CARBON MONOXIDE EMISSION ANALYSIS OF LIQUID PETROLEUM GAS (LPG), CHARCOAL, AND *Musa acuminata* (BANANA) LEAVES BIOMASS

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ABSTRACT

Energy plays a big role in one's daily activities. For the people in the community of Sitio Makabuhay, energy is used for electricity and cooking. In addition, banana leaves are a prominent waste factor in the community. According to one of the locals, these are commonly thrown away without purpose. With that in mind, the researchers aim to present a better renewable energy source in the community. Banana leaves can be utilized as biomass which is an example of renewable energy. Currently, the community uses Liquid Petroleum Gas (LPG) and charcoal; however, these are not very cost-efficient. Utilizing banana leaves as biomass would result to a cheaper and more accessible source. As a result, the researchers wish to determine if banana leaves would have the least environmental impact in terms of carbon monoxide (CO) emission when compared to LPG and charcoal. Based on the data and results, the average CO emission of LPG, charcoal, and banana leaves are 85 ppm, 168 ppm, 119 ppm, respectively. Hence, charcoal had the greatest CO emission. It was identified that there is a significant difference between the five groups observed (atmospheric concentration outdoors and indoors, and the CO emitted by LPG, charcoal, and banana leaves). Moreover, there was a significant difference between banana leaves and LPG as well as banana leaves and charcoal. Therefore, banana leaves has a greater CO emission than LPG but has a lower CO emission than charcoal.

Key Words: biomass; banana leaves; emissions; carbon monoxide

APPROVAL SHEET

This research entitled, **Carbon Monoxide Emission Analysis of Liquid Petroleum Gas (LPG), Charcoal, and *Musa acuminata* (Banana) Leaves Biomass** prepared and submitted by **Justin G. Bisuna, Patricia Mae G. Enriquez, Kaitlyn Raye T. Llanes, Gian Carlo V. Malabanan, Bela Louise Magtibay, and Michael Jared R. Viado,** in partial fulfillment of the requirements for practical research 2 has been examined and is recommended for acceptance and approval for oral defense.

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Approved by the De La Salle Santiago Zobel School-VermosaResearch Review Panel on ____________ (date Month Year) with __ grade.

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CHAPTER I

BACKGROUND OF THE STUDY

Introduction

Energy is a vital aspect of everyday life. There is an increasing demand for energy as it is needed to "support economic and social progress and build a better quality of life." The global demand for energy is expected to increase by 25% from 2014 to 2040 (Imperial Oil, n.d.).

Based on the 2011 Household Energy Consumption Survey (HECS), around 87% of 21 million households in the Philippines use electricity, the most common source of energy. On the other hand, at least one-third of the households use other sources such as fuelwood, charcoal, LPG, and kerosene (Philippine Statistics Authority, 2011). In terms of lighting, electricity was the "dominant fuel" for majority of the regions but for places like Sulu, Masbate, Tawi-Tawi, and Palawan, kerosene was the fuel for lighting (PSA, 2013). Aside from lighting, the demand for energy prevails as well for cooking. According to the Philippine Statistics Authority, wood is the most used fuel by around 44.1% of the households in the country while Liquid Petroleum

Gas (LPG) is the second most used fuel with 36.9% and charcoal being the third with 13.1%.

Currently, the electricity generation in the Philippines is almost half from coal which is a non-renewable energy source (Lee, 2019). Another example of a non-renewable source is LPG, a fossil fuel that is top used for cooking. From the term itself, non-renewable energy has limited supply thus cannot be renewed. Moreover, non-renewable sources have a great negative impact to the environment in terms of greenhouse gas emissions and air pollution. In line with this, “providing energy around the globe comes with a responsibility and commitment to developing and using resources responsibly” (Imperial Oil, n.d.); it is of importance to protect the people and the environment.

Energy sources are not limited to non-renewables. Renewable energy is a type of energy that naturally restores itself but has a restricted flow. Some of its major advantages is that it will not run out of supply and it does not contribute to pollution or global warming. It can be a way to reduce problems of environmental pollution and expensive cost. Biomass is a type of renewable energy wherein the main sources are found in organic materials. It comes in different types such as garbage, wood, crops, landfill gas, and alcohol fuels. Biomass is converted to energy through heat.

Charcoal is an example of biomass; it is commonly used around the country especially in the study's focused community; however, charcoal production is perceived as the cause of deforestation and environment degradation (Rowena, et al., 2016). As a result, new sources of biomass should be discovered in order to avoid overdependence on one source.

There has been a number of studies conducted in order to discover potential sources for biomass. According to this study conducted by Fernandes, et al. (2013), the thermochemical characteristics of semi-dried and wet banana leaves presented that it is a promising source of biomass. Another study done by Brunerová, A., et al. (2017) explored tropical fruit waste biomass including banana for bio-briquette fuel. It was concluded that "bio-briquettes from tropical fruit waste biomass can offer a potentially attractive energy source with many benefits, especially in rural areas." However, the study was limited to exploring the characteristics of the different fruit waste as biomass and as bio-briquettes. Hence, it is of the researcher's interest to investigate the environmental impact of banana leaves biomass in comparison to a commonly used fossil fuel which is LPG, and a commonly used biomass which is charcoal. Through doing this, the researchers will be able to identify if there is a significance between the main sources of fuel (LPG, charcoal) and the suggested alternative, banana leaves biomass, thus presenting another sustainable biomass source to be mainly implemented in the community of interest, Sitio Makabuhay, in Muntinlupa City.

Statement of the Problem

The study generally aims to conduct an emission analysis on the carbon monoxide emission of LPG, charcoal, and the banana (*Musa acuminata)* leaves biomass when undergoing combustion.

Specifically, it sought to answer the following questions:

1. What is the concentration of the carbon monoxide emitted by LPG, charcoal, and banana leaves biomass when undergoing combustion?
2. Is there a significant difference between the concentration of carbon monoxide emitted by LPG, charcoal, and banana leaves biomass?

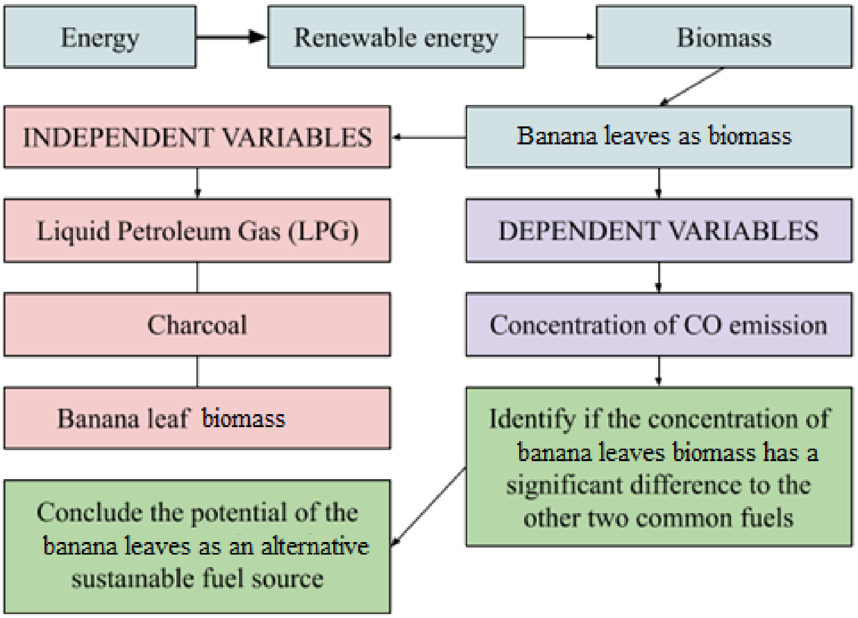
Hypotheses

The following hypotheses will be tested to accept or reject the proposed study on the carbon monoxide emission analysis of LPG, charcoal and banana leaves biomass through combustion.

H_0: There is no significant difference between the concentration of carbon monoxide emitted by LPG, charcoal and banana leaves biomass.

H_1: There is a significant difference between the concentration of carbon monoxide emitted by LPG, charcoal and banana leaves biomass.

Conceptual Framework



In this study, the researchers aim to provide a sustainable and low to no cost alternative renewable energy source in the form of biomass that may act as fuel. Energy plays a big role in one's daily activities. For the people in the community, energy is mainly needed for electricity and cooking. Currently, the community uses coal and liquid petroleum gas (LPG) in activities such as cooking; however, the costs are not cheap and the sources are not as reliable for the environment. On the other hand, supplying one self's fuel through renewable energy is more affordable especially when the source of biomass is found within the community itself. Banana leaves are a very prominent waste factor in the community. According to one of the locals, banana leaves are often thrown away or disposed of as they think it barely has use, but with this research, the banana leaves will have a purpose. It will be used as biomass to serve as fuel for the consumption of the community. The process begins as combustion occurs when the leaves are burned in the set-up.

Basically, the dependent variable is the concentration of carbon monoxide (CO) released whereas the independent variable is the type of fuel, LPG, charcoal and dried banana leaves biomass. As a result, the study aims to identify the CO emissions of LPG, charcoal and the banana leaves. In line with this, it will be determined if there is a significant difference between the three sources of fuel in order to conclude if the banana leaves biomass would serve as the best eco-friendly substitute or additional source.

Scope and Delimitations

The general intent of the study is to ponder on the carbon monoxide (CO) emission of LPG, charcoal, and banana leaves biomass to be implemented in the Sitio Makabuhay community. The research is limited to using the *Musa acuminata* banana tree species only or locally known as Lakatan. The banana leaves samples used are only dried. Moreover, the CO released by the LPG, charcoal, and banana biomass are the only things the research aims to measure; however, the study is limited to measuring the emissions at the end of 2 minutes and 30 seconds of burning the samples. The research is also limited in terms of the materials used; the results of the study are a product of a carbon monoxide sensor compatible with Arduino.

Significance of the Study

General Public.

The world is too dependent on non-renewable energy sources like fossil fuels. It is about time that there should be a slow shift into using renewable sources instead of non-renewable sources such as fossil fuels. Since fossil fuels, at the rate they are being consumed, are not sustainable. According to OpenStax (2018), around 40% of the world's energy comes from oil. Based from the APEC Energy Demand and Supply Outlook, oil will continue to dominate the Philippines' economy energy mix from the year 2010 to 2025. Last 2011, 31% of the country's primary energy consumption was met by oil. Moreover, around 6,917.21 kTOE is the total amount of energy consumed for petroleum products; 44.3% were consumed by energy-producing industries, 33.3% by energy-intensive industries, and 22.4% by other energy-consuming industries (Philippine Statistics Authority, 2014). The population reliant on fossil fuels had brought about multiple devastating changes to the major spheres of this planet. As the population increases, so as the demand for more affordable energy. This study provides more support to shift into renewable energy sources such as biomass. In the case of this research, the banana leaves biomass serves both as a more affordable and clean energy source.

Field of Sustainable Science.

The United Nations Environment have created 17 Sustainable Development Goals (SDGs) that they believe, if achieved, will lead to the prosperity of all mankind and the protection of the planet. The seventh SDG of the United Nations "Affordable and clean energy", aims to provide the population access to cheap energy that will also be beneficial to the well-being of nature in the long run.

Generally, the goal of the study is the aforementioned sustainable development goal of "affordable and clean energy" since biomass, a type of renewable energy, is less costly and less harmful to the environment. Moreover, the study will contribute to the field by presenting another possible biomass source since it is not advisable to solely depend on one source. Not all materials can be used as biomass.

Related Disciplines.

The research is not only limited to contributing in its own field. The findings of this research can greatly help as well in the biomass blend with biological engineering. The demand for more biomass energy had greatly pushed the profession of biological engineering beyond the boundaries. Biologists discovered deep understanding on the real constituents of living organisms. The biomass demand developed a building discipline that requires the structure of natural frameworks that collect natural material photosynthetically more effectively than those utilized in nourishment creation and with positive ecological effects (Wilson & Peter, 1988).

Sitio Makabuhay.

Aside from contributing additional findings to the field of study and other related disciplines, the research would be of significance and help to the community that is of focus in the research.

Energy is expensive yet a vital part of one's daily life. Unfortunately, the community of interest, Sitio Makabuhay, is not a privileged place. The people in the community make use of LPG or charcoal in activities like cooking. At the same time, LPG is expensive for them thus charcoal is more relied on as it is less costly. Additionally, the community is blessed with a great number of banana trees yet the banana leaves barely have any purpose to them and only add to their overall waste. Considering all the aforementioned factors, the research will greatly contribute to the community through presenting a better source of fuel, banana biomass. Utilizing banana leaves as biomass, especially as fuel, can greatly help the people in terms of cost since the source of banana leaves is within the community. Nevertheless, the beneficiaries of the research are not limited to Sitio Makabuhay. Other communities who are in a similar living environment as the community could also apply the results of this research; as well as people who are interested in using renewable energy.

Future Researchers.

The significance of this research is not limited to the field and specific community involved. The study can be used by future researchers as well, especially those who wish to research further on the characteristics of banana leaves as biomass energy. Researching about renewable energy sources will surely contribute to the world today since as previously mentioned, the world is too dependent on non-renewable sources. Those sources are not sustainable thus researching about potential renewable energy sources will greatly serve a purpose as overdependence on one source is not advisable as well.

Definition of Terms

The following terms are defined based on context or how they were used in the study:

Bio-briquettes. According to Sakhare, V. V., and Ralegaonkar, R. V. (2016), bio-briquettes are a source of renewable energy that is made through "converting agricultural waste into high density and energy concentrated fuel briquettes." Based on bionomicfuel.com (2009), bio- briquettes are "biomass materials compacted and compressed" that are burned like charcoal.

Biomass. According to Merriam Webster, biomass is plant materials and animal waste used especially as a source of fuel. Biomass refers to the type of renewable energy that is utilized in the study through banana leaves.

Combustion. Based on Merriam Webster, it is an act or instance of burning. In the research, combustion is one of the involved processes in converting biomass to energy.

Sustainable Science. According to Kieffer, Barton, Palmer, Reitan, & Zen, it is "the cultivation, integration, and application of knowledge about Earth systems gained … in order to evaluate, mitigate, and minimize the consequences, … of human impacts … across the globe and into the future" (2003). According to Kates, R. W. (2011), it is a field of research that deals "…with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems."

CHAPTER II

REVIEW OF RELATED LITERATURE

An essential part of one's daily life is energy for it is greatly used to accomplish daily activities. The use of energy can range from powering electrical devices to cooking. Despite energy being an essential aspect of everyone's daily life, energy sources are not cheap, but with harnessing renewable energy, one can cut costs and help save the environment. In this study, the concentration of CO emissions of LPG, charcoal and the banana leaves are explored.

Generally, agricultural materials are one of the possible sources for biomass. This concept has been further expounded by various researches in which materials such as wood, crops, and trees have been used as sources. The results of the different studies supported the idea of using agricultural materials as biomass. An example of the agricultural materials is the banana plant; the banana plant, specifically the leaves of the banana tree, is the subject of interest in the research. Based on a number of researches, banana leaves possess great potential as a biomass energy source. The different studies involve discussions about countries utilizing banana as biomass and the characteristics and contents of banana leaves. Additionally, there are different studies that investigated how leaves can be an energy source and how banana biomass can be utilized into bio-briquettes or pellets.

Banana Leaves as Biomass

In a study done by Fernandes, et al. (2013), the chemical characteristics and thermal behavior of banana leaves were observed through various experiments and demonstrations. The following are the results of the experiment. The semi-dried banana leaves had 8.3% moisture, 78.8% volatile solids, 43.5% carbon, and a higher heating value of 19.8 MJ/kg. On the other hand, the wet banana leaves had a moisture content of 74.7%. Moreover, the hemicellulose and lignin contents of the semi-dried and wet banana leaves were close in comparison to other biomass fuels but the semi-dried banana leaves had a lower cellulose content (26.7%). Despite exhibiting the same thermal events in oxidizing and inert atmospheres, the wet and semi-dried banana leaves differed in mass loss and energy release intensities. Based from the results, semi-dried banana leaves were concluded to have potential as biomass due to the similar chemical composition compared to other biomass.

According to Vinicius, et al. (2017), the fermentation process of biofertilizer from banana plant 'Prata Catarina' can influence the Nitrogen, Potassium and Calcium levels extracted. The research proved that anaerobic fermentation on banana leaves attained higher levels of N, K, and Ca compared to aerobic fermentation. N, K, and Ca are dominant contents of biomass thus making anaerobic fermentation a viable procedure to apply.

The research conducted by Fernandes, et al. (2013) on the thermochemical characterization of banana leaves and the fermentation process study of Vinicius, et al. (2017) provided a basis. However, both studies were limited to only comparing the characteristics of the banana leaves to other biomass. Nevertheless, the two studies supported the utilization of banana leaves as a biomass source due to the similar characteristics and composition harnessed.

The community of interest in this study, Sitio Makabuhay, has limited financial capacity, difficulty in electricity, and an abundance of banana trees. A case study done by Gumisiriza, et al. (2017) present that the rural areas in Uganda share similar conditions. The banana industry in Uganda, an African country, is greatly hindered by the "lack of cheap, reliable and sustainable energy mainly needed for processing of banana fruit into pulp and subsequent drying into chips before milling into banana flour that has several uses in baking industry, among others." In addition to the problem, the country also has the lowest electricity access levels, especially in rural areas. There is an approximation of 2-3% electricity level present in the rural areas that mainly grow the bananas. In their banana production, there is a great amount of banana waste produced in which it is simply disposed of. Gumisiriza, et al. (2017) suggests that due to the energy content of the banana waste, it may be used as energy through proper waste to energy technologies. As a result, it would help solve the lack of sustainable energy and provide the benefit of helping save the environment since it is a renewable energy.

Aside from Uganda, there are also other places that the feasibility of the banana waste as energy can be applied to. The study of Santa-maria, et al. (2013) studied about other possible uses for the banana residue after it bears its fruit. The residues included pseudostems, leaves, and rachis. The study focused on the rural agricultural communities in Peru and Columbia since as mentioned in the study, "banana cultivation is widespread in tropical and subtropical regions where many rural agricultural communities exist." The results of the study concluded that stems and rachis portrayed as more promising biofuel than leaves due to the higher glucan conversion of 77% and

93% glucose yields, respectively. Based on the results, the residue of the banana plants can be a potential source for the production of biofuels. Despite the study concluding that the pseudostem and rachis proved as more promising than leaves, this research will still utilize leaves due to the findings of the aforementioned studies and taking into consideration the different procedures applied by Santa-maria, et al. and their focus on biofuel.

Another study with similar findings is the case study by Tock, et al. in the year of 2010. The research discussed that banana plants can be a great source of biomass fuel in Malaysia. Due to its high growth rates and uselessness after it bears its fruit, this proves that it is the most likely useful source of renewable energy in Malaysia today. The study suggests combustion, supercritical water gasification and digestion as the processes involved in the conversion of biomass to energy. Moreover, the maximum theoretical potential power generation is 950 MW. This is more than half of the renewable energy requirement in Malaysia's Fifth Fuel Policy found in the 8th Malaysia Plan 2001-2005.

Based from the different studies, the banana plant proves to be a viable biomass energy source, mainly due to the following. First, the energy content of the banana waste present potential as an energy source. Second, banana cultivation is common in tropical areas especially in rural agricultural communities. Having a biomass source that is abundant and easily accessible will provide less hassle. Third, aside from its abundance, the banana plant has high growth rates and is “useless” after a fruit is bore. In reality, it is not useless at all due to the fact that the residues (pseudostem, leaves and rachi) can be harnessed as biomass.

According to the study of Brunerova et al. (2017), banana harnesses one of the highest proportion of fruit waste biomass. The research findings show that banana contributes as an alternative to coal and charcoal as bio briquette and presented satisfactory levels of bulk density (>1050 kg·m−3). When investigating the energy demands to produce bio-briquettes from tropical fruits such as durian, coconut, and cacao, banana showed the highest level of bio-briquette bulk density alongside rambutan and durian.

Leaves as an Energy Source

A study done by Malak, et al. (2016) presents the concept of eco-friendly “green fuel” made from waste leaves. The research aimed to harness the leaves biomass and turn it into bio-briquettes/pellets through a roasting process. In the study by Ebon (n.d.), the feasibility of dried leaves as alternative cooking fuel was explored. The researchers turned dried leaves into bio-briquettes and identified if there was a significant difference between the three samples in the aspects of lifespan, combustibility, and heat intensity. It was concluded that dried leaves are feasible as alternative cooking fuel.

Bio-briquettes

According to “Biomass briquettes” (2009), India’s use of biomass briquettes reduces the amount of CO2 (carbon dioxide) emissions when compared to the conventional burning of coal for sourcing energy. This also allows the local industry to gain unblemished energy in an ecologically sustainable way. Presently, at Kotdwara, Uttarakhand, 15000 tons of briquetted biomass is produced annually. This accounts for the 20 000 t CO2 /year (total CO2 per year) that mitigates approximately 0.75 Carbon emission/year per ton. Furthermore, people in the rural areas, especially women, acquires access to employment. The agricultural residues will be collected for briquette production and provide an orderly community.

The study done by Wei, et al. (2012) focuses on verifying the emission factors (EFs) of carbon dioxide (CO2) and carbon monoxide (CO) in uncompressed biomass such as crop residues and firewood and biomass pellets like pine wood pellets and corn straw pellet. The two types of biomass products underwent urban applications to figure out their impact on CO2 and CO emissions. The study concluded that pelleted biomass harnesses reduced amount of emissions compared to the uncompressed type.

Banana Bio-briquettes

Based on a research done by Selin (2013), banana culture wastes, specifically leaf and pseudostem, can be used to produce bio briquettes as fuel for energy generation. In Santa Catarina State in Brazil, they produce an estimate of 24,300 tons of bananas per year. From the overall amount of harvested bananas, 1.5 tons of leaves and 2.5 tons of pseudostem are generated as a waste product. In this context, the researcher presents the preparation steps and characterization of banana wastes for the production of bio briquettes. One of the author's findings is the best moisture content for briquetting which is 8 to 15%. In addition, the banana leaves and pseudostem showed carbon contents of 43.28% and 38.92%. The thermal properties of these wastes presents a great potential candidate to produce bio briquettes as a fuel in several applications.

According to a research done by Oyelaran, et.al (2018), briquettes of coal and banana waste (leaves and pseudostem) were produced, with calcium hydroxide as the desulphurizing agent were used as an alternative for the traditional energy resources. Mixing the coal and banana leaves and coal and banana pseudostem at different ratios categorized by weight produced briquettes of varied biomass concentrations. Using a manual briquetting machine with pressure constant at 7MPa, the briquettes were mechanically produced. The researchers concluded that the composite briquettes and biomass briquettes are as convenient as solid fuel due to their higher calorific value and lower volatile matter.

A study done by Mopoung and Udeye (2016) characterized and evaluated charcoal briquettes from banana peel and bunch wastes for household heating. The total CO emission of both the banana peel and bunch charcoal briquette is 1568 ppm. It was concluded that the results of the study serves as a contribution into the further development of banana waste as a renewable and sustainable energy source.

Agricultural Materials as Biomass

Aside from the banana plant, there are also several other agricultural materials that possess the potential as biomass. A study by Zivkovic, et al. (2013) suggests that the remains of the orchards trees can be used as a source of biomass fuel. It can serve as a new renewable source of energy and it also helps the agricultural practices in the fields of Siberia.

Another example is a study done by Carvalho-Netto, et al. (2014) which focuses on the shifting of energy usage from fossil energy to renewable energy known as biomass. The study discussed that the downsides of using fossil energy petrol is its insufficiency in number and its greenhouse emissions that may lead to different consequences to mankind. Renewable energy biomass should be the new major source of energy since it basically converts waste to energy. Sugar cane was the focus of the study and was proven to be more effective than most other plants. Banana leaves and rind can also be seen in the same light as they are fibrous plants just like the sugar cane and have characteristics such as high processing capacity of solar energy into biomass, fast growth, long-term canopy, possibility of large-scale production.

In a study done by Gonzales and Bacenetti (2018), the effectiveness of wood biomass in four scenarios to the current energy status in Italy was the main focus. Wood biomass was seen as more efficient when compared to the conventional Italian scenario and it was seen that the longer supply distances were inversely proportional to the impact of the use of biomass from traditional popular plantations. The results obtained from the study support the idea that forest residues could be a potential source of bio-energy although further research is required on the optimizing of supply distances.

The study conducted by Dahunsi, et al. (2018) evaluated the biochemical potential of converting pumpkin rind. Mechanical and thermo-alkaline pre-treatments were applied to two samples, O and P while one, Q was left untouched. The results of the biogas yield showed noticeable improvement compared to the untouched sample. The yields were 2614.1, 2289.9 and 1003.3 10-3m3/kg VS for digestions ‘O’, ‘P’ and ‘Q’ respectively. The treated samples emitted more carbon dioxide and less methane compared to the untreated sample. Using these findings, it shows how effective fruit skin can be for producing environment-friendly biogas that lowers the amount of methane from being released in the air while being a source of energy.

According to the European Union (EU) and the world’s most developed countries (2012), the world should lean towards the substitution of fossil fuels to renewable energy sources. Bilandzija, et al. (2012) tested the possibility of using pruned biomass from fruit cultivars. The calculation of the energy potential can be acquired from the calculated biomass (kg ha-1) and the analysis of combustible (carbon, hydrogen, and sulfur) and non-combustible matters (oxygen, nitrogen, moisture, and ashes) as well as the impact of lowering the biomass heating value. As a result, the potential of the pruned fruit biomass is at 4.21 PJ.

In this study of Khan, et al. (2015), it discusses how fruit waste streams can be a potential source of developing a bio-economy. Previous studies focused on the application of food waste as renewable energy. Each fruit's characteristics and compositions were studied and their potential as feedstocks in the production of value-added (with regard to enzyme production) product were also identified. The conversion of wastewaters from agri-industrial to bioenergy and value added products were discussed as well as the potential production of biofuels and enzymes from waste streams.

Fruit waste biomass samples [(durian (Durio zibethinus), coconut (Cocos nucifera), coffee (Coffea arabica), cacao (Theobroma cacao), banana (Musa acuminata) and rambutan (Nephelium lappaceum)] showed an extremely high level of initial moisture content with 78.22% as the average.

Fruit samples with the highest proportion of fruit waste biomass (of total unprocessed fruit mass) were cacao (83.82%), durian (62.56%) and coconut (56.83%). Highest energy potentials (calorific value) of fruit waste biomass were observed in case of coconut (18.22 $MJ \cdot kg^{-1}$), banana (17.79 $MJ \cdot kg^{-1}$) and durian (17.60 $MJ \cdot kg^{-1}$) fruit samples.

The aforementioned studies tackles on a wide range of agricultural materials as biomass or for some specifically as biofuel. As seen from the results and findings of the different researches, agricultural materials are a viable and effective type of biomass.

Carbon Monoxide

Carbon monoxide is also a big part of environmental pollution. Kreuzer, et al. (1972) conducted a research on ten of the most common gas pollutants related to pollution and found that carbon monoxide was abundant and common in all of them. It is harmful due to the fact that it is good at absorbing infrared radiation which is harmful to the surroundings and also traps more heat in the environment; leading to global warming. Plant life also takes a hit when exposed to carbon monoxide. A study done by Wilks (1959) showed that green plant growth and development were stunted when exposed to the gas. A plant gives out oxygen and when taking in carbon monoxide, the oxygen that is given out is affected as well. The surrounding living things that depend on these plants for oxygen will ingest small amounts of carbon monoxide that add up over time and the negative side effects will occur. Aside from this, carbon monoxide poisoning is an enigmatic illness with many deadly symptoms that go unnoticed until the person's condition becomes severe. This is often due to inhaling large amounts of carbon monoxide and about a third of non-fatal cases go undetected (Ritz & Yu, 1999).

Thermal Conversion of Biomass

One of the forms of biomass is bio-fuels; there are three ways of creating bio-fuels - biological, physical, and thermal conversion. However, the study done by Bridgwater (2003) mainly focuses on the thermal processing. Fast pyrolysis is one of the processes used; it requires high heating and high heat transfer, a temperature at around 450 degrees and rapid cooling to finish the process. Carbonization and gasification are also used to determine the composition for each set up. The former requires low temperature for a very long period of time while the latter requires higher temperature for a long but shorter period of time compared to carbonization.

Another example of a study done on thermal conversion is by Effendi, Gerhauser, and Bridgwater (2008) investigates the production of renewable phenolic resins by thermochemical conversion of biomass wherein the thermochemical conversion used to produce such were fast pyrolysis and vacuum pyrolysis, pressure liquefaction and phenolysis.

Bioenergetics

According to Alexander (1999), bioenergetics is the "study of the flow, exchange and transformation of energy along trophic pathways in ecosystems, populations, and organisms;" another term for bioenergetics is ecological energetics. Basically, it deals with the energy flow between living organisms. In line with this, bioenergetics follow the laws of thermodynamics since the biomass found in the tropical levels are measured and converted into energy in joules.

In the perspective of food webs and food chains, producers such as plants are always at the start. The "photosynthesis and respiration done by higher plants are responsible for the bulk of energy and carbon flow through the biosphere" (Grace, 2004).

Combustion

The research of Ferreira, et al. (2016) tackles on comparing the combustion and pyrolysis process for two types of lignocellulosic biowastes - agricultural and industrial. The findings of the research are that (a) agricultural biowastes presented the highest calorific values which are close to fossil fuel values (20-30MJkg(-1)) and (b) the emission of gases containing the carbon element was higher than the industrial biowastes. Therefore, agricultural biowastes are highly competitive for combustion applications like gas fuel. In light with this, combustion is one of the processes involved in the conversion of biomass to energy. Additionally, banana leaves fall under agricultural biowastes thus it can be concluded that combustion is a great method to be used for the conversion of the banana leaves. At the same time, backing up further the decision of using banana leaves, an agricultural biowaste, than an industrial biowaste.

According to Siddique, et al. (2016), appropriate eco-friendly methods to mitigate the problem of emissions from combustion of fossil fuel are highly demanded. This study was focused on the effect of using coal & coal-biomass co-combustion on the gaseous emissions. The coal used was lignite coal and the biomass were tree waste, cow dung and banana tree leaves. The study revealed that the ratio of 80:20 of coal (lignite)-cow dung and 100% banana tree leaves emits less emissions of CO, CO2, NOx and SO^sub 2^ as compared to 100% coal. Maximum amount of CO emissions were 1510.5 ppm for banana tree waste and minimum amount obtained for lakhra coal and cow dung manure (70:30) of 684.667 ppm. Maximum percentage of SO^sub 2^ (345.33 ppm) was released from blend of lakhra coal and tree leaves (90:10) and minimum amount of SO^sub 2^ present in samples is in lakhra coal-banana tree waste (80:20). The maximum amount of NO obtained for banana tree waste were 68 ppm whereas maximum amount of NOx was liberated from lakhra coal-tree leaves (60:40) and minimum amount from cow dung manure (30.83 ppm). In line with this, the utilization of biomass with coal could make remedial action against environmental pollution.

CHAPTER III

METHODOLOGY

Research Design

Experimental design is a systematic and scientific approach wherein the researchers manipulate and control the variable to achieve the desired outcome (Blakstad, 2008). Experimental design is also the depiction and assessment of what will be, or what will happen, under careful and meticulous conditions (Price, Jhangiani, & Chiang, n.d.). It is through this research design that the researchers will observe the effects and relationships of the variables when employed through an experimental setup.

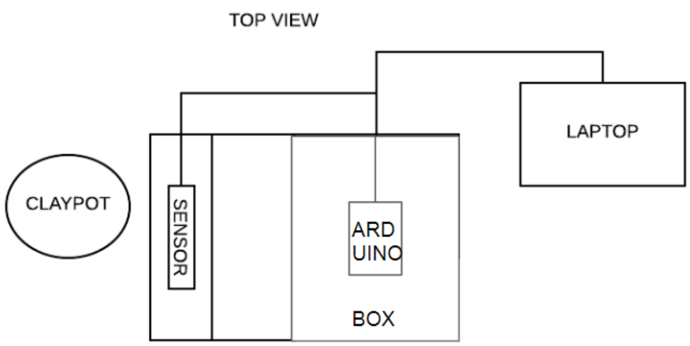
In more specific terms, the research involves a non-equivalent control group design under the quasi-experimental design. A non-equivalent control group design has both an experimental and control group and performs a pre-test and post-test to the two groups. There is no random assignment of samples in the groups.

This research design can be used in the study because the researchers need to compare the experimental group which is the banana leaves biomass, with the control groups which are charcoal and LPG. Since the experiment was not done in a vacuum but rather in an open area, the researchers needed to conduct a pre-test to measure the initial CO found in the atmosphere. At the same time, the researchers did not utilize any random assignment.

Research Locale/Setup

The research was done in an outdoors in BF Homes, Las Pinas City Metro Manila. The main beneficiaries of the research are the members of the community Sitio Makabuhay. The community is located in Muntinlupa City, Metro Manila.

Figure 1. Flat Diagram of Set-up



Research Instrument/Materials

This study used the following materials and equipment:

A. Materials

1 kg Dried banana leaves

1 kg Charcoal

1 Tank of LPG

B. Equipment/Apparatus

6 Containers of the same size

1 Carbon monoxide sensor compatible with Arduino

1 Clay pot

1 Box of matches

1 Weighing scale

Data Collection Procedures and Techniques

Accumulations of Samples

The researchers gathered the samples of dried banana leaves at Sitio Makabuhay, Muntinlupa City. The dried leaves are the leaves that have fallen from the tree. The charcoal was bought from a common market place in Paranaque City, Metro Manila. Moreover, the researchers made use of the LPG found in their households.

Preparation of Samples

In preparing the samples, the banana leaves were cut into smaller pieces. There are three samples needed and each sample must be 30 grams. The charcoal will also be weighed to ensure that per sample is also 30 grams.

Measurement of CO Emissions

According to McGee (2018), experiments need to be done more than once “due to the potential of variation.” Richmond County Schools also stated that doing multiple trials can ensure consistent results that are not altered by random events. The carbon monoxide sensor was set-up above and to the side of the burning set-up. The leaves and charcoal were both burned in the clay pot. However, before burning, the CO concentration of the atmosphere was measured and recorded. Then, the concentration of carbon monoxide was measured for a duration of five minutes of letting the banana leaves, LPG, and charcoal combust. Only the concentrations at the end of 2 minutes and 30 seconds were recorded.

Safety Procedures

1. Keep the area clean and organized- a cluttered workplace is prone to accidents, and unused equipment may be broken or affected. The banana leaves must be placed in containers.
2. Report all accidents, injuries, and breakage of glass or equipment to the instructor immediately so that immediate action and precaution can take place.
3. Do not play with the fire as this can cause injuries, damage to other property in the experiment space.
4. Handle glassware properly. Broken glass may alter results and may cause injuries to the researchers.
5. Wear laboratory coats and mask to prevent fire, dust, smoke and other small particles from making contact with the eyes and face, also to protect our clothes from spills and stains.
6. Manage resources honestly so as not to waste any of the leaves or charcoal for the experiment.
7. Report results accurately since there should be no bias so that the most efficient leaf type can be implemented in the use of banana leaves for electricity generation.

8. Maintain patience when conducting the experiment; each experiment takes about 20 minutes; there is no need to rush the burning process since rushing may cause errors and accidents.

Statistical Treatment of Data

The data gathered by the researcher was sorted, tabulated, and summarized in tables. The researchers made use of the following statistical tools:

One-way analysis of variance (ANOVA)

The hypothesis testing technique called Analysis of Variance (ANOVA) is used to test the differences between three or more means through analyzing the variances (Lane, n.d.). There are several types of ANOVA tests but the researchers utilized the one-way ANOVA. One way ANOVA is used to compare two means from two independent groups using the F-Distribution. Moreover, "it aims to evaluate multiple mutually exclusive theories about our data" (MacKenzie, 2018). Only one independent variable is involved but three or more categorical groups of that variable.

In this study, the independent variable is the types of fuel. There are three categorical groups under the independent variable, namely LPG, charcoal, and banana leaf bio-briquette. The dependent variable is the concentration of carbon dioxide (CO) emitted by the different types of fuel. The researchers find one way ANOVA as the appropriate statistical treatment as it is used to create assumptions on the differences between the means of the three samples (LPG, charcoal, banana leaves biomass). Through this, it can be inferred if banana leaves as biomass can be an eco-friendly substitute or addition. The researchers will make use of SPSS in order to perform one way ANOVA. The formulae needed are shown below:

$$F = \frac{MST}{MSE}$$

$$MST = \frac{\sum_{i=1}^{k} (T_i^2/n_i) - G^2/n}{k-1}$$

$$MSE = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} Y_{ij}^2 - \sum_{i=1}^{k} (T_i^2/n_i)}{n-k}$$

CHAPTER IV

DATA ANALYSIS AND INTERPRETATION

This chapter presents the data gathered by the researcher to be able to answer the following specific questions:

Specific Question No. 1. What are the concentrations of the carbon monoxide emitted by LPG, charcoal, and banana leaves bio-briquette when undergoing combustion?

Table 1. Concentration of CO (ppm) emitted by LPG, Charcoal, Banana Leaves and atmospheric concentration of CO outdoors and indoors

Trial #	Outdoors (Negative Control 1)	Indoors (Negative Control 2)	LPG (Positive Control 1)	Charcoal (Positive Control 2)	Banana Leaves
1	64	75	87	177	115
2	68	75	86	167	119
3	63	76	82	160	123

Table 1 presents the concentration of carbon monoxide (CO) in ppm of the different groups. Negative control 1 which is the atmospheric concentration outdoors presented 64, 68, and 63 ppm for the three trials. Negative control 2 which is the atmospheric concentration indoors presented 75, 75, and 76 ppm. Positive control 1 or LPG emitted 87, 86, and 82 ppm for the three trials, respectively. On the other hand, positive control 2 or charcoal had 177, 167, and 160 ppm. Lastly, the CO concentration emitted by the banana leaves was 115, 119, and 123, respectively.

Specific Question No. 2. Is there a significant difference between the concentration of carbon monoxide emitted by LPG, charcoal, and banana leaves?

Table 2. One way ANOVA Results for the CO emissions

Co_Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21039.06	4	5259.797	254.505	.000
Within Groups	206.66	10	20.667		
Total	21245.733	14			

Table 2 shows that the computed F (254.505) is greater/less than the critical F (3.48) and the p-value (5.1833E-10) is smaller than the significance level (0.05). This means that there is a significant difference between the carbon monoxide (CO) concentrations emitted by the LPG, charcoal, and banana leaves and present atmospheric concentration found outdoors and indoors.

Table 3. Tukey's Honestly Significant Difference of Banana Leaves

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Banana Leaves	Outdoors	54.00000	3.71184	3.6843E-7	41.7840	66.2160
	Indoors	43.66667	3.71184	0.000003	31.4507	55.8826
	LPG	34.00000	3.71184	0.000027	21.7840	46.2160
	Charcoal	-49.00000	3.71184	9.2848E-7	-61.2160	-36.7840

Table 3 presents banana leaves in comparison to the two negative and two positive control groups. The p-value (3.6843E-7) of banana leaves and outdoors (negative control 1) is less than 0.05 thus there is a significant difference. At the same time, the p-value (0.000003) of banana leaves in comparison to indoors (negative control 2) is less than 0.05 thus there is also a significant difference. Meanwhile, banana leaves compared to LPG has a p-value of 0.000027 which is less than 0.05. This means there is a significant difference. Lastly, the banana leaves and charcoal present a p-value of 9.2848E-7. Since this is lower than 0.05, there is a significant difference between the two.

CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary of Findings

Based on the data gathered, the following are the major findings:

1. The average CO emission of LPG is 85 ppm.
2. The average CO emission of charcoal is 168 ppm.
3. The average CO emission of banana leaves is 119 ppm.
4. There is a significant difference between the carbon monoxide (CO) concentrations emitted by the LPG, charcoal, and banana leaves and present atmospheric concentration found outdoors and indoors.
5. There is a significant difference of banana leaves in comparison to the four control groups.

Conclusions

Based on the major findings, the following are concluded:

1. Charcoal had the highest average CO emission.
2. Since there is a significant difference between the carbon monoxide (CO) concentrations emitted by the LPG, charcoal, and banana leaves and present atmospheric concentration found outdoors and indoors, the null hypothesis is rejected.
3. Since there is a significant difference between the carbon monoxide (CO) concentrations emitted by the banana leaves and LPG, LPG emits less CO than banana leaves.
4. Since there is a significant difference between the carbon monoxide (CO) concentrations emitted by the banana leaves and charcoal, banana leaves emit less CO than charcoal.

Recommendations

Based on the conclusions and results of the study, the following are the recommendations:

1. Future researchers can utilize more samples of charcoals from different markets to have varying quality.
2. Future researchers can research further on banana leaves in the form of bio-briquettes.
3. Future researchers can observe the carbon monoxide emissions for a longer period of time.
4. People can utilize banana leaves biomass as a replacement for charcoal since there is a significant difference.
5. People from the community or those who live in similar conditions may use banana leaves biomass in place of LPG because the significant difference between the two is not as big and the banana leaves would be no to low cost.
6. Future researchers can utilize other species of banana.
7. Future researchers can use a different part of the banana plant such as pseudostem and fruit peelings.

8. Future researchers can investigate the emissions using a different set of materials and sensor.
9. Future researchers can investigate other emissions aside from carbon monoxide.

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APPENDIX A

LETTERS

July 3, 2019

MR. RICHARD T. LASAP
DLSZ SHS Vice Principal
De La Salle Santiago Zobel School – Vermosa

Dear Mr. Richard:

Greetings of peace!

We are Senior High School students under the STEM strand of De La Salle Santiago Zobel School – Vermosa. We are currently conducting our scientific research entitled, **"Thermal Conversion of Musa acuminata (Banana) Leaves Biomass through Combustion and Pyrolysis".**

In line with this, we would like to request permission and endorsement to gather data on the electricity produced of the different variations of leaves in the laboratory of De La Salle Santiago Zobel School - Vermosa. Data that will be gathered from the aforementioned procedures will be significant to achieve the objectives of this study.

Rest assured that confidentiality of the data gathered will be strictly observed and will be solely used for the above-mentioned purpose.

We are hoping for your most favorable response.

Thank you very much.

In St. La Salle,

Kaitlyn Raye T. Llanes
STEM Student

Gian Carlo V. Malabanan
STEM Student

Justin G. Bisuna
STEM Student

Patricia Mae G. Enriquez
STEM Student

Bela Louise DV. Magtibay
STEM Student

Michael R. Viado
STEM Student

Noted by:	Endorsed by:	Approved by:
Mr. Gerald B. Gamboa Research Adviser	Mr. Henry Leen A. Magahis Research Coordinator	Mr. Richard T. Lasap DLSZ SHS Vice – Principal

De La Salle Santiago Zobel School
A.Y. 2019 - 2020
FIRST TERM

PARENTAL CONSENT
Research 2: Quantitative Research

Name of the Activity: Data Gathering and Analysis
Nature of Activity: Gathering of samples
Objectives of the Activity: To gather samples for research description and technical feasibility
Venue/s: Sitio Makabuhay Muntinlupa City, Metro Manila
Date/s: July 12, 2019
Time:
Group/Members involved:

SURNAME, First Name MI	Contact Numbers
BISUÑA, Justin G.	0916 286 5372
ENRIQUEZ, Patricia G.	
LLANES, Kaitlyn T.	0967 259 0416
MAGTIBAY, Bela D.V.	0998 556 3898
MALABANAN, Gian V.	0917 509 2227
VIADO, Michael R.	0917 887 0126

Adult Leader and contact numbers:

NAME	CONTACT NUMBER/S	CAR'S PLATE NUMBER
GAMBOA, Gerald		

REPLY SLIP

De La Salle Santiago Zobel School
PARENTAL CONSENT FORM
Academic Year 2018-2019

NO PARENTAL CONSENT, NO ACTIVITY

Name of the Activity: Data Gathering
Nature of Activity: Gathering of Samples
Venue/s: Sitio Makabuhay Muntinlupa City, Metro Manila
Date: July 12, 2019
Time:

I have read the details of the activity and I hereby permit my **son/daughter**

____ of

(Year & Sec./ 12E Group 2) ______________________________ to join.

We are aware of the benefits that our **son/daughter** will derive from his/her participation to this activity and the diligence to be exercised by the adult leader/s thereof to ensure his/her safety during the activity/outing. We are also expected to make sure that our child comes on time.

____
Signature over Printed Name of Parent/Guardian:

APPENDIX B

MATERIALS

APPENDIX C

RAW DATA/COMPUTATIONS/SPSS RESULTS

Oneway

Descriptives

CO_Concentration

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
Outdoors (Negative Control 1)	3	65.0000	2.64575	1.52753	58.4276
Indoors (Negative Control 2)	3	75.3333	.57735	.33333	73.8991
LPG (Positive Control 1)	3	85.0000	2.64575	1.52753	78.4276
Charcoal (Positive Control 2)	3	168.0000	8.54400	4.93288	146.7755
Banana Leaves	3	119.0000	4.00000	2.30940	109.0634
Total	15	102.4667	38.95577	10.05834	80.8937

Descriptives

CO_Concentration

	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Outdoors (Negative Control 1)	71.5724	63.00	68.00
Indoors (Negative Control 2)	76.7676	75.00	76.00
LPG (Positive Control 1)	91.5724	82.00	87.00
Charcoal (Positive Control 2)	189.2245	160.00	177.00
Banana Leaves	128.9366	115.00	123.00
Total	124.0397	63.00	177.00

Test of Homogeneity of Variances

CO_Concentration

Levene Statistic	df1	df2	Sig.
2.407	4	10	.118

ANOVA

CO_Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21039.067	4	5259.767	254.505	.000
Within Groups	206.667	10	20.667		
Total	21245.733	14			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: CO_Concentration

	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	Outdoors (Negative Control 1)	Indoors (Negative Control 2)	-10.33333	3.71184	.109	-22.5493	1.8826
		LPG (Positive Control 1)	-20.00000*	3.71184	.002	-32.2160	-7.7840
		Charcoal (Positive Control 2)	-103.00000*	3.71184	.000	-115.2160	-90.7840
		Banana Leaves	-54.00000*	3.71184	.000	-66.2160	-41.7840

	Indoors (Negative Control 2)	Outdoors (Negative Control 1)	10.33333	3.71184	.109	-1.8826	22.5493
		LPG (Positive Control 1)	-9.66667	3.71184	.143	-21.8826	2.5493
		Charcoal (Positive Control 2)	-92.66667*	3.71184	.000	-104.8826	-80.4507
		Banana Leaves	-43.66667*	3.71184	.000	-55.8826	-31.4507
	LPG (Positive Control 1)	Outdoors (Negative Control 1)	20.00000*	3.71184	.002	7.7840	32.2160
		Indoors (Negative Control 2)	9.66667	3.71184	.143	-2.5493	21.8826
		Charcoal (Positive Control 2)	-83.00000*	3.71184	.000	-95.2160	-70.7840
		Banana Leaves	-34.00000*	3.71184	.000	-46.2160	-21.7840
	Charcoal (Positive Control 2)	Outdoors (Negative Control 1)	103.00000*	3.71184	.000	90.7840	115.2160
		Indoors (Negative Control 2)	92.66667*	3.71184	.000	80.4507	104.8826
		LPG (Positive Control 1)	83.00000*	3.71184	.000	70.7840	95.2160
		Banana Leaves	49.00000*	3.71184	.000	36.7840	61.2160
	Banana Leaves	Outdoors (Negative Control 1)	54.00000*	3.71184	.000	41.7840	66.2160
		Indoors (Negative Control 2)	43.66667*	3.71184	.000	31.4507	55.8826
		LPG (Positive Control 1)	34.00000*	3.71184	.000	21.7840	46.2160
		Charcoal (Positive Control 2)	-49.00000*	3.71184	.000	-61.2160	-36.7840
Scheffe	Outdoors (Negative Control 1)	Indoors (Negative Control 2)	-10.33333	3.71184	.181	-24.1782	3.5115
		LPG (Positive Control 1)	-20.00000*	3.71184	.005	-33.8448	-6.1552

	Charcoal (Positive Control 2)	-103.00000*	3.71184	.000	-116.8448	-89.1552
	Banana Leaves	-54.00000*	3.71184	.000	-67.8448	-40.1552
Indoors (Negative Control 2)	Outdoors (Negative Control 1)	10.33333	3.71184	.181	-3.5115	24.1782
	LPG (Positive Control 1)	-9.66667	3.71184	.227	-23.5115	4.1782
	Charcoal (Positive Control 2)	-92.66667*	3.71184	.000	-106.5115	-78.8218
	Banana Leaves	-43.66667*	3.71184	.000	-57.5115	-29.8218
LPG (Positive Control 1)	Outdoors (Negative Control 1)	20.00000*	3.71184	.005	6.1552	33.8448
	Indoors (Negative Control 2)	9.66667	3.71184	.227	-4.1782	23.5115
	Charcoal (Positive Control 2)	-83.00000*	3.71184	.000	-96.8448	-69.1552
	Banana Leaves	-34.00000*	3.71184	.000	-47.8448	-20.1552
Charcoal (Positive Control 2)	Outdoors (Negative Control 1)	103.00000*	3.71184	.000	89.1552	116.8448
	Indoors (Negative Control 2)	92.66667*	3.71184	.000	78.8218	106.5115
	LPG (Positive Control 1)	83.00000*	3.71184	.000	69.1552	96.8448
	Banana Leaves	49.00000*	3.71184	.000	35.1552	62.8448
Banana Leaves	Outdoors (Negative Control 1)	54.00000*	3.71184	.000	40.1552	67.8448
	Indoors (Negative Control 2)	43.66667*	3.71184	.000	29.8218	57.5115
	LPG (Positive Control 1)	34.00000*	3.71184	.000	20.1552	47.8448

	Charcoal (Positive Control 2)	-49.00000*	3.71184	.000	-62.8448	-35.1552

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

CO_Concentration

	Groups	N	Subset for alpha = 0.05 1	2	3	4
Tukey HSD[a]	Outdoors (Negative Control 1)	3	65.0000			
	Indoors (Negative Control 2)	3	75.3333	75.3333		
	LPG (Positive Control 1)	3		85.0000		
	Banana Leaves	3			119.0000	
	Charcoal (Positive Control 2)	3				168.0000
	Sig.		.109	.143	1.000	1.000
Scheffe[a]	Outdoors (Negative Control 1)	3	65.0000			
	Indoors (Negative Control 2)	3	75.3333	75.3333		
	LPG (Positive Control 1)	3		85.0000		
	Banana Leaves	3			119.0000	
	Charcoal (Positive Control 2)	3				168.0000
	Sig.		.181	.227	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

APPENDIX D

PHOTO DOCUMENTATIONS