyond the project period and Memoranda of agreements signed between the partners by the end of the project. 5) Increased knowledge and skills in mushroom and biogas production among factory workers 6) Through proper information dissemination, it is expected that the project outputs will increase interest in potential stake holders and engage them in verification of the developed technologies and 7) The project will prompt investments in large-scale spawn (mushroom seed) production industries.

11. Methodology and description of project activities

11.1 Project Design

The project will be implemented under three major components that include 1) coffee processing waste 2) sisal decortication waste and 3) sisal post-harvest waste in two phases. In Phase 1, the technology will be established and optimized followed by up-scaling for demonstration and dissemination in Phase 2. The following specific activities will be carried out:

Phase 1

1. Holding of project inception workshop.
2. Procurement of equipment.
3. Determination of abundance and characteristics of coffee waste streams in Ethiopia, and sisal wastes at collaborating factories in Kenya and Tanzania.
4. Evaluation of suitability of various coffee waste streams and optimization for oyster mushroom cultivation.
5. Optimization of substrate formulations using sisal decortication wastes (SDW) and sisal post-harvest wastes (SPHW) for oyster mushroom cultivation.
6. Investigations on biogas yield potentials of coffee waste spent substrates (CWSS) singly and in combination with coffee processing wastes (CPW) and other organic wastes in batch bioreactors.
7. Investigations on biogas yield potentials of sisal decortication waste spent substrate (SDWSS) singly and in combination with sisal processing wastes (SPW) and other organic wastes in batch anaerobic bioreactors.
8. Investigations on biogas yield potentials of SPHW spent substrate singly and in combination SPW and other organic wastes in batch anaerobic bioreactors.
9. Examination of performance of a two-stage anaerobic digester for biogas production from selected blends of CWSS with CPW, other organic wastes and optimization.
10. Optimization of biogas production from selected blends of SDWSS and SPHSS with SPW and other organic wastes in a laboratory scale stirred tank bioreactor (STBR).
11. Design and construction of demonstration mushroom growing facilities (1000 kg/month capacity) on site at collaborating factories.
12. Design and construction of a 10^3 m. demonstration biogas plants.

Phase 2

1. Training of selected factory employees in mushroom cultivation and biogas technology.
2. Commercial scale mushroom cultivation on site at collaborating factories.
3. Start-up, operation and monitoring of scaled-up biogas digesters utilizing the optimal spent substrate mixtures
4. Coupling of biogas digester to the upgrading unit and electricity generator and monitor
5. Designing and constructing a biogas-fired infrared roaster and briquette making machine
6. Production of briquettes from roasted coffee waste and evaluation of energy density
7. Determination of fertilizer value of resultant biogas manures
8. Determination of optimum logistics for mushroom farm and bioenergy plants, identification of markets and distribution of the products
9. Carrying out of techno-economic analyses of the established technologies
10. Holding of a dissemination workshop
11. Analysis of results and final reporting

11.2 Methodology

Abundance and characteristics of waste: Field surveys will be conducted at collaborating factories in Tanzania and Kenya to quantify sisal decortications waste and sisal post harvest waste (boles) while in Ethiopia, national generation of coffee waste will be established. All waste streams will characterized by standard methods and will require ovens, furnaces, COD analyses, dissolved oxygen meter, pH probes, etc.

Oyster mushroom cultivation: Selected strains of oyster mushrooms will be procured from reputable mushroom culture banks and will be sub-cultured and cryo-preserved. Sub-cultured mushroom strains will also be used for spawn making. Spawn will be produced using spawn making facilities which include autoclaves, laminar flow hoods, incubators etc. A cold storage facility shall be used for temporary storage of the produced spawn prior to propagating on the substrates. In order to determine optimal substrate formulations that will shorten the crop cycle and increase mushroom yield, different substrate blends and conditions for oyster mushroom cultivation will be investigated at laboratory scale.

Laboratory scale experiments: Anaerobic batch bioreactors will be constructed using 1L Erlenmeyer flasks and accessories to investigate biogas yield potentials from spent mushroom substrates and different blends of spent mushroom substrates with other waste streams. Biogas quantity and content will be monitored using innovative analytical methods that have been developed in the laboratory. Two-stage anaerobic digester (for coffee-based waste) and intermittently stirred tank bioreactor (for sisal-based waste) using optimum substrate blends for biogas production will be tested and operational conditions optimized.

Up-scaling: Mushroom production will be scaled up to 1000kg/month using best coffee and sisal based substrate formulations in an innovative, low technology farm to be constructed along with a steam chamber for bulk pasteurization of substrates. A facility for composting coffee waste substrates will also be constructed. The optimum blends of spent mushroom substrates with other waste streams will be used in scaling up of biogas production. A two stage (10 cu.m) anaerobic digester will be evaluated for generating biogas that will be used as feed for a gas-fired infrared dryer/roaster for production of briquettes from solid coffee waste. A 10 cu.m STBR will be evaluated for production of biogas from optimum sisal waste based blends. The demonstration plants will be installed in all the three countries on site at development partners' premises. The locations of the plants will be as follows: 1) In Ethiopia, at one of the Coffee Plantations Development Enterprise factory 2) In Kenya, at Kilifi Plantations utilizing sisal decortications wastes 3) In Tanzania, at Alawi sisal estate, at one of the factories owned by Mohamed Enterprises Tanzania Ltd utilizing sisal postharvest wastes (sisal stems/bole).

Coffee waste briquettes production: To produce high energy briquettes from solid coffee waste, an innovative approach will be employed. This will involve designing and constructing a biogas-fired infrared roaster for roasting solid coffee waste. Roasted coffee wastes obtained will then be used for making briquettes using a low technology briquette making machine that does not use conventional binders at different temperatures and raw materials. The heating value of the briquettes will be determined by using a bomb calorimeter.

Fertilizer value of biogas manure (BgM): BgM emanating from the biogas plants after anaerobic digestion of spent mushroom substrate and sisal and coffee-based wastes will be determined by comparing with other common organic manures and chemical fertilizers in terms of nutrient composition and in growth of vegetables in green houses or enclosed vegetable farms. Microbial populations in BgM-treated and non-BgM treated soils will be evaluated using standard methods.

Training workshops: In order to demonstrate and transfer the integrated technologies of mushroom and biogas production from coffee and sisal based wastes to delivery partners, tailor-made training courses for factory personnel will be conducted on site using the up-scaled mushroom and biogas production facilities in place.

Biogas upgrading: Biogas will be upgraded using bio-scrubbers to remove hydrogen sulphide, carbon dioxide and water vapour prior to its utilization for electricity production and firing the infrared roaster.

Logistics and markets: Optimum logistics for mushroom farms and bioenergy plants, and distribution of their products to the markets will be established. All products supply chain will be studied for the market centers and respective capacities identified. A mathematical model will be developed to the computation of the entire process chains and scenarios. Demand for the products and potential market centers, their distance from the production site will be studied.

Techno-economic analysis: All inputs for project products will be considered in the analyses and standard feasibility study tools will be used. Both conventional and software methods will be employed.

12. Pathway to impact, applicability of the results in practice and potential impact

A team of biotechnologists, applied microbiologists, environmental and process engineers will carry out research work to optimize and validate the proposed concepts in the laboratory. The validated technologies will be demonstrated by up-scaling on site at partner factories in Ethiopia, Kenya and Tanzania. Here the technologies will undergo testing, incubation and further improvement in collaboration with the industrial partners. Techno-economic evaluation will be carried out to establish feasibility of these technologies for commercialization.

It is expected that the feasible demonstrated technologies will first be adopted by our industrial partners and later on will be replicated elsewhere in the region. Hence in the long term, the project is anticipated to impact on the industrial project partners, and other sisal and coffee processing industries, large scale farmers, and municipalities who will adopt the demonstrated technologies. First, the utilization of the wastes and residues will significantly reduce environmental pollution and at the same time add value to the waste which will by then, be regarded as a resource. Secondly the project will provide economic benefits with respect to savings through use of own generated bio-energy which is sustainable and in line with Millennium Development Goal (MDG) No. 7 which calls for ensuring environmental sustainability. The partner industries could benefit from the global carbon credits scheme. Secondly, apart from providing economic benefits and an alternative protein rich food supplement to the people, commercial scale production of edible mushrooms will motivate investments in other economic ventures for example mushroom seed production companies, and packages production companies in the region and most likely result in foreign markets. This will contribute to economic development in the region.

13. Quality and organization of the consortium

The project team is multidisciplinary, competent, and of a regional character. It is composed of two chemical and process engineers with experience in biological waste treatment technologies and biogas utilization; two environmental biotechnologists with a long time research experience in biogas production from agro-industrial wastes and mushroom science; a mycologist with experience in large scale mushroom cultivation; and a seasoned biochemist with expertise in industrial biotechnology. The team will collaborate with two international partners including 1) an environmental science and process engineer with expertise in biogas plant design and extensive experience with two-stage biogas digesters and 2) An environmental biotechnologist with long term experience with large scale biogas systems utilizing agro-industrial waste. These individual capabilities complement each other to form a synergy required to execute the stated project objectives successfully. The partner institutions include the University of Dar es Salaam (UDSM) in Tanzania, which is the lead institution; Addis Ababa University (AAU) in Ethiopia; and Pwani University College (PUC) in Kenya. The international collaborators include Brandenburg University of Technology (BTU) and Danish Technical University in Denmark. For product delivery, the team has three industrial partners including Coffee Plantations Development Enterprise in Ethiopia, Kilifi Plantations in Kenya, and Mohamed Enterprises Ltd Sisal Plantations in Tanzania. The roles and responsibilities of development and delivery partners are shown in Table 1.

Table 1. Roles and responsibilities of project partners

Development partners		
Partner institution	**Scientist**	**Roles**
University of Dar es salaam, Tanzania: 1. Department of Molecular Biology and Biotechnology, 2.Department of Chemical and Process Engineering,	Prof. Amelia Kivaisi	PI-Project coordination; Dissemination
	Dr Anthony Manoni Mshandete	CO-PI; Technology development: Integration of production of mushroom with biogas production utilizing sisal boles; Dissemination; Providing backstopping expertise at PUC
	Dr. Oscar Kibazohi	Technology scaling up in collaboration with industrial partners in Tanzania and Kenya; Dissemination
	Dr N. Mwaluko	Techno-economic analysis
Pwani University College Department of Biological Sciences, Kenya	Dr. Suhaila Omar Hashim	CO-PI; Integration of mushroom cultivation with biogas production using sisal decortication waste; Dissemination
	Dr Juma Mzee Amana	Integration of mushroom cultivation with biogas production using sisal decortication waste; Dissemination ;

		Dissemination of results
Addis Ababa University 1. Institute of Technology Department of Chemical Engineering 2. Biology Department Applied Microbiology Unit	Dr Berhanu Assefa	Project coordination (CO-PI); Technology development: Two stage biogas digester using coffee waste; High density coffee waste briquette production; Dissemination
	Dr Dawit Abate	Technology development: mushroom cultivation utilizing coffee waste; Dissemination
Brandenberg University of Technology, Germany	Prof. Dr-Ing. Gunter Busch	Technological support: Two stage anaerobic digestion process
Danish Technical University	Prof. Irini Angelidaki	Technological support: Up-scaling of stirred tank anaerobic bioreactor
Product delivery partners		
Name of Industry	**Name of Manager**	**Roles**
Mohamed Enterprises Tanzania Ltd (Sisal plantations)	Dr N. Subbaih	Technology demonstration on site the factory in collaboration with scientists; provide data for techno-economic analysis
Coffee Plantations Development Enterprise, Ethiopia	Mr Baye Mokennen	Technology demonstration on site the factory in collaboration with scientists; provide data for techno-economic analysis
Kilifi Platantions Kenya	Eng. Patrick Kagema	Technology demonstration on site the factory in collaboration with scientists; provide data for techno-economic analysis

14. Competence and skill track record of principal Investigator

Prof. Amelia Kivaisi, University of Dar es Salaam (UDSM) in Tanzania will be responsible for the overall management of the project. Hence UDSM will be the lead institution. Prof. Kivaisi has long-term experience in research and development project management. She has managed a number of big research projects involving teamwork/more than one departments/institutions including the Applied Microbiology Project (AMU) at the University of Dar es Salaam under the sponsorship of NUFFIC-the Netherlands (1996-2005), a Sida /SAREC-Sweden sponsored project on mushroom cultivation in Tanzania utilizing agricultural waste (1995-2004), a Sida/SAREC-Sweden sponsored project entitled “Towards Enhancing Molecular Biology and Biotechnology” at the University of Dar es Salaam (2005-2008), and she was the PI of a project entitled “Development of improved technologies to utilize industrial and agricultural waste for bioenergy and value-added chemical production” under the just ended BIO-EARN programme (2006-2010). Her brief CV is attached in Annex 1.

For reference, contact: Prof. Makenya Maboko, DVC Academic Research and Consultancy, University of Dar es Salaam, P.O Box 35090 Dar es Salaam, Tanzania, email: maboko@admin.udsm.ac.tz.

The PI will be assisted by the following Co-Principal Investigators (CO-PIs) at partner institutions: 1) Dr Berhanu Assefa, Addis Ababa University, Ethiopia. Dr Assefa is Assistant Professorin the Department of Chemical Engineering, Addis Ababa Institute of Technology 2) Dr Suhaila Omar Hashim, Pwani University College, Kenya. Dr Hashim is currently a lecturer and researcher in biochemistry in the Department of Biological Sciences and 3) Dr Anthony Manoni Mshandete , University of Dar es Salaam, Tanzania. Dr Mshandete is Senior Lecturer in environmental biotechnology and researcher in the Department of Molecular Biology and Biotechnology. CVs of all CO-PIs are attached in Annex 1.

15. Proposed consortium project management

Matching funds: Industrial partners will offer land for location of demonstration mushroom cultivation facilities, biogas plants and coffee briquette making equipment, and provide security of the installed facilities and equipment. Support from participating universities will be in the form of provision of research laboratory space, basic equipment, the cost of water and electricity, and salaries for the scientists. Institutional support letters will be sent separately.

Monitoring and Evaluation: The progress of the project will be monitored at Main Activity level

(MA) by Co-Principal Investigators (CO-PI) and at project level by the Principal Investigator (PI). The main focus will be on completing each aspect of the project on-schedule within the budget. Regular meetings to evaluate the progress in details in terms of expected outputs as per activities carried out, to identify problems and make any decisions about the changes in the strategy. At project level, annual meetings of all developmental partners will be held. Monitoring will also be through six-monthly reports where achievements will be evaluated against the planned activities where a monitoring Ghant chart will be used to track progress. Furthermore, the project progress will be monitored by performing a self evaluation exercise annually at MA and project levels.

Dissemination and communications plans: All the achievements will be disseminated through publications in peer reviewed scientific journals and presented at national, region and international conferences. Project results will also be published in trade journals to reach a wider audience where our innovative approach to utilize agro-industrial wastes will be advertised in the Eastern African region. The information will not only be disseminated to the scientific and technical recipients, but also to the public and policy makers through workshops. Specifically, training workshops on biogas/mushroom technologies for collaborating factory workers, and (2) a dissemination workshop at the end of project period will be conducted. Leaflets and brochures with project results will be printed out and distributed among different research organizations. Two simple handbooks one in mushroom cultivation and the other on biogas digester monitoring will be produced.

Intelectual property and other policy issues: All Intellectual Property (IP) issues will be guided by IP policies of all partner institutions as well as corresponding host countries. However, for common interest, all partner institutions will operate within an alliance agreement framework to be formulated and agreed upon after inception of the project. It will include: 1) Material transfer agreement to cater for materials such as biological agents to be transferred from one institution to another. Purpose, use and sharing of outputs from use of the materials among the institutions will be stipulated in the agreement 2) Record keeping of research information, confidentiality and non disclosure agreement among partner institutions and with private sector partners. This agreement intends to inform all researchers on how to maintain research logbooks (dates and entries) and that any material, notes or discoveries belonging to the project should be kept confidential in order to avoid unauthorized use of research output resulting in financial loss to researchers and partner institutions 3) Patenting in case of new inventions will be stipulated to cover how and where to apply for a patent, and which institution will be an applicant and how to share proceeds from commercialization of patent 4) The framework will clearly specify collaboration agreement with private partners. Agreement will include ownership of research equipment during and after project life cycle, responsibility and duties of private partner and participating institutions, material transfer agreement, loyalties beyond project life cycle if the partners wished to continue with and/or upscale production based on project findings, and non discloser to third party and transfer of technology to a third party agreement. Agreements with private partners will be signed at the commencement of the project.

16. Milestones and time frame

Milestones towards achieving project objectives are shown in the Table 2 below.

Table 2. Milestones towards project goal

Milestones	Period (months after start of project)
Completion of waste auditing and optimization of oyster mushroom cultivation on coffee and sisal wastes	**9**
Completion of investigations on biogas yield potentials of mushroom spent substrates and blends	**8**
Lab scale optimization experiments with coffee-based waste in a two stage anaerobic bioreactor completed	**23**
Lab scale optimization experiments with sisal-based wastes in stirred tank bioreactors completed	**12**

Construction works of demonstration mushroom cultivation facilities completed	**12**
Construction works of biogas digesters completed	**12**
Training workshops on mushroom cultivation carried out	**23**
Training workshop on biogas technology carried out	**23**
Commercial scale mushroom cultivation commenced	**22**
Scaled up biogas digesters started-up and in operation	**22**
Biogas-fired infrared roaster and briquette machine construction completed	**23**
Production of briquettes commenced	**23**
Data for biogas manure fertilizer value obtained and information on markets for project products	**33**
Optimum logistics for mushroom farm and bio-energy plants and distribution of products determination completed	**33**
Techno-economic analyses completed	**33**
Final dissemination workshop held	**36**

17. Indicators of progress towards the results

The proposed project is anticipated to results into a number of outcomes with the following indicators: 1) The quantity of waste used for mushroom cultivation, biogas and briquette production 2) The number of employees for the mushroom farms and bio-energy plants 3) Quantity of mushrooms sold to communities 4) MOUs signed between the partners by 2012 to take over the bioenergy plants and mushroom farms beyond the project 5) At least one additional factory shown interest in the coffee briquette production technology and a collaboration MOU signed by 2013 6) At least three more factories seeking product development collaboration with development partners and MOUs signed by 2013 7) Number of acres utilizing biogas manure at collaborating plantations 8) Quantity of manure sold to the public 9) At least one investor in large scale spawn making by 2013.

18. Appendix A : Project Activity Plan

Activity description	Project duration																																		
	Year 1 (Quarters)												Year 2 (Quarters)												Year 3 (Quarters)											
	1			2			3			4			1			2			3			4			1			2			3			4		
Holding of a project inception workshop																																			
Procurement of equipment																																			
Quantification and characterization of coffee and sisal waste streams																																			
Renovation of mushroom house at PUC																																			
Evaluation of suitability of coffee waste streams and optimize for oyster mushroom cultivation.																																			
Optimization of substrate formulations using sisal decortication and post-harvest wastes for oyster mushroom cultivation																																			
Investigations on biogas yield potentials of coffee waste spent substrates																																			
Investigations on biogas yield potentials of sisal decortication and post-harvest waste spent substrates																																			
Optimization of a two-stage anaerobic digester for biogas production from selected coffee waste blends																																			

Optimization of biogas production from selected blends of sisal decortication and post harvest spent substrates in STBR																																				
Design and construction of demonstration mushroom growing facilities																																				
Design and construction of up-scaled demonstration biogas plants																																				
Training workshops for selected factory employees on mushroom cultivation and biogas technology																																				
Commercial scale mushroom cultivation on site																																				
Start-up, operation and monitoring of scaled-up biogas digesters																																				
Biogas upgrading and monitoring																																				
Design and construct a biogas-fired infrared roaster and briquette making machine																																				
Roasted coffee waste briquettes production and evaluation of energy density																																				
Coupling of up-graded biogas to power generator and monitor																																				
Determination of optimum logistics for mushroom farm and bio-energy plant and distribution of their products																																				
Identification of markets for the resultant products																																				
Evaluation of fertilizer value of																																				

biogas manure																																				
Techno-economic analyses																																				
Final dissemination workshop																																				
Analysis of results and final reporting																																				
Annual meetings between project partners																																				

19. Detailed and summary project budget (USD)

The project is estimated to cost USD **1,200,000.** Summary and detailed budget per major activity per EA collaborating institutions are provided in tables 3 and 4 below.

Table 3. Summary budget (AAU=Addis Ababa Univ.; PUC=Pwani Univ. College; UDSM=Univ. of Dar es Salaam ;

Item description	Year 1			Year 2			Year 3			Total
	AAU	PUC	UDSM	AAU	PUC	UDSM	AAU	PUC	UDSM	
Equipment	79700	70040	60850	46450	27800	64182	-	19500	4500	373022
Lab./consumables	11300	4700	5340	6410	4271	5750	5310	3000	4100	50181
Travel	26338	16165	24440	27251	37816	27665	12115	9825	13400	195015
Fieldwork costs	-	-	-	2400	-	-	2550	-	-	4950
Contractual labor*	24700	75400	84250	36350	45700	38000	13550	1000	1000	319950
Consultancy	-	-	-	-	-	1000	9500	9500	8500	28500
Printing and publishing	-	-	5000	2080	2000	3500	2000	2000	2000	18580
Workshops	-	-	21840	1400	-	-	1500	6440	11880	43060
Training costs	-	-	-	4100	12650	14150	1145	-	3000	35045
Overhead	6944	1000	1000	7000	-	-	2874	-	-	18818
Coordination costs*	6600	3120	7320	10050	8120	32000	7800	3120	17000	95130
Unforeseen	3750	1500	1500	3500	1500	**1500**	2000	2000	**2000**	19250
Total	**159332**	**170425**	**211540**	**146990**	**139857**	**187747**	**60344**	**56385**	**67380**	**1,200,000**
% of total allocation	**43.45**	**46.48**	**45.33**	**40.08**	**38.14**	**40.23**	**16.46**	**15.38**	**14.44**	

*Contractual labor includes casual labor, research assistants, design and construction works; coordination includes management cost, travel of PI and CO-PIs, meetings

Table 4. Budget per main activity per EA partner institution for the period 2011-2013

MAJOR ACTIVITIY	PARTICIPATING INSTITUTIONS			TOTAL (USD)
	AAU*	PUC*	UDSM*	
1. Inception workshop	8,000	1,550	14,585	24,135
2. Procurement of major equipment	65,200	23,190	17,250	105,640
3. Waste audit and characterization	8,245	2,115	15,355	25,715
4. Technology development and opti	23,933	26,990	18,700	69,623
5. Design and construction of mushr	21,160	40,260	37,100	98,520
6. Design and construction of biogas	13,500	64,700	76,190	154,390
7. Project management	13,787	**10,120**	**25,860**	**49,767**
8. Dissemination (brochures, leaflets)	-	-	**5,000**	**5,000**
9. Contingency	**5,508**	**1,500**	**1,500**	**8,508**
Subtotal	**159,333**	**170,425**	**211,540**	**541,298**
YEAR 2 (2012)				
1. Design and construction of biogas	36100	-	0	36,100
1. Commercial mushroom cultivation	17535	59171	79482	156,188
2. Training workshops on mushroom	7315	14270	7700	29,285
3. Training workshops on biogas	0	6300	6450	12,750
4. Up-scaling and monitoring of biog	58400	39796	38090	136,286
2. Biogas upgrading, monitoring and	-	-	21875	21,875
3. Project management	16800	8620	19750	45,170
4. Dissemination of results	4940	10200	12900	28,040
5. Contingency	3,500	1500	1,500	6,500
Subtotal	**146,990**	**139,857**	**187,747**	**474,594**
YEAR 3 (2013)				
1. Biogas upgrading, monitoring and	16715	21125	0	37,840.0
2. Determination fertilizer value	11210	6000	7600	24,810.0
3. Identification of markets	3500	3000	3500	10,000.0
4. Biogas –mushroom production log	9445	-	0	9,445.0
5. Techno-economic analysis	3000	4000	13000	20,000.0
6. Project Management	7273.5	3620	18000	28,893.5
7. Dissemination	4800	16640	23280	44,720.0
8. Contingency	4400	2000	2000	8,400.0
Subtotal	**60,344**	**56,385**	**67,380**	**184,109**
Grand total (Year 1,2.3)	**366,666**	**366,667**	**466,667**	**1,200,000**

Logframe

Title of Consortium Project: Sustainable utilization of agro-industrial wastes through integration of bio-energy and mushroom production

Goal of the Project: The development goal of this project is that by 2013, the Eastern African region has in place, pilot scale plants demonstrating the utilization of agro-industrial wastes by applying an innovative bio-refinery approach of integrating production of edible mushrooms and biogas.

Outputs	**Outcome**	**Performance Indicator of Outcome**	**Data Source**	**Collection Method**	**Assumptions - Assessment of Progress/Achievements**
Objective # 1: To establish technologies for integration of mushroom cultivation with biogas production from coffee processing and sisal wastes.					
• Protocols for optimal formulations of substrates and conditions for oyster mushroom cultivation by January 2012 • Optimal conditions for digesting the spent substrate mixtures in two-stage bioreactor and in stirred tank bioreactor Dec. 2012 • 1000 kg/ month -scale mushroom growing facilities and 10,000L biogas digesters installed on site at collaborating factories by Sep. 2012 • Data on performance of scaled-up biogas digesters By Dec. 2013	1.1 By 2013, a significant decrease in waste disposed off in the vicinity of the collaborating coffee and sisal-processing factories 1.2 An increase in the number of employees at collaborating factories due to mushroom cultivation 1.3 An increase in availability of mushroom to communities in vicinities of the factories 1.4 The project delivery partners engaged in running and monitoring the	1.1 The quantity of waste used for mushroom cultivation, biogas and briquette production 1.2 The number of employees for the mushroom farms and bio-energy plants 1.3 Quantity of mushrooms sold to communities 1.4 MOUs signed between the partners by 2013	• Progress report • Factory reports • Site visits	• Surveys/visits • Interviews	• Political situation is conducive in the region • Alliance of agreement for the consortium signed • MOUs between development and delivery partners signed and parties complying • Project funds per activity delivered timely

	demonstrated systems at their premises beyond				
Objective # 2 : To evaluate the suitability of coffee solid waste for production of high energy briquettes utilizing a biogas fired infrared roaster					
• Infrared roaster and briquette making machine • Coffee waste briquettes and data on their energy density.	2.1 The technology prompted interest in other coffee processing factories	At least one additional factory shown interest and a collaboration MOU signed by 2013	• Progress reports	• Surveys/visits • Interviews	• Competence to develop improved process gained • More effective linkages with factory formed • Project funds per activity delivered timely
Objective # 3: To evaluate techno-economic feasibility of the improved technologies					
• Information on optimal logistics for the mushroom bio-energy plants ans available markets for the resultant products • Techno-economic feasibility of the integrated technologies	3.1 Delivery partners adopting the technology for commercialization 3.2 Interest of other agro-processing factories to verify the developed technologies increased	3.1 At least one partner shown interest in adopting the technology by 2013. 3.2 At least three more factories seeking collaboration with development partners and MOUs signed by 2013	• Progress reports	• Surveys/visits • Interviews	• Political situation is conducive in the region • Alliance of agreement for the consortium signed • MOUs between development and delivery partners signed and parties complying • Demonstration plants in place and operating • Project funds per activity delivered timely
Objective # 4: To assess the fertilizer value of the biogas manure					
• Data on fertilizer value of biogas manures.	4.1 Decrease in utilization of commercial fertilizer on sisal and	4.1 No. of acres utilizing biogas	• Progress reports	• Surveys/visits • Interviews	• MOUs between development and delivery partners signed and parties

	coffee farms at partner plantations. 4.2 Biogas manure used by the public in horticulture	manure. 4.2 Quantity of manure sold to the public	• Site visits		complying • Experimental plots made available by partner plantations • Organic food producers to utilize the manure present
Objective # 5: To disseminate the results of the established technologies.					
• Handbooks on mushroom cultivation and biogas production • Skilled employees in mushroom cultivation and biogas production at collaborating factories • Brochures on the project • At least 10 Scientific paper publications in referred journals	6.1 Awareness on potential project impacts raised among stake holders 6.2 Increased knowledge and skills in mushroom and biogas production among workers at the factory 6.3 The project will prompt investments in large-scale spawn (mushroom seed) production industries.	6.1 Number of sectors/institutions that attended the dissemination workshop 6.2 Number of factory employees working on the mushroom farms and bio-energy plants 6.3 At least one investor in spawn making by 2012	• Progress reports • Factory reports • Paper reprints • Copies of brochures and books	• Visits • Interviews	• Participants to attend the workshop sensitized and interested • Demonstrated spawn making in technology environment is accepted and cost-effective

ANNEX 1: PI and CO-PI Curriculum vitae

Amelia Kivaisi

Personal Data

Name:	Kajumulo Kivaisi, Amelia
Position:	Professor
Affiliation:	Department of Molecular Biology and Biotechnology, University of Dar es Salaam, Tanzania

Qualifications

1978: BSc (General), University of Dar es Salaam, Tanzania
1984: MSc in Microbiology, Stockholm University, Sweden
1990: PhD (Applied Microbiology), University of Dar es Salaam, Tanzania

Scientific experience

Auditing of waste materials including mapping. Biogas production from waste organic materials. Anaerobic digestion of lignocellulosic materials using rumen microorganisms and optimization of the processes including application of biological pre-treatment. Mushroom production. Lignolytic enzymes in basidiomycetes. Composting of municipal solid waste. Supervised over 25 postgraduate research students and published over 50 scientific publications in referred journals.

Managerial skills

Coordinator of a number of research projects, under the sponsorship of NUFFIC-The Netherlands for 12 years and SIDA/SAREC-Sweden for more than 10 years. Chief Editor of the Tanzania Journal of . Science for 3 years.

Recent publications since 2008

1. Anthony Manoni Mshandete, Lovisa Björnsson, Amelia Kajumulo Kivaisi, Mugassa, Steven Thomas Rubindamayugi, Bo Mattiasson.(2008). Performance of biofilm carriers in anaerobic digestion of sisal leaf waste leachate. *Electronic Journal of Biotechnology* [online]. 15 January 2008, vol. 11, no. 1 [cited date]. Available from Internet: http://www.ejbiotechnology.info/content/vol11/issue1/full/7/index.html. ISSN 0717-3458.
2. Anthony Manoni Mshandete, Lovisa Björnsson, Amelia Kajumulo Kivaisi, Mugassa, Steven Thomas Rubindamayugi, Bo Mattiasson.(2008). Two-stage anaerobic digestion of aerobic pre-treated sisal leaf decortications residues: hydrolases activities and biogas production profile. *African Journal of Biochemistry Research*2: 211-218
3. Anthony Manoni Mshandete, Lovisa Björnsson, Amelia Kajumulo Kivaisi, Mugassa, Steven Thomas Rubindamayugi, Bo Mattiasson.(2008). Effect of aerobic pre-treatment on production of hydrolases and volatile fatty acids during anaerobic digestion of solid sisal lead decortications residues. *African Journal of Biochemistry Research.* 2(5): 111-119.
4. Muthangya, M, Mshandete, A.M. Kivaisi, A.K. (2009). Enhancement of anaerobic digestion of sisal leaf decortication residues by biological pre-treatment. *ARPN Journal of Agricutural and Biological Science.* Vol 4(4), 66-73.
5. Muthangya, M, Mshandete, A.M. Kivaisi, A.K. (2009). Two-stage fungi pre-treatment for improved biogas production from sisal leaf decortication residues. *Int. J. Mol. Sci. 10*, 4805-4815.

Anthony Manoni Mshandete

Personal Data

Name: Anthony Manoni Mshandete
Position: Senior Lecturer
Affiliation: Dept. of Molecular Biology and Biotechnology, College of Natural and Applied Sciences (CoNAS), University of Dar es Salaam (UDSM), Tanzania.

Qualifications

1992: B.Sc. (Chemistry and Biology) with Education , University of Dar es Salaam, Tanzania.
1998: M.Sc in (Applied Mushroom Biology/Mycology, University of Dar es Salaam, Tanzania
2005: Ph.D. in Applied Microbiology, University of Dar es Salaam, Tanzania

Scientific experience

Building, operating and monitoring anaerobic bioreactors: batch and high rate two-stage anaerobic, packed bed and fixed bed anaerobic bioreactors for biogas production from waste organic materials. Auditing and mapping of organic waste materials. Improvement of anaerobic digestion of lignocellulosic materials including application of physical, biological pre-treatment methods, immobilization using support materials, addition of additives and co-digestion (blending) of protein and carbohydrates rich waste materials. Mushroom production from lignocellulosic organic wastes using edible mushrooms of genus Pleurotus, Coprinus and Volvariella. Fermentation of macrofungi (mushrooms) mycelia for the production of exo-polysaccharides. Natural products (bioactive agents from higher fungi particularly Coprinus cinereus an indigenous edible and medicinal mushroom from Tanzania.

Managerial Skills

Principal Investigator of projects on production of biogas from aquatic weeds and co-production of oyster mushrooms and biogas from weeds (2005-2006, 2009), which was supported by sida/SAREC. Currently a coordinator of research project supported by World Bank (2009-2014) on bioconversions of organic wastes using biotechnology and sida/SAREC (2009-2013) on bioenergy production from bioorganic wastes. Editorial member of the Tanzania J. Science from (2009-2011). Postdoctoral fellow in BIOEARN PROJECT 4 supported by sida/SAREC (2006-2010) responsible for research as well as assist in guiding and supervising postgraduate students. Supervised over 30 B.Sc. dissertations since 2005, currently supervising 3 Ph.D's and 2M.Sc's. Over 20 scientific publications in referred journals, one book on mushrooms and fours chapter in a mushroom book written in Kiswahili.

Summary of publication record from 2008

1. Mshandete, A.M.; Björnsson, L.; Kivaisi, A.K.; Rubindamayugi, M.S.T. and Mattiasson, B. (2008). Performance of biofilm carriers in anaerobic digestion of sisal leaf waste leachate. Electronic Journal of
   Biotechnology. Vol.11 (1): 1-8.
2. Mshandete, A.M. and Cuff, J. (2008). Cultivation of three types of indigenous wild edible mushrooms:
   Coprinus cinereus, Pleurotus flabellatus and Volvariella volvocea on composted sisal decortications residue in Tanzania. African Journal of Biotechnology Vol. 7(24): 4551-4562.
3. Mshandete, A.M.; Björnsson, L.; Kivaisi, A.K.; Rubindamayugi, M.S.T. and Mattiasson, B. (2008).Two-stage anaerobic digestion of aerobic pre-treatedsisal leaf decortications residues: hydrolases activities and biogas production profile. African Journal of Biochemistry Research Vol.2,
   (11), 211-218
4. Muthangya, M, Mshandete, A.M. Kivaisi, A.K. (2009). Enhancement of anaerobic digestion of sisal leaf decortication residues by biological pretreatment. ARPN Journal of Agricultural and Biological Science. Vol 4(4), 66-73.

Suhaila Omar Hashim

Personal data

Position: Lecturer (Biochemistry/Biotechnology)

Affiliation Department of Biological Sciences, School of Pure and Applied Sciences, Pwani University College, Kilifi, Kenya

Academic qualifications

1995: B.Sc (Biochemistry and Zoology; Honours), University of Nairobi, Kenya.

2000: M.Sc (Biochemistry), University of Nairobi, Kenya.

2004: Ph.D (Biotechnology), Lund University, Sweden.

2008-2010: Postdoctoral Research Fellow, Biotechnology, Lund University, Sweden.

Scientific experience

Screening and isolation of microorganisms for production of novel biocatalysts for industrial application, enzyme technology involving production, purification and characterization of enzymes, bioseparation processes (downstream processing) of proteins and other biomolecules, protein stability studies, molecular biology, bioinformatics. Postdoctoral fellowship between 2008 and 2010, in an on going "Green Chem" project – Greener chemistry for a cleaner environment, at the Department of Biotechnology, Lund University. Activities involved production/development of suitable biocatalysts for enzymatic transformation of renewable raw materials to chemicals and participated in on-going doctoral research projects on stability of enzymes.

Managerial skills

Supervised BSc. and MSc. research projects, was in charge of computer facilities, was departmental representative at the Faculty of Science timetabling committee and Secretary of the departmental committee for the review of Biochemistry programme at the Department of Biochemistry, University of Nairobi during the year 2005. Assisted in supervision of three PhD candidates during the postdoctoral fellowship between 2008 -2010. Coordinator of Medical Programmes at Pwani University College. Member of research and training, and curriculum review committees of the Department of Biological Sciences at Pwani University College. Acting Chairman of Department of Biological Sciences during July-August, 2010. She has served as a reviewer/referee for peer-reviewed journals in various journals and has published over 10 papers.

Relevant publications

1. Hashim SO, Delgado O, Martinez A, Hatti-Kaul R, Mulaa FJ and Mattiasson B (2005). Alkaline active maltohexaose forming α-amylase from *Bacillus halodurans* LBK 34. Enzyme and Microbial Technology 36: 139-146
2. Quillaguaman J, Hashim SO, Bento F, Mattiasson B and Hatti-Kaul R (2005). Poly(β-hydroxybutyrate) production by a moderate halophile, *Halomonas boliviensis* LC1 using starch hydrolysate as a substrate. Journal of Applied Microbiology 99 (1); 151-157.
3. Mamo G, Kasture S, Faryar R, Hashim S, Hatti-Kaul R. Surfactants from Xylan: Production of n-Octyl Xylosides using a highly thermostable Xylanase from Thermotoga neapolitana (2009). Process Biochemistry 45 (5); 700-705.
4. Doan Van-Thuoc , Hashim S, Hatti-Kaul, R, Mamo G. Enzyme stabilization by ectoine and hydroxyectoine at high pH. In: Thuoc Doan-Van (2009), Production of poly(3-hydroxybutyrate) and ectoines using a halophilic bacterium. Lund University, Sweden. ISBN978-91-89627-64-2.
5. Doan Van-Thuoc , Hashim S, Hatti-Kaul, R, Mamo G (2010). Enzyme stabilization by ectoine and hydroxyectoine at high pH – a study using *Bacillus halodurans* xylanase as a model. Submitted to Biochimie journal.
6. Tran T.T., Hashim, S.O., Mamo, G., Mattiasson, B. and Hatti-Kaul, R. (2010). Thermostable phytase from *Bacillus* sp. MD2: effect of divalent metal ions on activity and stability. Submitted to Biotechnology and Bioengineering Journal.

Berhanu Assefa Demessie

Personal Data

Name: Berhanu Assefa Demessie Position: Assistant Professor Affiliation: Dept. of Chemical Engineering, Addis Ababa Institute of Technology (AAIT),

Addis Ababa University, Ethiopia.

Academic qualification

1991: B.Sc in Chemical Engineering, Addis Ababa University (AAU), Ethiopia 1997: M.Sc. in Petroleum Engineering, Norwegian University of Science and Technology, Norway. 2002: Ph.D. in Chemical Engineering, Norwegian University of Science and Technology, Norway.

Scientific experience

Industrial material and energy auditing; designing pollutant removal of system from industrial effluents; process effluent treatment and technology selection; designing, building and operating waste treatment unit and investigating the performance of treatment unit; investigation of removal of fluoride from ground water membrane technology and adsorption using local materials; industrial wastewater treatment using membrane technology; - investigating of lab single and two stage biogas generations from vegetable solid wastes; cities solid waste generation, characterization and management strategies. Solid waste stream analysis for energy potential and

Managerial Skills

Assistant dean of the Faculty of Technology, AAU, from 2006 to 2009; Principal investigator of project on two stage biogas generations from vegetable solid wastes funded by Ethiopian Ministry of Science & Technology from 2008 - 2009; Principal investigator of project on Textile Factory wastewater treatment using membrane technology, which was funded by Ministry of Water Resources from 2008 to 2009; Co-Principal investigator of IGNIS project on recovery of resources from Municipal Solid Waste in a sustainable way in emerging mega- cities and converting into biogas, compost, etc. It is financed by German Government from 2008 - 2013. Supervised over 15 M.Sc student thesis dissertations and 5 projects since 2003, currently supervising 3 M.Sc students, and one project on producing simple hand tool to cover dry waste organic solid into dense briquette fuel

Publications

Berhanu A., Investigation of the performance RO membrane for fluoride removal, Zede – Journal of Ethiopian Engineers and Architecture, 21, 1 - 12.