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Addis Ababa Institute of Technology

School of Chemical and Bio Engineering

Environmental Engineering M.Sc. Program

INVESTIGATION OF ENVIRONMENTAL AND ECONOMIC BENEFITS OF BIOSLURRY FROM COFFEE HUSK RELATIVE TO CHEMICAL FERTILIZER

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A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the Degree of Master of Science in Environmental Engineering

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SCHOOL OF GRADUATE STUDIES

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Acronym

UN	United Nations
MoRAD	Ministry of Rural Agriculture and Development
CH	Coffee Husk
CSA	Central statistics agency
C: N	Carbon to Nitrogen ratio
CO2-e	Carbon dioxide emission
CO2-eq	Carbon dioxide equivalent
gpot-^{1}	Gram per pot
IPCC	International Panel for Climate Change
ISWM	Integrated Solid Waste Management
Kgha-^{1}	Kilogram per hector
KgNha-^{1}	Kilo gram nitrogen per hector
Pmm	part per million

ABSTRACT

Agriculture dominates the Ethiopian economy. It is the major supplier of raw materials to food processing, beverage and textile industries. Application of fertilizer is one of the major interventions made by the government to increase the productivity of the sector. The government focuses on productivity improvement of smallholder agriculture through diffusion of fertilizers and improved seeds. However, the price of chemical fertilizer is increasing from time to time which results in shortage of the supply and unaffordable to smallholder farmers.

The objective of the study was to (i) to see the effect of bioslurry from coffee husk on the macro nutrients of the soil (ii) to assess the influence of bioslurry from coffee husk on soil organic carbon content (iii) to compare the effect of bio slurry on yield and yield components of the test crop (iv) To compare the economic benefit of bio slurry application from yield perspective.

In order to achieve the stated objectives, a pot study was conducted under greenhouse condition. Seven treatments were designed with combined and sole application rates of bioslurry and urea to 5 kg soil pot^{-1} using wheat as a test crop.

The results of the study revealed that combined and sole application of the bioslurry with chemical fertilizer positively increased the yield, yield component of the test crop and organic carbon soil. The conjugate application of bioslurry with chemical fertilizer at (3.1m^3 bioslurry +62 kg urea) ha^{-1} gave the highest yield (4368.2 kgha^{-1}) and highest spike length was also recorded with this treatment. The high application rate of bioslurry at (6.2m^3 ha^{-1}) increased the soil organic carbon content over 100% compared to the control without any amendment. The simple economic calculation based on economic efficiency indicated that the combined application of bioslurry with chemical fertilizer at (3.1 m^3 +62 kg urea) ha-^{1} gave a net benefit of 23, 460.8 ETB.

The study showed that the appropriate utilization of bioslurry as soil amendment not only increases soil fertility but also plays a great role in alleviation of climate change through increment of soil organic carbon which in turn serves as a carbon pool of planet earth.

Key words / soil, organic carbon, yield, carbon pool, soil fertility

1.INTRODUCTION

1.1 Background

Agriculture dominates the Ethiopian economy. It is the major supplier of raw materials to food processing, beverage and textile industries. Agriculture employs more than 85% of the population and contributes about 90% of the export earnings of the country (MOFED, 2005).

The Ethiopian agricultural sector is important for both overall economic performance and poverty alleviation. In the last decade, it has shown rapid growth, but there is still substantial chance to improve productivity, production and market linkages. Increasing productivity in smallholder agriculture is Government's top priority. Most farmers in the country are small farm holders. The government recognizes the importance of the smallholder sub-sector; improving the productivity of small holders will reduce the prevalence of rural poverty and the large productivity gap.

The productivity and yields of most Ethiopian farms are low and stagnant despite the large emphasis given to agriculture by the government. These are attributed to traditional farming practices and erosion of soil fertility. To improve this, the government has introduced different measures to make accessible different farming technologies: farming equipment, modern farming practices, farm improved seed, application of fertilizer. Application of fertilizer is one of the major interventions made by of the government to improve productivity. The application of the right type of fertilizer can improve the production and income of farm households. It focuses on productivity improvement of smallholder agriculture through diffusion of fertilizers and improved seeds.

The fertilizer is imported from abroad. The amount of chemical fertilize imported is increasing from time to time. For example, 440,000 MT was imported in 2008 and 890,000 MT in 2012 (CSA, 2011/2012).

However, the price of chemical fertilizer is increasing from time to time which result in shortage of the supply and unaffordable to smallholder farmers.

Moreover the environmental impact of chemical fertilizer production and application is believed to be very large. IPCC (2004) reported that Agriculture, Energy supply, waste and waste water takes the lions share for greenhouse gas emissions. The report summarizes that agriculture alone contributes 5.1 to 6.1 Gt CO_2 equivalents per year which is 10-to 12 % of anthropogenic greenhouse gas emissions .From 5.1 to 6.1Gt of CO_2 equivalent emitted to the atmosphere from agriculture 1.2 % is emitted due to synthetic fertilizer production (Wood and Cowie, 2004).

On the other hand, agriculture generates large bio wastes. In most cases, improper disposal of these wastes causes serious environmental damages. For instance, thousand tons of agricultural remnants such as coffee husk, animal manure and the like are produced in Western zones of Oromia and South Western regions of Ethiopia. If these wastes are not properly handled and managed, they will continue to challenge the life and livelihood of millions of people by polluting receiving environments (air, water and soil). However, these wastes have a potential to be converted into resources that gives energy and soil conditioner or fertilizers. This calls for rethinking of integrated approach of waste management and to sustain agricultural productivity and reduce greenhouse gas emission.

An anaerobic digestion of bio wastes can convert the wastes into usable clean energy and manures can increase the carbon content of the soil and supplement nutrients. This ensures the closure of global energy and nutrient cycles (Janssen et al., 2008). Consequently, appropriate use of the residue not only reduces the application rate of chemical fertilizer but also reduces global climate challenges due to bio-mass waste integration approach.

The Bio Innovate research conducted at AAiT showed that the considerable amount of coffee waste discarded has considerable bio-gas production Potential. However, no comparative researches have been conducted so far on the fertilizing potential of the bioslurry. Definitely the residue contains macro plant nutrients (NPK) as well as the mineralized remains of dead bacteria derived from within the digesters in addition to its carbon content. Therefore, the study was aimed to investigate the suitability of the residue as a substitute or supplement of chemical fertilizer so that application of chemical fertilizer can be substituted fully or partially by biogas sludge (manure).

1.2 Statement of the Problem

According to the Federal Democratic Republic of Ethiopian Development plan in the agricultural sectors, the country seeks to enhance production and productivity of smallholder farmers and reduce degradation of natural resources. Agriculture accounts for more than 50% of Ethiopian's GDP, 90% of foreign exchange earnings, 70% of raw materials for domestic industries, and 85% of employment for the population (Getachew, 2011).

Chemical Fertilizer use is one instrument to be implemented as a means of raising production, yield and income of farm households. The other important tool is efficient use of natural resources with minimum wastes.

However, smallholder farmers living in rural area with low income currently do not have the capacity to afford chemical fertilizer as per the recommend rate per hector (ha). In terms of application rate per hectare of cultivated land, wheat accounted for the largest share (57 kg/ha). These statistics indicate that the national level intensity of fertilizer use is still lower than the recommended rate of 200 kg per ha (100 kg of DAP and 100 kg of Urea) (Demeke et al., 1998)

This problem coupled with current currency devaluation and environmental problems caused by synthetic fertilizer are the straddles challenging the smallholder farmer's improved production and productivity plan.

On the other hand, there is huge amount of bio wastes generated from the agricultural sector. Some of wastes are left in the field to decompose through natural processes. As result, the leachate from the wastes is contaminating the rivers and ground waters. Moreover, they make the productivity land idle. However, different research showed that it can be converted into resources such energy and bio fertilizer.

In order to reduce environmental impact and economic pressure of the usage of chemical fertilizer, it is necessary to establish a appropriate mechanism of utilizing different biomass wastes such as bioslurry and other organic remnants as soil amendment. To this effect, this research work has investigated the fertilizer value of bioslurry to utilize it as organic fertilizer and soil conditioner.

1.3. Objective

1.3.1. General Objective

To investigate Environmental and Economic benefits of Bioslurry from coffee husk relative to chemical fertilizer

1.3.2. Specific Objective

- To investigate the effect of bioslurry from coffee husk on the macro nutrients of the soil
- To assess the influence of bioslurry from coffee husk on soil organic carbon content
- To compare the effect of bio slurry on yield and yield components of the test crop
- To compare the economic benefit of bio slurry application from yield perspective

1.4. Scope of the Study

The study was intended to cover environmental and economic benefits of Bioslurry relative to N-fertilizer on wheat as a test crop. Pot study had been conducted under greenhouse condition. The bioslurry application was compared with recommended application rate of N-fertilizer (46% N). The biological impact of bioslurry application to soil has not been seen by this study due to facility limitations and expensive budget requirement of the study.

2. LITERATURE REVIEW

2.1. Agro- Productivity, Population Growth, and Climate Change

The world population is growing exponentially while agricultural productivity is in a linear dynamism. In 2050, the global population will reach around 9 billion, a 50% increase since 2007 (Warnars and Oppenoorth, 2014). By the same year, Ethiopia's population number is projected to exceed 173 million (UN Population Division, 2009). These people need to be fed; therefore agricultural production and efficiency must be increased.

Agricultural lands currently occupy 40% of land surface worldwide and the sector contributes 4% to the global GDP, providing employment to 1.3 billion people (Warnars and Oppenoorth, 2014). In Ethiopian context (Getachew, 2011), however, agriculture contributes more than 50 % of Ethiopia's GDP, 90 % of foreign exchange earnings, 70 % of raw material for domestic industries, and 85 % of employment for the population. This is exceptionally true because of the fact that in Ethiopia large numbers of farmers own small tiny plots of land for agricultural purpose.

There are different instruments and packages designed for agro productivity and per hectare optimization for smallholder farmers. The intent of the package is not only for productivity but also for per household income and wise utilization of agro-processing wastes.

However, climate change has a significant impact on agriculture and vice versa: agriculture is one of the main sources of GHG emission. Indeed, the IPCC3 concludes that the direct effects of agriculture account for 14% of global GHG emissions in CO_2 equivalents (5.1 to 6.1 Gt CO_2-eq/yr in 2005) and indirectly it accounts for 17% of emissions when biomass burning, deforestation, and conversion to cropland and pasture are included that is to say climate change and agro- productivity are highly interrelated. The changes in the global climate system and the demand for more food security together with more nutrients for health will require innovations in policy options and substitutability. One possible solution can be found in a combination of matrix and trend analysis of the three parameters(Agro- productivity, Population growth, and climate change) with energy-efficient biotechnology such as biomass waste digesters(climate change mitigation option), promoting bio farm initiatives(organic farming), and implementing family planning with full health extension package.

2.2. Chemical Fertilizer, the Environment and Economies

There are studies on chemical fertilizer potentials for cereal productions. These studies have revealed that chemical fertilizer use is one instrument implemented as a means of raising production, yield and income of farm households at the cost of the environment. However, there have not been many studies on the effects of fertilizers on long term productivity, soil conditioning (soil restructuring), deliverability, capacities of smallholder farmer's purchasing power, and its long term effect on the environments.

2.2.1. Effects of Nitrogen Fertilizers on Environment and Associated Social Coast

During production of urea, considerable amount of CO_2 is emitted during the production of urea and much of the CO_2 emission is associated with ammonia synthesis, modern urea factories emit 3.1 kg CO_2-eq kg-1N (Wood and Cowie, 2004). The emission due to transportation does not directly related to urea synthesis, however it contributes for the carbon foot print of the urea until it reaches to application farms. The truck or ship used for transportation and amount of fuel consumed per km during transportation of the product, European average 0.1 kg CO_2-eq kg-1 N (www.yara.com, 2014).

During the application of urea fertilizer nitrogen on the farm, the farm emits as N_2O-N which is deemed as highly "effective" greenhouse gas with a global warming potential of 310 times stronger than CO_2 (IPCC, 1996a). The default emissions factor for direct N_2O emission (N2O-N) is 1% of the applied nitrogen, plus another 0.325% due to indirect emission, occurring elsewhere from nitrogen that has been leached or emitted, thus 0.01325 kg of applied nitrogen is emitted as N_2O-N (Edi et al., 2003). This is equivalent to 6.45 kgCO_2-eq kg-1N, with the conversion factor of N2O-N to N2O, 44/28 (IPCC, 2006).

Moreover the leachate produced during applications nitrogen fertilizer is polluting the surface and ground water. Only a small fraction (about 2.5%) of earth's water is fresh and suitable for human consumption. The rest (more than 97%) is in oceans and seas. Of the less than 2.5% of fresh water approximately 13% is groundwater; an important source of drinking water for many people worldwide. For example, more than 50% of the world's population depends on groundwater for drinking water. For many rural and small communities, groundwater is the only source of drinking water (Mahvi et al., 2005). Hence, the application of chemical fertilizer has serious negative environmental impact.

Elevated concentration of NO_3 - in ground water from intensive agriculture has raised concern over possible contamination of drinking water supplies (Mahvi, et al., 2005). The effect of excessive nitrate in drinking water is linked to methemoglobinemia (or blue baby syndrome) which affects the fetus and young children and non-Hodgkin's lymphoma. Often nitrate concentrations in agricultural areas are also associated with pesticide and microbial contaminations. Nitrogen fertilizers or manure applied to farmlands can be considered as non-point sources of nitrate. Nitrogen compounds in these sources are oxidized in aerated soils to soluble nitrate. With sufficient surface-water infiltration, soluble nitrate can leach below the root zone to underlying groundwater. Unconfined aquifers with shallow water tables overlain by permeable soils are especially vulnerable to agricultural contaminations.

To maintain yield increase and minimize nitrate pollution of the ground waters, "best management practices" for N-fertilizer should be disseminated and an excessive fertilizer application prevented. The practices include soil conservation, balanced fertilization, more frequent N-top dressings at smaller rates during the rainy season, use of slow release fertilizers, improving nutrient capture from soil by the genetic manipulation of crop plants, feed lot runoff collection and abatement, and use of wetlands (Mahvi et al., 2005).

Schematic representations of the nitrogen cycle often make it looks as if the nitrogen undergoes simple chemical reactions to change from one form to another. However, while many chemical reactions do take place in the soil, the nitrogen conversion occurs primarily through the action of soil organisms. The most common form of nitrogen is ammonium (NH_4 +), and is found in the excretions of larger organisms. This quickly consumed by plants, fungi and special bacteria (nitrifying bacteria). Their excrement contains nitrogen first in the form of nitrite (NO_2 -), which is then consumed by other bacteria that excrete nitrogen in the form of nitrate (NO_3 -). This is the preferred form of nitrogen for grasses and most row crops. It is not surprising then the most grassland soils are dominated by bacteria. Most of our agricultural crops are grasses (grains, forage grasses) and grassland plants. These plants are accustomed to, and will be healthiest in soil high in humus. Because the metabolic activity in the soil is highest during the most active growth period of plants (highest temperature), the nitrogen will become available to plants just as it is required ,so supply and demand are in perfect balance.

Soils that are low in oxygen (due to water logging, compaction, etc) contain a large number of (facultative) anaerobic bacteria (those that can exist without oxygen =denitrifying bacteria).

These will take much of the excess nitrate (NO3 -) convert it to form of nitrogen (N_2 or N_2O) and oxygen. This supplies the soil with badly needed oxygen, and supplies the nitrogen fixing bacteria in this air –starved environment with nitrogen (N_2). Any excess returns to the air as nitrogen gas (N_2O). Of course in all situations some of the nitrogen will be leached to deeper levels of the soil and into the waterways, where it feeds other organisms (Hermary, 2007).

So we can see that here, too, nature creates balance. In natural systems, nitrogen is never "lost". However, with the application of chemical nitrogen fertilizers, which are either applied as nitrates, or converted to nitrates through the bacterial activity in the soil, this delicate system will be disrupted. Nitrates (NO_3 -) are anions, that is, they are not held on cation exchange sites. So anything that is not immediately taken up by plants is quickly leached out, and dissipates into the air as gas, as these fertilizers must be applied with large amounts of water to prevent salinization of the soil.

Thus the soil environment deals with the artificially created excess nitrogen in the way the system works naturally. Of course these leads to the pollution of our ground water and rivers, and all the health problems associated with that. However, an excess of nitrate also creates other problems. Nitrates are salts, dehydrating their surroundings. They are also very strong oxidizers, literally burning up the organic matter in the soil. These attributes not a problem in natural ecosystems where nitrates are made available only as quickly as they can be consumed, but become a serious detriment when excess nitrates are applied. To slow down this expensive loss of synthetic nitrogen, various form of nitrogen are then coated, or combined with, various substances, creating so-called "slow release" fertilizers. Supposedly these various coatings make nitrogen available at a rate plants can absorb. What all these advertisements don't tell us is that these products undergo chemical reactions in the soil, with serious "side effects" on the soil and soil life. Here are just some examples of the most common nitrogen fertilizers (Casiday and Frey, 1998).

Urea (NH_2CONH_2) is consumed by bacteria which convert it to (excrete) anhydrous ammonia (which is a gas) and carbon dioxide (2(NH_3) +CO_2). Anhydrous ammonia is highly toxic and kills organisms. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia gas vapors formed. These are heavier than air and can accumulate in low lying areas. If urea is incorporated into the soil, the ammonia gas reacts with water (H_2O) to produce ammonium hydroxide (NH_4OH). Which has a pH of 11.6; it is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills the seeds, seedlings and soil dwelling organisms. Within a few days further chemical reactions in the soil release the ammonium ion NH_4+, which then follows the same path as naturally occurring, ammonium, with any excess nitrate crated in this way leached into the environment (Hermary, 2007).

Triple super phosphate is produced by treating phosphate rock with either sulfuric acid or phosphoric acid, making it extremely acidifying. When applied to the soil it reacts with calcium to form tri-calcium phosphate, which is water insoluble, i.e. requiring microbial action for breakdown. Even in soil with health microbial activity only about 15-20% this phosphorous is easily available to plants, considerably less in soil which does not have good microbial diversity.

The production of each ton of phosphoric acid is accompanied by production of 4.5 tons of calcium sulphate, also called phosphogypsum. This is a highly radioactive and also contains heavy metals and other impurities. Depending on the production process, radioactive substances and heavy metals can be execrated into the fertilizer. These are just some examples of the potentially highly determinant effects of some common fertilizers. It is important to know that any substance used to excess will unbalance the soil, even naturally occurring substances such as dolomite lime (Casiday R and Frey R, 1998).

2.3. Organic Fertilizers

2.3.1. Organic Waste and Organic Waste Management

As the human civilization grew year by year, the production of organic solid wastes increased by quantity as well as by variety. The action of microorganisms and others present in the surroundings digested and converted the biodegradable wastes into harmless useful nutrient products.

The recycling of organic waste into organic manure (fertilizer) helps in the maintenance of healthy soil by improving soil quality thereby increasing crop production and ultimately the welfare of mankind (Gaur and Singh. 1995). Among the bioconversion methods, composting and vermicomposting, and anaerobic digestion are relatively nonpolluting methods in the recovering organic resource from solid wastes. The conversion of organic waste into energy and manure by biological process reduces the organic waste disposal problems for municipalities, for agro -industries and for the industrial enterprises. However demonstration of the recycling process and application prior to the farmland are essential at the laboratory level specifically to identify the extent of practical utility and potential to turn into products of high economic value.

The following three methods can be used in the bio-processing of organic wastes and reclaiming the resources:

(i). Anaerobic digestion (ii) Composting (iii) Vermicomposting

i. Anaerobic Digestion: It is digestion of organic solid waste in the absence of free oxygen. It is also referred to as hot fermentation method (Acharaya. 1940). Anaerobic digestion process can be broadly grouped into two major steps (a) Acid fermentation, (b) Methane fermentation. In acid fermentation the hydrolytic fermentative, (acido -genic) bacteria hydrolyze the complex polymeric substrates into organic acids, alcohols, sugars, H and CO. In methane fermentation, fermentation of amino acids and sugars takes place, where hydrogen producing, acetogenic organisms convert the fermentation products into hydrogen, acetates and CO. In methane fermentation, long-chain fatty acids and alcohols are converted into short-chain fatty acids, and CO. Hydrogenation of CO_2 produces methane in addition to methane produced from digestion of acetate. ii. Composting: This is the conversion of organic solid waste which is rich in humus and plant nutrients by microorganisms. In this process, the organic residues of plant and animal origin get converted into organic waste manure. When the wastes is directly applied to agricultural fields, it causes phytotoxicity and other soil related environment related problems (Hsu and Lo. 1999)

Composting is traditionally practiced in the transformation of organic waste by biological methods and is useful for the development of a productive and sustainable agricultural system (Parr et a1, 1990) Composting process involves a biological treatment in which aerobic thermophilic microorganisms use organic matter as a substrate. Dumping of organic wastes in open areas (landfilling) causes environmental problems such as the accumulation of heavy metals in soil, pollution of ground and surface waters due to leaching and run-off of nutrients. To solve such problems after the separation of solids from slurry, the organic matter when composted under controlled conditions provides a better alternative in terms of pollution management and manure production.

2.3. Coffee Production and Processing

Coffee represents an agricultural crop of significant economic importance to the coffee producing countries of the world. The Ethiopian annual coffee production is estimated at 0.35 million tons of which 10% of the total annual production is from the western, southern and eastern part of the country respectively (Alemayehu et al., 2007).

The aim of coffee processing (both dry and wet method) is isolating coffee beans by removing shell and mucilaginous part from the cherries. The solid residues obtained from wet and dry coffee processing is termed as coffee pulp and coffee husk respectively (Pandy et al., 2000). Coffee pulp represents approximately 40% of the weight of fresh fruit. Coffee husk is the most abundantly available agro industrial waste produced during the pulping action of the coffee cherries to obtain coffee beans in many coffee-producing areas of the tropics including Ethiopia.

It is estimated that, for a single kilogram of coffee beans produced, about 1kg husks are generated, whereas in the dry process 0.18 kg coffee husk is generated for every kilogram of fresh coffee cherries (Pandy et al., 2000). That is to say for every 50% of coffee bean to be produced, there is 50% of coffee husk is produced as a waste. Coffee wastes are generally dumped in large open piles in gorges or near rivers and cause both water and soil pollution

(Aranda and Barois.2000; Sera, 2000). The same is true in most coffee producing and processing areas of Ethiopia. The husk does not have much commercial or other industrial advantage other than, becoming the major polluting agent of environment (rivers, air, and soil)

Figure 1 Coffee husk being burnt as disposal at Yayu, Illubabor, Ethiopia: field observation

The data from CSA shows that, Ethiopia is Africa's largest producer of coffee with more than 400,000 tons of coffee produced each year. More than half of the coffee produced is exported, generating revenues of US$ 525 million. However, more than 50% of these export revenues are used to import petroleum based products and chemical fertilizers while, at the same time, coffee husk generated in the hulling centers is being burnt. This leads not only to environmental pollution but also a waste of a potentially important source of renewable energy and nutrients that could be used as soil conditioner.

Considering the size of the coffee industry in Ethiopia, the amount of energy and nutrients wasted is significant. A better utilization plan of this resource may contribute to (i) improve productivity and profitability of the coffee milling and processing centers, (ii) reduce oil and chemical fertilizer import independency, and (iii) mitigate environmental and health problem.

For instance, it is expected that by implementing coffee husk gasification technology in coffee hulling centers across Ethiopia, one could substitute up to 70% of diesel fuel; diesel fuel that is currently consumed in diesel generator sets used in the coffee processing industry or for decentralized power and heat generation. Therefore, efficient energy conversion of coffee husk could provide Ethiopia with a highly attractive possibility to reduce its dependence on imported oil, though this is beyond the concern of this paper.

So districts or cooperatives where coffee processing industries are found should pioneer various initiatives for improving the environmental performance of the coffee industries.

As the coffee husk is easily available from coffee processing units, its utility as bio sorbent for chromium will be economical and be viewed as part of waste management strategy. On the other hand, huge presence of proteins, sugars and minerals in coffee husk and its high humidity favors the rapid growth of microorganisms which can pose due to environmental pollution. However, if the right biotechnology is applied, it can be converted into compost or bio-manure that easily improves soil nutrient content.

Recognizing the rich organic content and chemical composition of coffee husk and other coffee processing wastes, , Bio- innovative project at School of Chemical and Bio Engineering studied potential biogas and substrate for mushroom production. There is a need to make a comparative study on fertilizer potential biogas manure versus chemical fertilizer in order to encourage farmers to apply compost as substitute or supplement chemical fertilizers.

2.4. Available Organic Waste (Coffee Production and Associated Waste Residue)

The coffee economy employs thousands of workers in processing either red cherry (key eshet) or dried pulp coffee (jenfel) in hundreds of washing stations and hulling mills around the country. An accurate estimate of production is difficult because part of the harvest is gathered from semi-wild and wild forests, and a good proportion of the crop is consumed on-farm or locally .Table 1 below shows the trends in production. Over 50% of the coffee produced in Ethiopia today is prepared for export. Given the rising demand for coffee worldwide, Ethiopian coffee production has grown at a compound annual rate of 10% from 2003 to 2008.

Table 1 Total coffee production and associated residue from 2002/ 2003-2007/2008

PY	02/03	03/04	04/05	05/06	06/07	07/08	08/09
TP (tons)*10^3	232.44	274.08	240.18	234.96	343.98	596.7	494.9
Residue(dry base)*10^3	232.44	274.08	240.18	234.96	343.98	596.7	494.9

Source: MoRAD, 2009

Another study on the production of coffee for 2009/10 – 2014/2015 over the six years estimates from 341 tons in 2009/10 to 831 tons in 2014/15 showing a 53.8 percent growth from the base year.

Table 2 Total coffee production and associated residue from 2009/ 2010-2014/2015

PY	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015
TP(tons)*10^3	341	405.7	482.89	579.468	695.362	831
Residue (dry base)	341	405.7	482.89	579.468	695.362	831

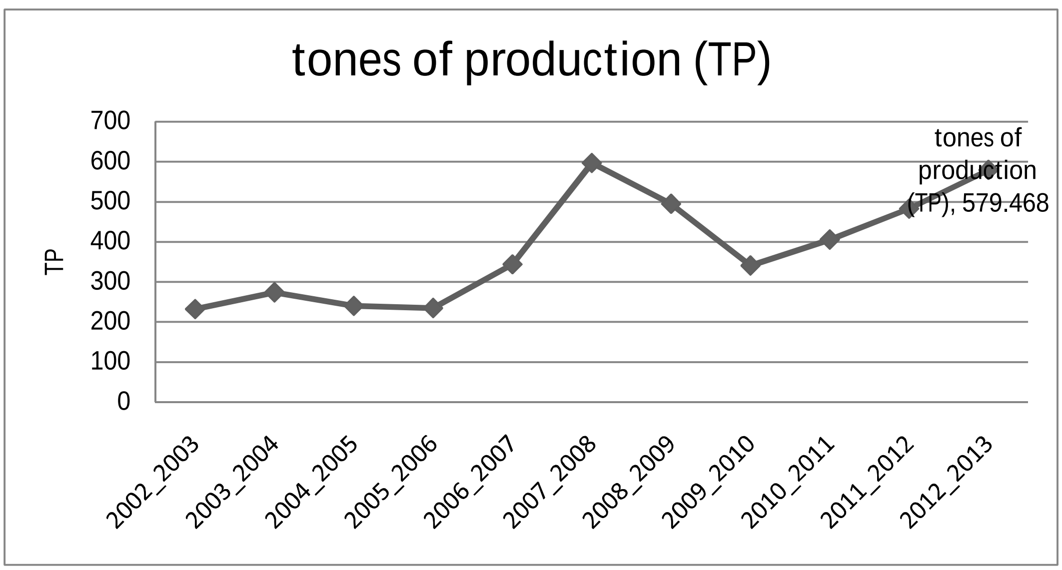

Figure 2 Coffee production, source: CSA

From the above two tables and annual growth rate, it is possible to summarize that coffee processing and coffee bean production produce huge amounts of coffee husk and coffee pulp(waste). Different literature citing links the amount of coffee husk being produced during coffee processing amounts to 45% to 50% by weight per the processing unit. It is estimated that, for a single kilogram of coffee beans produced, about 1kg husks are generated (1:1 ratio).

2.5. Quality Management of Bioslurry Used As Fertilizer

The underlying principles that define the ‘quality’ of digestate as a bio fertilizer, suitable to replace mineral fertilizers in crop production, are the same irrespective of the size and location of the biogas plant. High quality digestate fit for use as fertilizer is defined by essential features such as: declared content of nutrients, pH, dry matter and organic dry matter content, homogeneity, purity (free of inorganic impurities such as plastic, stones, glass etc.), sanitized and safe for living organisms and the environment with respect to its content of biological (pathogenic) material and of chemical pollutants such as organic and inorganic Lakehurst (2012).

The digestion process cannot degrade all potential chemical contaminants which are supplied with the feedstock. This means that the only way to produce high quality digestate is to use feed stocks for anaerobic digestion which do not contain unwanted impurities. For this reason, countries with developed biogas sectors and with policies of environment and human and animal health protection have introduced “positive lists” of feedstock materials for anaerobic digestion (Lukehurst, 2012).

2.5.1. Importance of Bioslurry Quality

Digestate quality assurance means not only that digestate is safe for use but that it is also perceived as a safe product by farmers, food wholesalers, food retailers, politicians, decision makers and the general public. Improved confidence in the quality and safety of digestate is expected to lead to its more widespread use as bio fertilizer. Moreover, it also enables (i) Production of renewable methane, to displace use of fossil fuels (ii) Displacement of mineral fertilizers, lowering their negative impact on the environment (iii) Increased recycling of organic matter and nutrients and conservation of natural resources (iv) Sanitation of organic wastes and animal manures, breaking the chain of pathogen transmission (v) Cost savings to farmers through enhanced use of own resources, reduced purchases of mineral fertilizer and higher nutrient efficiency (vi) Potential for reduced air pollution from emissions of methane and ammonia through application of “good practices” (Lukehurst, 2012).

2.5.2. Bioslurry Production and the Management of Quality

A biogas digester can be filled with locally-available raw materials, coffee husk, crop residues, and animal (pig, poultry, and cattle) and human waste such as urine and dung. 'During digestion, about 25-30% of the total dry matter (total solids content of fresh residue) of agriculture, animal/human wastes will be converted into a combustible gas and a residue of 70-75% of the total solids content of the fresh coffee residue comes out as sludge which is known as digested slurry or biogas slurry(Gurung, 1998). Biogas and bio slurry offer several benefits by improving fertilizer qualities, reducing odors and pathogens and providing renewable energy and fuel (Holm et.al 2009.). Bio slurry can be used to fertilize crops directly or added to composting of other organic materials. Bio slurry is an already-digested source of agricultural waste. The bio slurry also contains nitrogen, phosphor and potassium as well as zinc, iron, manganese and copper.

Generally speaking, there are two methods of processing coffee cherries, dry and wet method. These release solid waste such as coffee husk and coffee pulp. Pandy et.al ,2000 ; Brassani and Braham 1980, showed that coffee husk is rich in organic matter(Cellulose, Hemi-cellulose ,Pectin , and lignin) and chemical nutrients such as nitrogen (N) ,phosphorus(P) , and Potassium(K). Additionally, coffee husk contains secondary compounds such as Caffeine and tannin. Therefore, coffee husk and coffee pulp have great potential for biotechnology.

Table 3 chemical Composition of coffee husk

Nutrient data (%)	Composition of coffee husk
Moisture	17.3
OC	50.8
PH	5.74
N	1.27
P	0.06
K	2.46
Ca	0.37
Mg	0.42
C/N ratio	40.02

Source: Dias et.al 2010

The production and recycling of digestate as fertilizer requires quality management and quality control throughout the whole closed cycle of anaerobic digestion, from the production of the anaerobic digestion feedstock until the final utilization of digestate as fertilizer. Quality management implies the use of high quality feedstock, pre-processing of specific feedstock types, close control of the anaerobic digestion process and of process parameters affecting digestate quality, digestate processing, declaration and optimal storage and application as fertilizer.

2.6. Environmental Effects of Using Bioslurry as a Fertilizer

Adoption of the best management practices outlined above will give the direct environmental benefits from use of digestate as a fertilizer. Such practices will result in lower gaseous emission into the atmosphere as well as in less diffuse pollution from surface run off and leaching. These direct benefits will help governments meet targets for reducing GHGs. Other major environmental benefits associated with using digestate as a bio fertilizer in place of untreated manures include: reduced odors, improved veterinary safety, plant pathogen reduction and the reduction of weed seeds.

2.7 Different uses of Bioslurry

Bioslurry for soil remediation: Kadian *et al* (2008) studied the degradation of the herbicide atrazine in soil amended with Bioslurry. The results showed that when Bioslurry was added as soil amendment, it accelerates the breakdown of atrazine to 34 percent in 21 days, compared to the control. Bio seems to support maximum microbial growth resulting in highest dissipation of atrazine.

In a different study, Kandian *et al* (2012) examined the suppressing effect of organic amendments on the insecticide chlorpyrifos (CPF) in agricultural soils. CPF is known to inhibit the microbial activity in soil. Bioslurry proved to be able to reduce this inhibitory effect of CPF, considerably enhancing the microbial activity of the soil again.

Effects of Bioslurry pathogens and seed viability: Livestock faeces can be significantly contaminated with pathogens and many outbreaks of gastroenteritis related to livestock have been reported (Massè *et al*. 2011). The anaerobic digestion process may inactivate bacteria, viruses, fungi and parasites in the feedstock, which is crucial prerequisite if Bioslurry is to be directly applied to crops. If treated appropriately, Bioslurry reduces the risk of contaminating crops with harmful pathogens as opposed to undigested farmyard manure (e.g. Yen-Phil *et al*, 2008). Else, pathogens can be directly transmitted to vegetables, animals and/or agricultural workers, and groundwater or surface water may be contaminated with faecal material deriving from field runoff.

The sanitation of the end product depends on the quality of the substrates fed into the digester, and on the digester performance, such as previous pasteurization, digestion temperature, slurry retention time, pH and ammonium concentration, among others (Sahlström, 2003 and Ottoson *et al*., 2008).

Bacteria: The process of anaerobic digestion in biogas plants usually takes place either under thermophilic (53 to 58 °C) or mesophilic (30 to 42 °C) conditions. Anaerobic degradation using thermophilic temperatures significantly reduces the number of bacteria; mesophilic digestion is not as effective in this regard (Slana *et al*, 2011). This particularly concerns smallholder biogas digesters which usually only work at mesophilic conditions.

Bacterial pathogens from livestock residues provoking human and/ or animal health issues include Salmonella spp., Campylobacter ssp. and Yersinia enterocolitica, Listeria monocytogenes, E. coli O157, Mycobacterium avium subsp. Paratuberculosis, Clostridium spp. and Bacillus spp (Bagge et al. 2005; Slana et al, 2011).

Weed seeds: Schrade *et al* (2003) investigated the effects of digestion on the viability of seeds, including weed seeds present in raw manures. They found that the operating temperature of the digester and the time of digestion played a significant role in reducing the germination potential of the analyzed seeds. Seeds of winter wheat, canola, foxtail and wild mustard were completely immobilized after 24 hours in the digester under mesophilic temperatures. By contrast, seeds of tomatoes, white goosefoot, and yellow dock root required thermophilic temperatures to stop germination after 24 hours. Further factors that influenced the results were assumed to be the micro bacterial activity, the emissions from the decomposing organic matter and the moisture content of the seeds.

Accumulation of heavy metals in Bioslurry: Bioslurry can contain heavy metal impurities. They may accumulate in the soil with repeated fertilizer applications and thus increase heavy metals in soils, raising concern about the entry of these metals in the human food chain and related health implications. This might have health implications as crops for human consumption accumulate these metals in their tissue. In recent years, livestock production systems, especially those common in intensive swine farming, have been utilizing heavy metals as growth promoters. Tulayakul *et al* (2010) found that Zn, Cd and Pb levels in biogas covered lagoon wastewater samples were higher than in non-biogas wastewater samples. Despite the fact that the differences were not significant, the researchers recommend that these results should be considered for future evaluations.

Over-fertilization through slurry application: Over-fertilization of crops can be critical if too much fertilizer is applied to arable lands. Critical concentrations of plant-available P and K that are necessary for maximizing crop yield have been documented for a limited number of soil types and crops worldwide (e.g. Syers *et al*., 2008; Johnston *et al*, 2001). Above these critical P and K levels, there is no additional yield benefit. To the contrary, high P soil concentrations can lead to significant P losses to drainage waters resulting in eutrophication (Zhao *et al*, 2007).

Likewise, high ammonia emissions from over-fertilization with N may create considerable environmental risks. Ammonia (NH_3) volatilization from field application of organic slurries not only results in financial loss through fertilizer-N loss, but NH_3 volatilization from agriculture is also considered to be the main source of atmospheric pollution by NH_3 (e.g. Vitousek *et al*, 2009). Subsequent excess NH_3 deposition from the atmosphere causes soil acidification and eutrophication of N-limited natural and semi-natural ecosystems as well as surface water bodies (Dragosits *et al*, 2002; Sanderson *et al*., 2006). As the NH_4+ As the NH4+ content and pH of the Bioslurry increase during fermentation of biogas crops (Wulf *et al*., 2002), there is a high potential of NH_3 emissions after Bioslurry application to the fields (Ni *et al*, 2012).content and pH of the Bioslurry increase during fermentation of biogas crops (Wulf *et al*., 2002), there is a high potential of NH_3 emissions after Bioslurry application to the fields (Ni *et al*, 2012).

Nonetheless, to our best knowledge, there has been no comprehensive quantification of NH_3 volatilization (Ni *et al*, 2012) nor of P and K loss from Bioslurry in different contexts (e.g. small or large crop and livestock farms), nor of the subsequent risks for soil acidification and eutrophication.

Bioslurry methods of storage: The storage of Bioslurry is an important issue as sometimes not all of the slurry produced is directly applied to the fields or used as feed. Either there is no need for it at the given moment, or regulations do not allow for spreading slurry at a certain time of the year. A farmer survey in Nepal found that only a few farmers incorporate the Bioslurry directly into the soil (SNV, 2009). However, leaving Bioslurry in the open air, exposed to the sun for a long period of time, leads to a significant nitrogen loss, which diminishes the quality of the fertilizer and increases the release of powerful greenhouse gases (e.g. Möller *et al*, 2008 and

Möller, 2009). It is therefore crucial to adequately treat the Bioslurry after the digestion process. This can either be done through the right farm storage facilities, through slurry transportation to another farm where it is directly used, or through the transformation of slurry into compost.

While new storage facilities are readily available in industrialized countries, where initial investment costs do not present a barrier to farmers, the storage of Bioslurry in developing countries is still one of the major challenges in terms of Bioslurry management. Even if adequate storage facilities are in place, storage itself still depends on various conditions and on duration, which may affect the characteristics of the stored materials and the separation of nutrients through biological decomposition as well as the amounts of bacteria in the materials through, for example, the growth of bacteria or availability of nutrients (Paavola & Rintala 2008; Bagge *et al.*, 2005). Temperature during storage time has strong influence on the chemical composition of the slurry. Sommer *et al*. (2007) reported that during 114- 138 days storage of fresh cattle slurry, the transformation of organic N to NH_4 was slow and insignificant at <15 °C but increased significantly at 20 °C. This is particularly important in the context of slurry storage in tropical countries where temperatures can vary considerably between different regions.

Tran et al. (2011) found that the fraction of N loss caused by N emission from covered bioslurry storage was 25 to 30 percent of initial N content, while that from uncovered bioslurry was 60 to 70 percent. They furthermore found that after 90 days of storage, 1.15 to 1.20 times the initial ammonium-N (NH-N) was found in the covered slurry and only 0.40 to 0.50 in the uncovered.

Nutrients can also be lost through leaching when slurry is collected in underground uncemented storage pits, which can be found in India for instance.

Bioslurry as material for compost: Since adequate storing facilities are not always in place, composting can be a good alternative. Compost is produced by aerobic micro-organisms and can be used as basal fertilizer when preparing soil or as an additional fertilizer for crops. Some practical tips on how to make compost from bioslurry have been published by SNV (2009), for instance.

Composted and stored bioslurry can serve as an important way of reducing farm operative costs, as it reduces the need for synthetic fertilizer and hence related household expenditures. In Vietnam for instance, the cost of producing composted bioslurry with the composting system is estimated at roughly US$15 per tonne, considerably cheaper than the current prices of synthetic fertilizers, which amounted to US$332 per tonne for urea in May 2011. The comparison of prices must take into consideration the substitution potential between these two types of fertilizers.

Nutritional value and physical properties of bioslurry: All studies report a reduced organic matter content of bioslurry compared to farm yard manure, as the digestion process leads to the breakdown of organic biomass.

The pH-value of bioslurry is usually higher than that of farm yard manure that bears the risk of an elevated release of ammonia. High concentrations of ammonia cause damage to vegetation and lead to acidification and eutrophication of soils. This has adverse effects on ecosystems. In addition, ammonia is an important precursor for the formation of secondary aerosols. The nutrient composition of Bioslurry varies widely between studies, always depending on the original substrate, the type of digester and the process applied. All studies report a higher percentage of available nitrogen in Bioslurry compared to FYM, which accelerates the N-uptake by plants. This is particularly visible in the early part of the growth cycle as the higher ammonium fraction of the Bioslurry is more easily accessible for the crops (Möller, 2009 and Möller et al, 2008). The difference seems to even out over the length of the growth cycle for most of the crops, as the remaining nitrogen mineralizes. The same study found, however, that this could not be concluded for plants with a shorter growth cycle such as spring wheat and potatoes.

Accordingly, the C/N ratio of bioslurry is lower than in farm yard manure, which accelerates the N mineralization process. This, in turn, helps the uptake of N in the crops, but also increases ammonia emissions. Farm yard manure, by contrast, is oxidized to nitrates and nitrites, which do not bond well with soil particles and therefore leach out faster (Ghoneim 2008).

Crop quality: The protein content of plants (duckweed and cassava leaves) has been shown to be higher when treated with Bioslurry compared to other organic farming. Another study showed that tomato quality in terms of amino acid content and macro and micronutrients increased compared to synthetic fertilizer treatments.

3. MATERIAL AND METHODS

3.1. Bioslurry

The bio-slurry used was sludge collected from pilot biogas plant of Bio Innovate IV/2010 project at Addis Ababa Institute of Technology. The pilot plant used as a feed coffee husk from Gomma II Coffee processing plant.

3.2. Soil sample

Degraded soil is used for the experiment. The degraded soil samples were collected from Holeta area in Western Shewa Zone at depths of 15 cm before the farm is sowed. .

3.3. Laboratory Analysis

The bio-slurry and soil characteristics were analyzed for physicochemical properties before and after application as soil conditioner or fertilizer. Look at Table 4. Organic matter in the soil was calculated using the Walkley and Black (1934) method, while organic carbon in the bioslurry was determined using the loss of weight on ignition method. Total N was estimated following Gunning and Hibbard's method (Jackson, 1962) of sulfuric acid digestion and distillation of ammonia into 4% boric acid by a micro- Kjeldahl apparatus. P was determined following Olsen's method (Jackson, 1962) and available K was determined using a Flame Emission Photometric Method. Soil pH was determined in Potentiometric – Water extract Electrical conductivity was measured from the saturated soil extract using an EC meter (FAO - Conductivity – Water extract). All analyses were made using JIJE Analytical Testing Service Laboratory (Aleme Gena, South-West Showa Zone).

After harvesting, the residual effect of bioslurry on the soil was also estimated, and N, P, K, and organic matter of the soil was determined by following proper procedures as described above.

3.4. Pot Experiment and Layout

A pot experiment was conducted under greenhouse condition at an experimental area of college of Natural Science, University of Addis Ababa. The experiment was laid down according to a randomized complete design (RCD), keeping pot-to-pot distances at 30 cm.

The treatments or amendment were made using estimated amount of application of the fertilizer for hectare [(T_1) control (without any amendments) (T_2) 6.2m^3 bioslurry (T_3) 4.7m^3 + 31kg urea (T_4) 3.1m^3bioslurry +62kg urea (T_5)1.6m^3 +92 Kg urea (T_6) 123kg urea(T_7) Excess bioslurry (7.5m^3)] ha^{-1} using wheat as a test crop. The pots were filled with <2mm sieved soil (5 kg pot^{-1}) and medium sized gravel at the bottom of the pots. The bioslurry was applied a week before sowing of the seed while urea was applied at the tiller stage of the plant. The amounts of bioslurry and urea were calculated from the recommended rate of nitrogen. The soil moisture was adjusted to 60% field capacity by weighting regularly.

The number of seeds placed in each pot was ten and thinned to four after emergency. The soil was then moistened to field capacity and distilled water was used for irrigating wheat throughout the experimental period. Yield and yield components of the wheat such as plant height and spike length were measured at maturity stage of the test crop.

Plant height and spike length were measured in centimeter (cm) with the help of measuring tape from soil surface to the top of plants. Average heights of all the replications were calculated. The grain yield of each pot was taken after harvesting and projected to kilogram per hector.

3.5. Statistical analysis

Some data subjected to analysis of variance (ANOVA) using SAS version 9 statistical software and mean comparison had been done with least significant difference (LSD) for the significantly differed means among the treatments at 5% probability level.

4. RESULTS AND DISCUSSIONS

4.1. Selected chemical properties of soil and Bioslurry

Table 4 shows the result of chemical analysis of the bio-slurry and soil for nutrients and organic carbon content. The analysis shows that the bio slurry contains considerable amounts of plant nutrients such as nitrogen, phosphorus and valuable amount of organic matter. Thus, the organic matter and nutrients in bioslurry are considered as the two factors that make bioslurry potentially suitable as a fertilizer in agriculture production. Many studies have indicated that the bioslurry can be effectively used as a fertilizer for crop yield and improving physical and chemical properties of soils (Subbiah and Ramulu, 1980; Qasim et al., 2001). Another study showed that bioslurry improves soil structure and aeration, increases water-holding capacity, and diversifies nutrients for sustainable crop productivity (Zhu and Chen, 2002; Yu et al., 2010).

Table 4 Chemical composition of bioslurry and soil before bio slurry application

	C:N	pH	OC (%)	N (%)	P (%)	K (%)
Bioslurry	3.9	7.6	49.9	1.7835	1.75	1.32
Soil		7.5	1.32	0.003	$6.01*10^{-4}$	$312*10^{-4}$

On the other hand, the Andosol was characterized by neutral pH, low organic carbon, and total nitrogen content and micro nutrients. In order evaluate the soil carbon content and nutrients improvement, soil analysis was made after application of the bio-slurry and plants have grown on the soil amended by bioslurry and chemical fertilizer.

Table 5 Soil nutrient (macro nutrients and organic carbon) analysis results due to bioslurry application post-harvest

Treatments	pH	OC (%)	N (%)	P (ppm)	K(ppm)
T_1	7.05	1.31	0.02	6.51	301
T_2	7.05	2.67	0.65	6.70	312
T_3	7.05	2.89	0.07	6.80	335
T_4	7.05	2.89	0.08	6.92	325
T_5	7.05	2.18	0.09	7.01	390
T_6	7.05	2.130	0.11	6.85	345
T_7	7.05	2.92	0.12	6.8	320

In addition, the effect of the application of chemical fertilizer supplement on the carbon content was evaluated and compared with soil conditioned only with bio slurry. Table 6 shows this comparison.

Table 6 : Combined Effect of bio slurry and Urea fertilizer on % Soil Organic Carbon

Treatments	%OC
T_1	1.31^b
T_2	2.67^a
T_3	2.89^a
T_4	2.21^b
T_5	2.18^b
T_6	2.13^b
T_7	2.92^a
CV %	7.19
LSD	0.306

**** Means with the same letter are not significantly different for $p<0.05$

4.2. Effects of Bioslurry Amendment on Soil Properties

The highest Bioslurry application resulted in higher organic C than all other treatments with the application of $6.2m^3$ ha^{-1} which was increased by 122.9% over the control. The present finding was in line with that of previous result of study which showed bioslurry application significantly increasing soil organic C than NP and NPK chemical fertilizers (Mkhabela, 1998).

Although a clear picture of the residual effects of bioslurry application cannot emerge after a single season of study, increased nutrient and organic matter concentrations in the soil showed a positive tendency regarding the residual effects of bioslurry application (Table 5). Application of a mineral fertilizer along with bioslurry has demonstrated a positive contribution on the availability of N, P, and K content in soil. Although an increasing trend in the content of organic matter and N concentration in the soil after harvesting wheat crops has been observed; however, long-term observation is required to determine any noticeable change. This was too short a period to notice the changes in the soil properties brought about by the application of bioslurry; however a postharvest increase in the concentration of N and organic C is clearly observable.

In general, the present study demonstrated that soil amended with Bioslurry increased soil carbon sequestration capacity in addition to supplementing nutrient to the soil. Therefore, using Bioslurry not only increases C-sequestering and improving soil fertility. The process helps recover resources instead of being leached into water body. Thus also it is one of the safest and useful strategies of agricultural wastes disposal methods to reduce their contribution to environmental pollution as the table below shows

4.3. Wheat response to Bioslurry and urea application

The addition of Bioslurry alone or in combination with N-fertilizer at different level increased the yield, the plant height, and the spike length of the wheat over the control treatment (Table5).

The lowest value of yield(1,569.6kgha^{-1}), plant height (48.8 cm),and spike length (6.4cm) were recorded from the control treatment, whereas the highest yield (4,368.2kgha^{-1})with application of 62kg urea+3.1m^{3} ha^{-1}, followed by 84.4 cm plant height with the application of 123kgha^{-1} urea alone and 9.1 cm spike length with application of 123 kg ha^{-1} urea alone and 7.5m^{3} ha^{-1} Bioslurry alone respectively. The application of above 7.5m^{3} ha^{-1} of Bioslurry on the soil used in the present study did not improve wheat yield and yield component.

Either the sole application of Bioslurry or in combination with N-fertilizer at various levels significantly increased wheat spike length over the control treatment. The highest spike length recorded was (9.1 cm) followed by (8.9cm) and (8.4cm) with application of 123kg urea, 7.5m^{3} Bioslurry ha^{-1} and 3.1m^{3} Bioslurry + 62kg urea ha^{-1}, respectively. Similar results were reported elsewhere where favorable environment results in increasing water and nutrient use efficiency of plants (Sarwar et al., 2008).

Table 7 Effect of bio Slurry and urea fertilizer on the grain yield, spike length and plant height of wheat crop per pot

Treatments	Yield(gm)	Spike length(cm)	plant height(cm)
T_1	3.27^{d}	6.37^{d}	48.93^{c}
T_2	5.28^{c}	8.33^{b}	79.44^{ba}
T_3	8.66^{a}	8.91^{a}	77.20^{b}
T_4	9.10^{a}	8.30^{b}	73.65^{b}
T_5	9.12^{a}	8.36^{b}	76.93^{b}
T_6	7.58^{b}	9.08^{a}	84.40^{a}
T7	5.91^{c}	7.10^{c}	77.77^{ba}
CV %	7.45	2.8	5.53
LSD	0.912	0.396	7.172

**** Means with the same letter are not significantly different for $p<0.05$

The highest wheat grain yield was 4368.1kg ha^{-1} followed by 4324.8kg ha-^{1} with the application of [3.1m^3 Bioslurry+62kg urea] and 4.7m^3 Bioslurry+ 31kg urea ha^{-1}, respectively.

This resulted in 178.3% to 175.5% more grain yield than over the control treatment. The result of the study demonstrated that the application of N-fertilizer in conjunction with Bioslurry can give far better result than either with the sole application of N-fertilizer or Bioslurry. Similar results were also reported with the integrated N and P -fertilizers either with farmyard manure and Bioslurry on wheat grain yield (Edwards et.al. 2010).

In general, the present results clearly indicated that Bioslurry is one of the potential fertilizer sources but underutilized in our country. Therefore, soil quality parameters can be improved with the integrated use of Bio fertilizer and chemical fertilizers to sustain agricultural productivity and environmental quality.

Table 8 Average yield and yield components of wheat (projected value)

Treatments	Average grain per treatments (gm/pot) (A)	Average plant height per treatment (cm) (B)	Average spike length per treatment (cm)	Grain average (Kg/ha)	% increase in the parameter over the control		
					%A	%B	%C
T_1	3.27	48.8	6.37	1,569.6	0	0	0
T_2	5.3	79.4	8.3	2,544	62.1	62.7	30.3
T_3	8.7	77.2	8.9	4,176	166.1	58.2	39.7
T_4	9.1	73.7	8.3	4,368	178.3	51.01	30.2
T_5	9.01	76.9	8.4	4,324.8	175.5	55.7	31.8
T_6	7.6	84.4	9.1	3,648	132.4	72.9	42.9
T_7	5.8	72.4	9.1	2784.1	77.4	48.4	42.8

4.4. Nutrient Uptake of the Wheat Plant

Bioslurry addition alone and in conjunction with urea enhanced the nutrients uptake of plants (Table 9). The concentration of nitrogen in wheat straw was substantially increased with the application of Bioslurry alone or in conjunction with N-fertilizer. The lowest percentage of total nitrogen (N) 0.91% was determined from control (whereas the highest N (1.26%) was observed with the application of 200kg urea ha^{-1}. Furthermore, the application of Bioslurry at different levels enhanced the phosphorus concentration in wheat straw and combination of chemical fertilizer with Bioslurry further improved the phosphorus concentration of the plant. Similar to N, the lowest concentration of P was 0.23% for control treatment, whereas the highest P was 0.29 % (T_2) with application of Bioslurry at the rate of 1m^3 $ha^{-1.}$ The status of potassium uptake improved in wheat straw with application of either Bioslurry in combination with N-fertilizer. The highest potassium concentration (19.52%) was observed with application of 200-kg urea ha^{-1}, followed by (16.01%) with application of 100kg urea ha^{-1}.

The results of this study realized that Bioslurry and N-fertilizer best work for growth and yield attributes of wheat when applied in combination. The results obtained also show a great potential in managing N utilization in plants through the use of bioslurry as a soil conditioner, along with reduced levels of recommended N. The influence will, however, depend on the soil type, form, amount of bioslurry added, and environmental conditions.

Increased organic matter, P, N, and K concentration in the soil (Table 1) will have a positive impact on plant growth for future crops; these results are also found to be in alignment with those of Caravaca et al. (1999).

Table 9 Effects of Bioslurry and urea on plant nutrient uptake

Treatments	TN %	%P	%K
T_1	0.91^{c}	0.19^{c}	9.49^{f}
T_2	1.16^{ba}	0.29^{a}	14.68^{b}
T_3	1.14^{ba}	0.22^{b}	9.68^{e}
T_4	1.17^{ba}	0.28^{a}	11.84^{c}
T_5	1.00^{bc}	0.28^{a}	11.54^{d}
T_6	1.21^{a}	0.23^{b}	16.01^{a}
Excess slurry	1.06^{bac}	0.27^{a}	9.09^{g}
%CV	10.19	4.82	0.22
LSD	0.195	0.02	0.046

** Means with the same letter are not significantly different.

4.5. Economic benefit of Bio slurry

Increased recycling of nutrients and replacement of expensive inorganic fertilizers through application of the bioslurry output from biogas digesters could impact the nutritional status of crops and so greatly improve yields. Although the potential economic benefits of increased crop yields through application of bioslurry are high, it is difficult to quantify the likely improvement in yields at a specific site without detailed dynamic simulation modeling and analysis of the nutrient status of the soils and crops. However, the value to the farmer can be partially estimated from the potential savings to the farmer of applying bioslurry instead of any planned applications of purchased inorganic fertilizer

Traditionally cost accounting system for Bioslurry preparation does not include the invisible costs and benefits of environmental and social aspects, since they are difficult to quantify. There are environmental externalities associated with anthropogenic activates.

As a result, in the present study only financial analysis was made at 0(zero) birr/kg of Bioslurry, 10birr/g of urea, and 7 birr/kg of grain yield. The assumption was, coffee processing has been associated with huge amount of coffee husk production and bio digestion plant was integrated for the sake of bio farming. Thus, Partial budget analysis for bioslurry from coffee husk and chemical fertilizer in terms of urea for the wheat production was considered.

Table 10 Partial budget analysis for Bioslurry and Urea application for wheat product

Treatment	Average yield(kg/ha^{-1})	Price (birr/kg of wheat)=7 (A)	Cost (birr/kg of bio)=0 (B)	Cost (birr/kg of urea)=10 (C)	Cost of operation (20% of yield sale) D	Net revenue E=A-(B+C+D)	Economic efficiency (%)
T_1	1569.6	10987.2	0	0	2197.44	8,789.76	-
T_2	2544	17808	0	0	3561.6	14,246.4	62.1
T_3	2176	15232	0	310	3046.4	15,232.3	73.3
T_4	4368	30576	0	620	6115.2	23,460.8	166.9
T_5	4324.8	30273.6	0	920	6,054.7	22,718.9	158.5
T_6	3648	25536	0	1230	5,107.2	18,428.8	109.7
T_7	2784.1	19488.7	0	0	3,897.7	15,590.9	77.8

The simple economic analysis based on economic efficiency (net revenue minus total cost against the control) revealed that the highest economic efficiency (23,460.8 Eth. Birr ha^{-1}) was recorded followed by 22,718.9 Eth.Birr ha^{-1} for the combined application of 3.1m^3 bioslurry + 62kg urea ha^{-1} and 1.6m^3 bioslurry+ 92kgurea ha^{-1} with economic efficiency of 166.9% and 158.5 respectively (Table 9). The study revealed that the combined application of bioslurry and urea were more economical than sole application of either N-fertilizer or bioslurry. However, further study needs to be conducted under field condition with detail analysis

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The addition of bioslurry as bio fertilizer at different levels to Andosol (soil type) significantly increased the N, organic C, available P, and other microelements. The organic C of the soil increased specially in the treatments where higher bioslurry was applied. This has important implication because all things being equal, soil with higher organic carbon become more productive than those with lower organic carbon. The addition of bioslurry had also positively responded on yield and yield component of wheat. The study demonstrated that the integrated use of bioslurry at $4.7m^3$ ha-1 with 31kg urea ha-1 and $3.1m^3$ bioslurry ha-1 with 62kg urea ha-^{1} appeared to show economic gain in all aspects. The finding of the research also shows that high dose of urea and/ or bioslurry applications are not economically feasible and not environmentally sound.

The application of bioslurry alongside a chemical N fertilizer resulted in an increased N content of the straw and ultimately in total N uptake as compared to control plants and plants applied with 100% of the recommended dose of a chemical N fertilizer. Application of bioslurry alongside different rates of inorganic N showed improvement in the plant growth, spike length, and yield of wheat. The concentration of N in the control soil was less than soil treated with medium or less amount of bio-slurry application. Therefore, optimum application of either organic and/or chemical fertilizer can improve the nutrient uptake of the plant.

In order to get the complete picture of economic gain and environmental advantage, the biogas produced from anaerobic digester that adds value to the coffee husk and coffee processing wastes should be considered. This approach shows an integrated solid waste management strategy which includes ensuring resource recovery and improving environmental performance.

5.2. Recommendation

Agro-processing wastes have high energy and bio manure potential. In coffee grown area, the wastes generated from coffee processing plant in the field, occupy the land until it get decomposed over several years, and leachate generated pollutes water body. However, the study has shown that anaerobic treatment of the coffee processing wastes can produce biogas as source of energy and slurry that have high energy potential. Thus, the recommendations to the farmers and environmentalists will be

- ❖ Disseminating anaerobic technology that decompose coffee wastes (any wet agricultural wastes) into biogas and bio-slurry to stakeholders for its wider application
- ❖ Using bio-slurry through integration urea to improve agricultural productivity for smallholder farmer and reduce the cost of fertilizer;
- ❖ Using biogas produced through anaerobic digestion as fuel to reduce the energy cost of the rural community;

However, further studies are required to understand the effects of bioslurry application on soil structure, soil organisms, and the biochemical changes in plants. In order optimize the economic and environmental performance further studies should be carried out. In this context, application of bioslurry to field scale is worth investigating.

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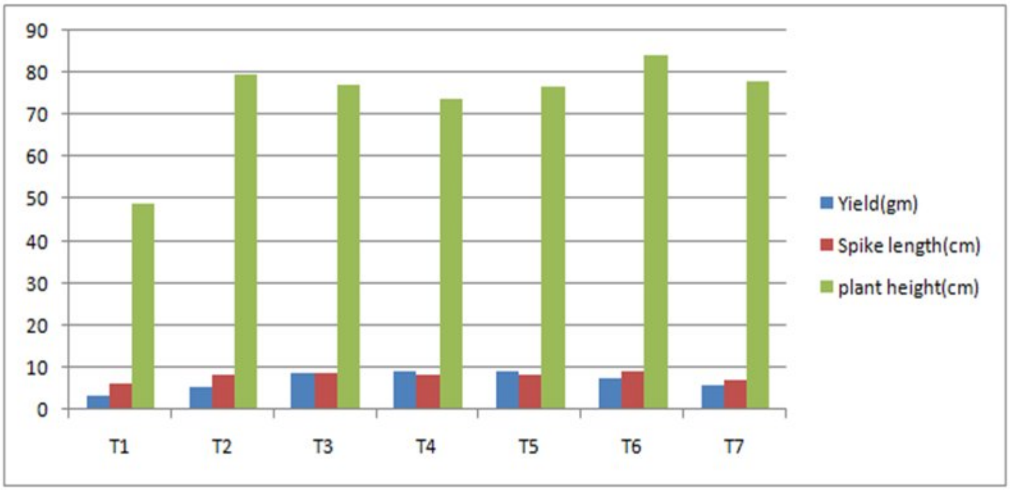
ANNEX



T1= control, T2=100%Bioslurry&0%fertilizer,T3=75% Bio slurry & 25% ferti :T4=50% Bio slurry & 50% ferti; T5=25% Bio slurry & 75% ferti; T6=0% Bio slurry& 100 % ferti; T7= Excess slurry

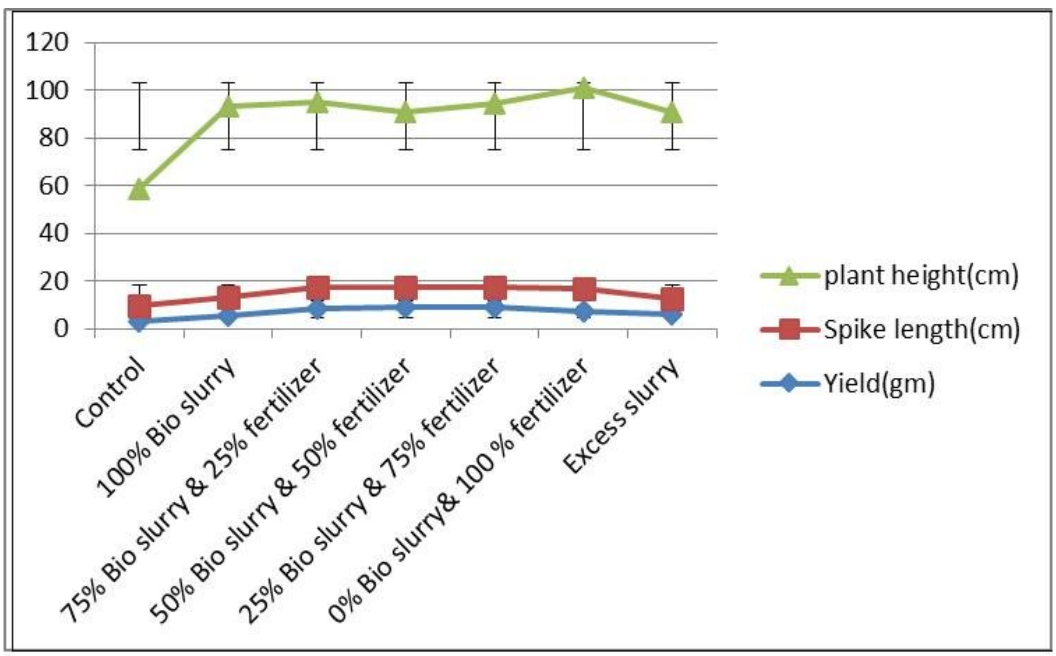


Table: Effects of Bioslurry and urea on plant nutrient status

Treatments	TN	%P	%K
Control	0.91^{c}	0.19^{c}	9.49^{f}
100% Bio slurry &)% fertilizer	1.16^{ba}	0.29^{a}	14.68^{b}
75% Bio slurry & 25% fertilizer	1.14^{ba}	0.22^{b}	9.68^{e}
50% Bio slurry & 50% fertilizer	1.17^{ba}	0.28^{a}	11.84^{c}
25% Bio slurry & 75% fertilizer	1.00^{bc}	0.28^{a}	11.54^{d}
0% Bio slurry& 100 % fertilizer	1.21^{a}	0.23^{b}	16.01^{a}
Excess slurry	1.06^{bac}	0.27^{a}	9.09^{g}
%CV	**10.19**	**4.82**	**0.22**
LSD	**0.195**	**0.02**	**0.046**

**Means with the same letter are not significantly different.

ANOVA TABLE: Total nitrogen

Source of variation	**DF**	**SS**	**MS**	**F-value**	**Pr >F**
Treatments	6	0.203	0.034	2.72	0.0577
Error	14	0.1745	0.012		
Total	20	0.377			

ANOVA TABLE: %P

Source of variation	**DF**	**SS**	**MS**	**F-value**	**Pr>F**
Treatments	6	0.025	0.004	28.97	<0.0001
Error	14	0.002	0.0001		
Total	20	0.0277			

ANOVA TABLE: %K

Source of variation	**DF**	**SS**	**MS**	**F-value**	**Pr>F**
Treatments	6	129.7	21.617	31.31	<0.0001
Error	14	0.0096	0.0006		
Total	20	129.71			

Raw data table

Treatments	Rep	Sample Weight(gm)	Spike length(cm)	plant height(cm)	%OC
control	1	3.78	6.5	50.00	1.97
control	2	2.66	6.4	49.50	2.08
control	3	3.38	6.21	47.30	2.04
100% Bio salary &)% fertilizer	1	4.56	8	78.00	2.9
100% Bio salary &)% fertilizer	2	5.425	8.5	87.00	2.80
100% Bio salary &)% fertilizer	3	5.856	8.5	73.33	2.3
75% Bio salary & 25% ferti	1	8.173	8.5	75.80	3.1
75% Bio salary & 25% ferti	2	9.093	9.1	79.40	2.78
75% Bio salary & 25% ferti	3	8.734	9.12	76.40	2.80
50% Bio salary & 50% ferti	1	9.432	8.2	76.30	2.15
50% Bio salary & 50% ferti	2	9.093	8.21	71.67	2.20
50% Bio salary & 50% ferti	3	8.78	8.5	73.00	2.29
25% Bio salary & 75% ferti	1	9.432	8.14	76.40	2.17
25% Bio salary & 75% ferti	2	9.33	8.61	75.21	2.30
25% Bio salary & 75% ferti	3	8.618	8.32	79.20	2.08
0% Bio slury& 100 % ferti	1	7.678	9.11	83.33	1.93
0% Bio slury& 100 % ferti	2	7.275	9.01	83.20	2.27
0% Bio slury& 100 % ferti	3	7.79	9.12	86.67	2.19
Excess slury	1	6.566	7.1	70.33	2.80
Excess slury	2	6.055	6.9	84.33	2.86
Excess slury	3	5.105	7.3	78.67	3.11




Declaration

I, the undersigned, declare that this thesis entitled Investigation of Environmental and Economic Benefits of Bio slurry relative to chemical fertilize is my Origin work, and has not been presented by any other person for an award of a degree in this or another University and that all resources of materials used for this thesis have been duly acknowledged.

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