ADDIS ABABA UNIVERSITY

ADDIS ABEBA INSTITUTE OF TECHNOLOGY

SCHOOL OF CHEMICAL AND BIOCHEMICAL ENGINEERING

CHARACTERIZATION AND OPTIMIZATION OF ALKLINE HYDROLISIS OF WASTE HUAMN HAIR FOR PRODUCTION OF NITROGENOUS FERTILIZER

A thesis is submitted to Addis Ababa Institute of Technology School of Chemical and Bio Engineering in Partial Fulfillment of the Requirements for the of Master of Science Degree in Environmental Engineering

By Fraol Tesfaye

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Approval page

This is to certify that the thesis prepared by **Fraol Tesfaye Asefa** entitled '**characterization and optimization of alkaline hydrolysis of waste human hair for Production of Nitrogenous fertilizer'** and submitted as a partial fulfillment for the award of the Degree of Master of Science in Chemical Engineering (Environmental engineering) complies with the regulations of the university and meets the accepted standards with respect to originality, content and quality.

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Declaration

I hereby to declare that the thesis entitled **— characterization and optimization of alkaline hydrolysis of waste human hair for Production of Nitrogenous fertilizer'** was prepared by me, with guidance of my advisor. The work contained herein is the original work of my own, except where explicitly cited otherwise in the text. And that this work has not been submitted, in whole or in part, for any other degree or professional qualification

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This thesis has been submitted for an examination with approval of advisor

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Abstract

In recent years, the efficient management of organic waste has become a critical concern for sustainable development. This study explores the potential of using waste human hair as a valuable resource for the production of nitrogenous fertilizer through lime treatment. Waste human hair, a readily available and abundantly generated organic waste, has shown promise as a rich source of nitrogen, an essential nutrient for plant growth. The aim of this study was to utilize discarded human hair as liquid organic fertilizers for Swiss chard plants. This was done by investigating the time of solubility of different amounts of hair (2, 4, 6 g) in varying concentrations of $CA(OH)_2$ *solutions (0,1g/ml, 0.5g/ml, 1g/ml) at different temperatures (100°C, 110°C, 120°C).For the Swiss chard plants, different treatments was applied at a control group, hydrolyzed hair fertilizer (at rates different rates), and DAP fertilizer. Preliminary results indicate that increasing lime treatment and temperature minimize the hydrolyzing time of waste human hair, in which for lowest lime loading and temperature hydrolyzing time is12 hr and for high lime loading and temperature value hydrolyzing time is 10hr. Furthermore, the resulting nitrogenous fertilizer exhibits desirable nutrient content nitrogen with an optimum yield of 9.54% at an optimum value for the factors temperature (112.37) degree centigrade time (11:27)hr and lime loading(0.72g/ml) and demonstrates the potential to improve soil fertility, acidity and crop productivity when applied to Swiss chard plant. Biomass analysis obtained for fresh and dry weight value of the Swiss chard was 90g and 25 g respectively. Proximate analysis done on moisture content ,ash content ,crude fiber and total protein was (92.6,9.01,1.80 and 2.5%)respectively This study not only addresses the pressing issue of waste management but also highlights the possibility of converting a waste stream into a valuable resource within the agricultural sector. using the synthesized fertilizer the has altered total nitrogen content of the soil to 1.9%. The findings of this study have the potential to offer valuable insights for waste management strategies and sustainable agricultural practices, promoting the efficient utilization of organic waste resources and fostering a more sustainable future.*

Key words Human hair, Fertilizer, Swiss chard, Hydrolysis, Optimization

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1. Introduction

1.1. Back ground

The tissue that makes up human hair is complex and has multiple morphological components.It is composed of three primary parts: the brain, medulla, and cuticle. Keratin and cytoplasmic components derived from dead cells make up the majority of the cuticle (kechosa & J., 2017). Melanin granules, uneven matrix proteins, and fibril proteins make up the cortex. The medulla is made up of dead cells with nuclear and cytoplasmic components arranged in a honeycomb pattern. With the exception of glutamine and aspartic acid, keratin, which comprises most hair, is composed of eighteen amino acids, of which 15–18% are cysteine. Melanin, in contrast to keratin, may have more structural stability because it is composed of a benzene ring and its derivatives.

Human hair is made up of several different structural and chemical elements, such as the cuticle, keratin, melanin, cytoplasmic chemicals, fibril proteins, and medulla cells. From a biophysical and chemical standpoint, these intricate (kechosa & J., 2017)structures show extraordinary durability, which clarifies the difficulty of destroying hair by biological or physicochemical means. A large portion of hair is made up of the fibrous protein keratin, which is insoluble and strongly cross-linked by hydrogen and disulfide bonds. It is high in nitrogen and mostly made up of proline, serine, cystine, and lysine, with trace amounts of other amino acids. The disulfide bond that characterizes cysteine aids in the creation of powerful intermolecular and intermolecular cross-links.

In many societies, hair is generally regarded as waste and unnecessary. As a result, it is commonly discovered in municipal waste streams in cities and towns all over the world. This trash category includes not only human hair but also animal horns, feathers, and hair, among other comparable things, producing millions of tons worldwide. The customary practice in rural and low-density areas is to throw hair in the wild, where it will naturally decompose over a few years (.C.R, 2012). The components that make up hair—carbon, nitrogen, sulfur, and other elements—reintegrate over time into their own natural cycles. On the other hand, hair frequently accumulates in significant amounts within solid waste in urban areas or other areas with high people density.

Numerous investigations have been carried out to devise diverse methodologies for the breakdown of human hair waste. These studies' main objectives are to maximize the potential of beneficial substances present in hair waste and provide an efficient waste disposal system (Arivalagan, 2017). Human hair has been broken down using a variety of processes, such as enzymatic, chemical, physical, and microbiological ones. These techniques cause the disulfide bonds in hair to dissolve, releasing nitrogen and sulfur in a form that is easier to reach.

in contrast to their keratin-resistant state. Keratin contains valuable amino acids like cysteine, lysine, proline, and serine. When hair debris is recycled, it can be used to produce amino acids with a wide range of commercial applications. Human hair waste has multiple uses, including in the fashion, theater, cosmetics, cosmetic brush production, agricultural, insect management, pollution control, cleanup, and many more fields.

Fertilizer is applied to soil or plants in agriculture to supply vital nutrients for the plants' growth and development. Because human hair waste has a high nitrogen concentration, it is used as fertilizer. Since proteins make up the majority of human hair, it is thought to be among the organic materials with the highest nitrogen concentration in nature—roughly 16%. Human hair debris was the main raw material used to create a liquid nitrogen-rich fertilizer. Alkaline was used as a solvent in the process to carefully reduce and cleave the proteins found in the hair. The resultant hair hydrolysate was effectively converted into a fertilizer by this process. It has been demonstrated that this fertilizer works very well at giving plants a valuable

The physical and chemical qualities that determine the composition and behavior of soil are referred to as physiochemical features of agricultural soil. These features are important in establishing the general appropriateness of the soil for plant development (VD), as well as its fertility, nutrient availability, and water holding capacity. Texture, composition, pH, organic matter content, CEC, moisture content, nutrient content, and compaction are some of the crucial physiochemical properties of soil (Barker, 2015). If the soil used to grow a plant has poor physiochemical qualities, several bad things could happen. For example, different aspects of soil and plant growth are affected by acidic soil, defined as a soil with a PH value of (4-6)

Acidic soil can have a number of negative effects on plant growth, including nutrient deficiencies that make elements like calcium, magnesium, and phosphorus less soluble and less available for plant uptake; increased solubility of certain elements, such as aluminum and manganese, which can reach toxic levels for plants; decreased population and activity of specific microbial groups that affect nutrient cycling and organic matter decomposition; and effects on soil structure and aggregation that result in poor soil drainage, compaction, and reduced water infiltration.

It is possible to degrade human hair using a variety of solvent chemicals. There are a few factors to take into account when choosing a solvent to break down leftover human hair. Similar to soluble, a solvent should target the proteins in human hair and be able to dissolve or break them down with the least amount of loss or degradation of other desired components. Impact on the environment: the solvents need to be safe for the environment and possibly even beneficial to the ecosystem. The recognized substances that break down human hair are hydrochloric acid, potassium hydroxide, sodium hydroxide, calcium hydroxide, sulfuric acid andmany others

Calcium hydroxide, sometimes referred to as slaked lime or hydrated lime, is one of the solvents used to break down human hair debris. In addition to being able to break down human hair waste, slaked lime is a soil amender that balances the acidity of the soil. by adding a supply of calcium to the soil, which is a necessary component for plant growth, raising the pH of the soil and improving its suitability for a greater variety of plants.Therefore, it is possible to obtain liquid fertilizer that may both add nitrogenous content to the soil and amend it by breaking down waste hair.

While the aforementioned procedures have been used to address the extraction of liquid fertilizer from discarded human hair, not much research has been done to evaluate the effectiveness of this liquid fertilizer to the most widely available fertilizers globally. In order to close this information gap, a study was carried out to evaluate the potency of liquid fertilizers made from the hydrolysis of human hair waste against DAP (diammonium phosphate) fertilizers that are sold commercially. In this experiment, the same plant was given two kinds of fertilizer, and the outcomes were examined.

Because of the possible harmful consequences of using chemical fertilizers excessively, a comparison between liquid fertilizers made from human hair waste and DAP fertilizer is crucial. These consequences include soil compaction, decreased fertility, greater dependency on pesticides, contamination of the air and water, and greenhouse gas emissions. Furthermore, human hair waste takes up a lot of space in landfills and waste streams due to its slow decomposition. Eutrophication problems arise as a result of the leachate from these garbage piles gradually raising the nitrogen levels in water bodies. The practice of burning human hair or waste mounds including hair is prevalent in certain areas, which exacerbates environmental issues.

In addition to harmful gasses like ammonia, carbonyl sulfides, hydrogen sulfides, sulfur dioxide, phenols, nitriles, pyrroles, and pyridines, the breakdown of human hair in open dumps creates disagreeable scents. Inhaling these gasses can have negative health effects and create respiratory issues, especially for those living close to the dumps. Furthermore, breathing in significant amounts of hair dust from these open dumps can cause pain and worsen existing respiratory problems.

The purpose of this study was to compare the effects of a commercial DAP fertilizer and a synthetic liquid nitrogenous fertilizer made from human hair using CA(OH)2 solution on Swiss chard plants.

1.2. Statement of problem

Agriculture accounts for more than 85% of the labor force and 90% of the export earnings in Ethiopia. The application of fertilizer is crucial for modern agriculture, as it promotes soil fertility and enhances plant growth. However, the continuous use of chemical fertilizers poses risks to human health and the environment. In Ethiopia, significant amount of money are spent on importing these chemical fertilizers, with DAP and UREA being the most commonly used types. On the other hand Acidic Rainfall, Weathering Processes, over use of commercial fertilizers, deforestation, decomposition of certain organic materials like coniferous needles, contribute to the increse of soil acidity.

To mitigate the negative effects of chemical fertilizers and adjust soil to its correct physiochemical state there are growing trend towards utilizing organic waste materials and by-products as alternatives. One such readily available organic waste is human hair, which is often discarded by beauty salons. If left untreated, human hair, like other municipal waste, can have various adverse impacts, including eutrophication and groundwater pollution. Incineration of human hair leads to the release of foul odors and toxic gases.

Several studies have shown that human hair is highly nutritious and can serve as a valuable raw material for the production of liquid fertilizer, plus being degrade with an multitask solvent it can be a great problem solver to the agricultural sector. In general Utilizing waste human hair as a fertilizer presents a win-win situation, as it substitutes chemical fertilizers while also addressing environmental concerns. This approach not only reduces reliance on chemical fertilizers but also contributes to the preservation of the environment. So this study was done to hydrolysis waste human hair with lime and analyzes the effect of temperature lime loading and hair mass on hydrolyzing time and finally optimizing the yield content.

1.3. Objectives of the study

1.3.1 General objectives

The main objective of study is to produce nitrogenous fertilizer by hydrolyzing waste human hair with lime and characterize its effect by applying it on Swiss chard plant.

1.3.2 Specific objective

- ✓ To determine the quantity and existence of human hair as a waste in a specified area
- ✓ To analyze the elemental composition of waste human hair
- ✓ Investigating the effect of lime loading, temperature and hair mass on the hydrolyzing time of human hair.
- ✓ Optimizing the total nitrogen content in the fertilizer
- ✓ Conducting a vegetation pot to compare the growth of Swiss chard plants using three different treatments: synthesized fertilizer, commercial fertilizer, and by application no fertilizer.
- ✓ To perform proximate analysis on Swiss chard plant.

1.4. Significance of the study

This study aims to address the issue of slow degradation associated with human hair by utilizing it as a fast degradation method. It seeks to mitigate the problem of eutrophication, a pressing environmental concern in Ethiopia, caused by excessive nutrient enrichment leading to increased plant and algae growth in estuaries and coastal waters. By utilizing discarded human hair, the study aims to reduce leachate from dumps, thus contributing to the resolution of this issue. Furthermore, the research aims to demonstrate the feasibility of maintaining soil pH and fertility through the use of cost-effective organic fertilizers instead of relying on expensive imports of commercial fertilizers. Ultimately, the study aims to highlight the potential for converting waste materials into valuable resources, thereby minimizing the adverse environmental and health effects associated with the accumulation of municipal waste.

1.5. Scope of the study

This study was carried out on kotobe wereda 12 human hair waste. The samples were collected every Friday and Tuesday for about 3 weeks before the municipality cleaners collect it from different barber shops. composition of human hair was determined using CHNS/O analyzer, meanwhile a solvent solution was prepared by using $CA(OH)_2$ in water with different concentration During hydrolysis of waste human hair , three factors were considered Those were temperature, lime loading and hair mass and the effect of each parameter on hydrolyzing time was studied and Finally the liquid fertilizer was demonstrated on Swiss chard green plant was compared with commercial fertilizer

2. LITERATURE REVIEW

2.1. Human hair

Human hair is the term used to describe the hair that grows naturally on our scalps. This filamentous structure primarily consists of keratin, a protein also found in our skin, nails and other parts of our bodies. Hair is a feature of mammals. Serves various functions including insulation, protection and sensory perception.

Human hair consists of two parts; a root located beneath the skins surface and a shaft that extends above it. The hair shaft is composed of three layers; the cuticle, cortex and medulla. The outermost layer, known as the cuticle protects the layers with overlapping scales. The cortex contains the pigment, for hair color well as providing flexibility and strength. Lastly there is the layer called the medulla, which may or may not be present, in all hairs.

Human hair consists of components. That possesses a complex chemical composition. The main components of human hair are keratin, Melanin, Lipids, Trace elements and minerals and chemical composition or structure consists of cuticle, cortex, medulla Keratin is the protein found in hair accounting for approximately 65 to 95 percent of its total weight (.C.R, 2012). This fibrous structural protein is responsible, for providing strength, elasticity and durability to the hair shaft. Comprised of amino acids, cysteine keratin forms disulfide bonds that contribute to the structure and resilience of hair.

Keratin is considered to be a complex structure that consists of long chains of amino acids linked together. These chains are rich in sulfur-containing amino acids, particularly cysteine. Sulfur atoms can create disulfide bonds, which are chemical bonding found in keratin proteins. By forming cross-links between neighboring keratin chains, these bonds strengthen and stabilize the protein structure as a whole.

Melanin is a pigment that gives hair its color.it is produced by melanocyts which is a specialized cell found in hair follicles. Melanin has two forms which are Eumelanin which gives rise to brown and black hair and Pheomelanin which gives rise to red and blond hair. Distribution of this pigments determine the natural color of hair. Lipids in hair are highly responsible for moisture balance and for maintaining hair structure and elasticity. They contribute to the luster of the hair, lubrication, and moisture retention. Minerals and trace elements including calcium, magnesium, iron, zinc, and copper are also present in human hair. These components support the hair's general strength and health.

Human hair has a complex chemical structure labeled in layers. The hair shaft's outermost covering or cuticle. Is formed of keratinized, flattened cells arrange in overlapping scales. The cuticle affects the structure and appearance of the hair while shielding the inner layers. Beneath the cuticle, the cortex exist which is responsible for containing the pigment granules (melanin) that give hair its color. It is made up of long keratin protein strands that are tightly packed and entangled, giving hair its strength, elasticity, and structural integrity. The innermost layer which is the is composed of loosely arranged cells and can vary in size and presence.

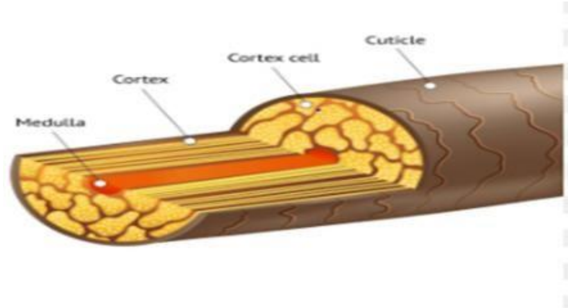


Figure 1 human hair structure

2.2. Human hair as a potential bio waste

Bio-waste refers to any waste generated from biological sources, primarily from human activities related to agriculture, food production, food consumption, and other organic waste-generating processes. It is characterized by the ability to decompose naturally through biological processes.so human hair is considered bio-waste, depending on how it is generated and disposed

A significant amount of human hair waste is generated from hair salons in the process of regular haircuts, styling, and maintenance procedures. This hair waste is typically collected and disposed of as general waste (Arivalagan, 2017). When disposed of in the environment, hair can break down naturally, contributing to nutrient cycling in ecosystems. However, the rate of biodegradation is highly dependent on factors such as environmental conditions and the presence of microorganisms that facilitate decomposition.

Improper disposal hair can have many negative effects on environment. Eutrophication a natural or human-induced process characterized by excessive nutrient enrichment, particularly nitrogen and phosphorus, in to the aquatic ecosystems. Waste human hair does have the ability release organic matter as it decomposes, leading to nutrient enrichment so it is clear to see that improper disposal waste human hair can be the cause for Eutrophication.

Elevated nutrient levels fuel the rapid growth of algae and other aquatic plants. This excessive growth often results in the formation of dense algal blooms on the water surface. Which can result in turning the water green or causing discoloration. Formation of algal blooms reduce the sun light penetration which limits the growth of submerged aquatic plants which might be crucial for providing oxygen and habitat for other organisms.

Disposed solid waste in landfills will take years to decompose due to lack of limited oxygen and microbial activity when it came to human hair since it is made of keratin it can persist for many years occupying landfill space. Hair treated with a chemical products like dyes or styling agents, can release pollutants into the soil as it decomposes. These pollutants may leach into groundwater or affect soil quality, potentially impacting plant growth and overall ecosystem health.

2.3. Uses of human hair

Human hair can have many various purposes beyond its natural application some of the uses could be as an extensions creating natural look. Fine human hair can be processed and spun into yarn or thread, which can then be woven or knitted into textiles. When hair is incorporated into the soil, it gradually decomposes, releasing nitrogen and other nutrients. This can help improve soil fertility and promote healthy plant growth so when properly composted; hair can be used as a nitrogen-rich additive to enhance plant growth.

2.4. Elemental composition of human hair

Human hair is primarily composed of keratin, a protein that forms the structural component of hair fibers. In addition to keratin, hair also contains various elements that contribute to its overall composition. Carbon is the primary element in hair, constituting approximately 50% of its dry weight. Carbon is a fundamental building block of organic compounds, including proteins like keratin (Zahir, 2019). Oxygen is another essential element found in hair, making up about 20% of its dry weight. It is present in various organic molecules, including keratin. Nitrogen is an essential component of proteins, including keratin. It accounts for approximately 17% of the dry weight of hair. Hydrogen is an integral part of organic compounds and is present in hair, constituting around 6% of its dry weight. It is particularly abundant in the protein structure of keratin. Sulfur is an essential element found in hair, contributing to its strength and structural integrity (Tinkov, 2017). It makes up about 5% of the dry weight of hair and is primarily present in the amino acids cysteine and methionine, which are building blocks of keratin. In addition to the major elements mentioned above, human hair also contains various trace elements. These elements include calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), phosphorus (P), iron (Fe), zinc (Zn), copper (Cu), selenium (Se), and others. The presence and concentration of trace elements in hair can vary depending on factors such as diet, environmental exposure, and individual characteristics.

2.5. Fertilizer

Fertilizer, natural or artificial substance containing the chemical elements that improve growth and productiveness of plants. Fertilizers enhance the natural fertility of the soil or replace chemical elements taken from the soil by previous crops. Fertilizers can be classified into two main types: organic and inorganic (synthetic) fertilizers (Havlin, 2013).

Organic fertilizers are derived from natural sources, such as animal manure, compost, bone meal, fish emulsion, or plant-based materials. They provide nutrients to plants in a slow-release form, as they need to be broken down by soil organisms before becoming available to plants. Organic fertilizers also improve soil structure and enhance soil fertility over time.

Organic fertilizer come from different source like from Manure from livestock animals such as cows, horses, chickens, and pigs is a common organic fertilizer. Compost which is created through the decomposition of organic materials such as kitchen scraps, yard waste, and plant residues. Ground-up animal bones which are a source of phosphorus and calcium in organic fertilizers. Fish byproducts which are processed into fish emulsion are also source liquid organic fertilizer.

Organic fertilizers which are broken down microorganisms release nutrients slowly over time as they decompose or are broken down by soil. This slow-release nature helps prevent nutrient leaching and provides a more balanced and sustained nutrient supply to plants. Application of organic fertilizer increase the organic matter content of the soil, enhance its structure, water-holding capacity, and nutrient retention (Gola). Organic fertilizer dose not contribute to nutrient runoff and groundwater contamination to the same extent since their slow-release nature reduces the risk of nutrient leaching. Plus it promotes soil biodiversity and can contribute to carbon sequestration in the soil.

Inorganic fertilizer also called as synthetic or chemical fertilizers, is manufactured through industrial processes and provides essential nutrients to plants in a readily available form. Most of them are formulated to contain specific ratios of essential nutrients, primarily nitrogen (N), phosphorus (P), and potassium (K) and also some secondary nutrients too. Inorganic fertilizers are typically water-soluble, allowing the nutrients to be quickly available to plants after application so they are Fast-Release Nutrients.

Inorganic fertilizer dose have higher amount of nutrient Concentration which means that smaller amounts of inorganic fertilizers are needed to deliver the same amount of nutrients. Application of nitrogen fertilizer offers precise control over the nutrient composition and dosage, allowing farmers and gardeners to tailor the fertilizer application to meet specific plant needs.

Disadvantage and disadvantage of organic and synthesized fertilizer

Advantage	**Organic fertilizer**	**Synthesized fertilizer**
Nutrient Release	Slow-release nutrients provide sustained nourishment to plants	Fast-release nutrients provide immediate nutrient availability
Soil Health	Improve soil structure, fertility, and microbial activity	May not contribute to long-term soil health or organic matter
Environmental Impact	Lower risk of nutrient runoff and groundwater contamination	Higher risk of nutrient runoff and water pollution

Sustainability	Derived from natural sources, promote organic farming	Precise nutrient control and efficiency
Availability	Available from various natural sources and can be produced	Widely available in different forms and formulations
Cost	Can be cost-effective when produced on-site or sourced locally	Can vary depending on the specific formulation and availability
	Organic fertilizer	**Synthesized fertilizer**
Nutrient Variability	Nutrient content can vary, requiring soil testing for accuracy	Nutrient imbalances can occur if not applied correctly
Application Efficiency	May require larger quantities due to lower nutrient concentration	Requires precise application to avoid overuse or imbalances
Environmental Impact	None	Potential for environmental pollution if misused
Regulatory Considerations	Generally compliant with organic farming standards	Subject to regulations regarding usage and environmental impact
Long-Term Soil Fertility	Organic matter additions improve soil fertility over time	Continuous use may reduce soil fertility and reliance on external inputs

Table 1 advantage and disadvantage of organic and inorganic fertilizer

2.6. Principle of fertilizer application

The principle behind application of fertilizer is to increase efficient use of fertilizer and increase the level of soil fertility. Based on the four R applications which are right time, right place, right amount and right method. From the four given above two are very crucial which are time of application and placement of fertilizer.

2.6.1 Time of application

Time of application is highly dependent on available soil moisture and response of crops to fertilizers. Early application is more effective for short duration crops. Rate of crop growth is proportional to the rate of assimilation of nutrients, especially nitrogen hence, nitrogen fertilizers should be applied at least twice, one at sowing planting and again before flowering. Whereas Phosphorus & potash requirement are higher during early phases of crop growth so it would be highly recommended if applied at early stage

2.6.2 Placement of Fertilizers

Placement of fertilizers in the root zone improves their effective. There should be minimum contact of fertilizers with the soil to avoid fixation of nutrients. Phosphorus fixation in acid soils can be minimized by placement of water soluble phosphate fertilizers. Ammonical fertilizers should be placed in reduced zone for lowland rice to avoid losses of applied nitrogen. Response of dry land crops to fertilizers increase with their placement at about 5-10 cm below the surface, where soil moisture will be available for over long period of time.

2.7 Methods of application of fertilizer

2.7.1 Broadcasting methods

Basically fertilizers are of two types solid or liquid. Solid Fertilizer Broadcasting is the method of application of fertilizer uniformly over the entire field. Broadcasting at planting is adopted under certain conditions. Soils highly deficient, especially in nitrogen. This method can sometime be named as top dressing method Top dressing is application of fertilizer to the standing crop. Usually, nitrate nitrogen fertilizers are top dressed. Depending on the duration of the crop and soil type, top dressings may be more than one to meet the crop needs at times of greatest need of the crops. Here the application of fertilizer in standing crop throw the broad casting ,spot dressing and side dressing.

2.7.2 Placement Method

An important item in efficient use of fertilizer is that of placement in relation to plant. Fertilizers are placed in the soil either before sowing or after sowing.

Deep placement	Deep placement is application of fertilizers, especially nitrogen, in the reduced zone to avoid nitrogen losses in lowland rice
Subsoil placement	It refers to placement of fertilizer in the subsoil And usually adopted where the subsoil is strongly acidic

Plow soil placement	Fertilizers are applied close to the seed or plant plant. It is usually adopted when relatively small quantities of fertilizers are to be applied
Counter placement	refers to drilling seed and fertilizer simultaneously at sowing
band placement	Depending on the root system, fertilizer band is placed directly beneath the seed or by the side of the row

Table 2 types of placement methods

2.7.3 Liquid Fertilizer Application Method

Most of liquid fertilizers are usually concentrated and need to be diluted with water before application. The timing of liquid fertilizer application depends on the specific needs, characteristics and the growth stage of the plants. Some liquid fertilizers are used as a foliar spray, meaning direct application on the plant leaves. Others are applied to the soil around the plant roots. Spraying is commonly used for foliar applications and drip irrigation systems can be used to deliver liquid fertilizer directly to the root zone of plants, since liquid fertilizers can be washed away easily weather condition should be considered.

Advantage and dis advantage of fertilizer application methods

Method of application	Advantages	Disadvantages
Broadcasting method	Easy way of application ,cost effective and can distribute nutrients uniformly	Nutrient loss, inefficient use, risk of over or under application
Fertigation (Irrigation-based application)	Precise nutrient delivery, Increased nutrient use efficiency	Costly, Limited application area
Foliar spraying	Rapid nutrient uptake, Targeted application	Limited nutrient absorption, Risk of leaf damage and Need for frequent application

Table 3 advantage and disadvantage of fertilizer application

2.8. Fertilizer use age in Ethiopia

Agriculture dominates the Ethiopian economy. It is the major supplier of raw materials to food processing, beverage and textile industries. It accounts for more than 85% of the labor force and 90% of the export earnings. To promote agricultural productivity and food security Fertilizer usage in Ethiopia has been increasing over the years.

Most of the fertilizer used in Ethiopia are imported costing a billions of dollars. According to United Nations COMTRADE database on international trade Ethiopia Imports of Fertilizers was US$1.3 Billion during 2022.

Areas with higher crop production intensively uses Chemical fertilizers in Ethiopia, basically for providing essential nutrients to crops, such as nitrogen, phosphorus, and potassium, which are often deficient in Ethiopian soils and also to support agricultural development by enabling farmers to cultivate more productive and profitable crops.

Excessive or improper use of chemical fertilizers can have negative environmental consequences like Leaching into water bodies, leading to water pollution and eutrophication. This can also contribute to soil degradation, nutrient imbalances, and loss of biodiversity.

Chemical fertilizers can create a dependency on the peace of land which frequent application exists this can be explained as the land which is used to being amended by fertilizer will keep on requiring some amount of fertilizer to give yield. This and many other effects has made use of chemical fertilizer in Ethiopia to be reconsidered and shift to development and application of organic fertilizers from different organic wastes.

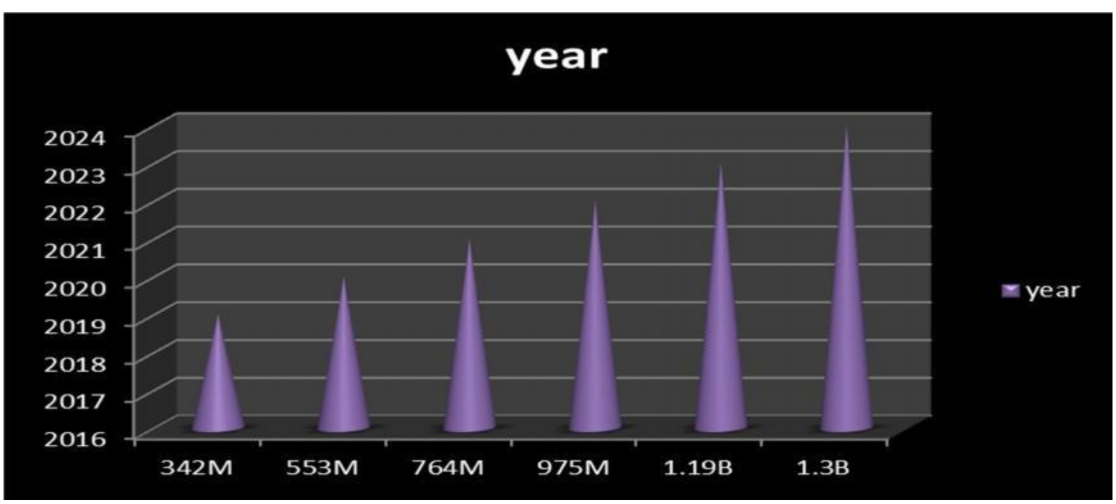


Figure 2 investment of dollars for importing fertilizer in Ethiopia

2.9. Essential nutrients for plants

2.9.1 Macronutrients for plants

Plants require several essential nutrients to grow. This nutrients are broadly divided in to two these are macronutrients and micronutrients. macronutrients are the essential nutrients required by plants in relatively large quantities for their growth and development. The major three macro nutrients are nitrogen ,phosphors and potassium.

Nitrogen is a fundamental component of amino acids, which are the building blocks of proteins. Proteins are essential for numerous plant functions, including the formation of enzymes, structural components, transport molecules, and defense mechanisms. Chlorophyll the pigment which is responsible for capturing of sunlight during photosynthesis, its structure's vital element is nitrogen (Barker, 2015). Plant height, leaf size and overall biomass accumulation is highly dependent on nitrogen since it plays significant role in promoting plant growth .Some plants have the ability to form a symbiotic relationship with nitrogen-fixing bacteria. These bacteria convert atmospheric nitrogen into forms that plants can utilize, such as ammonia or nitrates.

Phosphorus essential macro element for plant growth and development It is a component of ATP (adenosine triphosphate), which is the primary energy currency in cells aside to that phosphorus is important for root development. It promotes the formation of strong and healthy root systems, enabling plants to efficiently absorb water and nutrients from the soil. Phosphorus is involved in the activation of numerous enzymes in plants. Enzymes are biological catalysts that facilitate various biochemical reactions. Phosphorus helps in the transfer and utilization of energy within enzymatic processes and is often a component of the enzyme's active site

Potassium plays a critical role in various physiological processes like helps in regulating the osmotic potential within plant cells, maintaining proper water balance it is also essential for the activation of numerous enzymes in plants, the activated enzymes are highly involved in nitrogen metabolism, including nitrate uptake, assimilation, and amino acid synthesis. carbohydrate metabolism is facilitated by potassium in the conversion process of sugars into starches and vice versa. Adequate potassium levels enhance a plant's ability to withstand and recover from various stresses, including drought, temperature extremes, and pest or disease attacks.

2.9.2 Micronutrients for plants

Micronutrients are essential elements required by plants in small quantities for their proper growth and development. These micronutrients play crucial roles in various physiological and biochemical processes within the plant. The primary micronutrients required by plants are Iron, manganese, copper, boron, Molybdenum and chlorine which is essential for chlorophyll synthesis, energy transfer, and enzyme activity in plants. It is involved in the electron transport chain during photosynthesis. Manganese is necessary for photosynthesis, nitrogen metabolism, and enzyme activation. It also plays a role in the breakdown of carbohydrates and the synthesis of fatty acids. Zinc is involved in enzyme activation and is essential for the synthesis of auxins, proteins, and nucleic acids. It also aids in the regulation of plant growth and development. Copper is required for enzyme activity, particularly in processes related to photosynthesis and respiration. It also plays a role in lignin synthesis and iron uptake. Boron is involved in cell wall formation, pollen tube growth, and carbohydrate metabolism. It also affects calcium uptake and the movement of sugars within the plant. Molybdenum is necessary for nitrogen fixation and the conversion of nitrate to ammonium within plants. It also plays a role in enzyme activity and affects the uptake and utilization of phosphorus. Chlorine is involved in photosynthesis, osmotic regulation, and stomatal function. It also plays a role in the transport of cations within the plant.

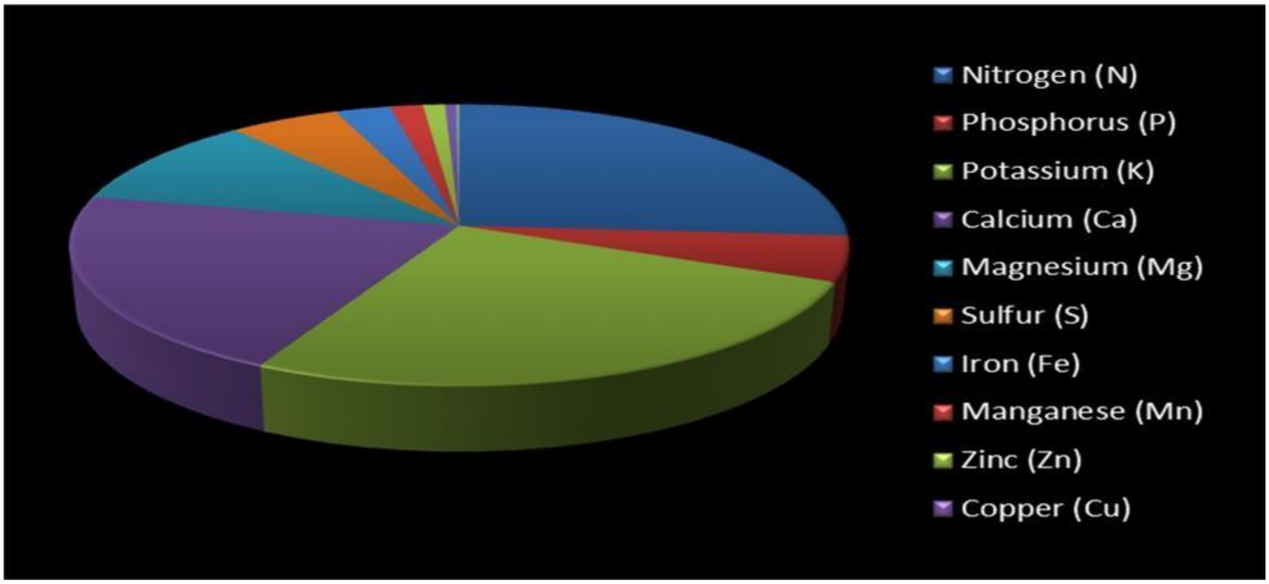


Figure 3 essential nutrients for plants

2.10 Nitrogen requirement for plants

Nitrogen requirements of plants can vary depending on the species, growth stage, and environmental conditions. Leafy greens such as lettuce, spinach, and kale have relatively high nitrogen requirements. They require a steady supply of nitrogen throughout their growth cycle to support vigorous leaf growth. Plants that produce fruits also have moderate to high nitrogen requirements. Root vegetables have lower nitrogen requirements compared to leafy greens and fruit-bearing plants excessive nitrogen can lead to excessive foliage growth at the expense of root development. Leguminous plants have a unique ability to fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing bacteria in their root nodules while they can acquire a significant portion of their nitrogen needs through nitrogen fixation.

It's important to note that while nitrogen is essential for plant growth, excessive nitrogen application can have adverse effects on plants and the environment. It can lead to excessive leaf growth, reduced fruiting, increased susceptibility to diseases, and environmental pollution.

2.11 Degradation methods of keratin wastes

Keratin waste in the form of human hair, animal hair, horns, feathers etc. Is generated in millions of tones globally. The objective for degradation of keratin wastes is to utilize of the valuable compounds present in keratin wastes and to create a system for managing the waste being generated. There exist different methods for degradation of keratin waste theses includes physical chemical, enzymatic and microbial methods for the degradation of keratin.

2.11.1 Pyrolysis

Pyrolysis is a process in which materials undergo thermal decomposition at high temperatures in the absence of oxygen, resulting in a change in their chemical composition. In a study, researchers conducted pyrolysis on 10g samples of keratin in a glass reactor, gradually heating it up to a final temperature of 500°C. The volatile products were then condensed in a water-cooled condenser and collected in a graduate cylinder. The resulting liquid pyrolysis product was separated into an organic fraction and a water fraction. The aqueous fraction was further refined by extracting any remaining organic compounds using ethyl acetate, and the extracted solution was concentrated under vacuum. When wool, hair, and feathers were subjected to pyrolysis, nitrogen and sulfur-containing compounds were produced. These compounds originated from the amino acids present in the protein composition of these keratin-based waste materials, as well as from the disulfide bridges in the keratin structure. Nitrogen was primarily found in compounds such as aliphatic/aromatic nitriles, pyridines, pyrroles, and amides. Sulphur was primarily present as sulfides, thiols, thiazoles, and thiophenes.

2.11.2 Hydrothermal

Hydrothermal treatment processes are conducted within a temperature range of 100°C to 150°C and a pressure of 1.5 atm. During these processes, acids such as HCl, H_2SO_4, HCOOH, or bases such as NaOH, KOH, Na_2CO_3, K_2CO_3, $NaSiO_2$, are often added for a duration of approximately 2-3 hours. The addition of these chemicals helps to break down the peptide bonds present in keratin, resulting in the production of water-soluble polypeptides, oligopeptides, and even amino acids. However, a drawback of using hydrothermal processes is that the hydrolysis can lead to the partial or complete denaturation of amino acids. As a consequence, certain essential amino acids like lysine, methionine, and tryptophan may be lost, while the formation of non-nutritive compounds such as lysinoalanine and lanthionine may occur.

2.11.3 KOH & TMAH chemically hair degradation

Hair contains a significant amount of cysteine, typically ranging from 1400 to 1500 micromoles per gram of hair. Cysteine is characterized by the presence of disulfide bonds, which contribute to the strong intermolecular structure of hair. When following the appropriate protocol, Potassium Hydroxide and Tetramethy lammonium hydroxide have been shown to effectively degrade hair. The rate of the degradation process is primarily determined by the breaking of these disulfide bonds. This bond breakage is pH-dependent, as alkaline chemicals with a pH above 10 can penetrate the hair and control the reaction rate. Therefore, an alkaline environment is the most suitable for the degradation of hair, as it facilitates the efficient disruption of the disulfide bonds.

Research indicates that Tetramethylammonium hydroxide (TMAH) can serve as a potential nitrogen source, contributing to the overall nitrogen content in degraded hair. On the other hand, potassium is an essential macro element necessary for plant growth when provided in adequate quantities.The degradation of hair necessitates the use of specific reagents, pH conditions, and instruments. In this method, pellets of KOH and TMAH are dissolved in water to create a 25% (w/v) solvent with varying concentrations. A measured amount of hair is then taken, cleaned, washed, and dried before being added to the solvent. The mixture is heated and stirred, repeating this process 3-4 times until the hair is completely dissolved.

2.11.4 Acidic hydrolysis

Acidic hydrolysis is a method employed to degrade human hair. Hair samples are exposed to controlled conditions where acid is used to break down the hair's molecular structure. The acidic environment aids in the hydrolysis of chemical bonds within the hair, particularly the disulfide bonds formed by cysteine residues. Commonly used acids for this process include strong mineral acids like hydrochloric acid (HCl) or sulfuric acid (H_2SO_4). During the degradation process, the hair samples are treated with the acid solution for a specific duration and at a controlled temperature. The acid works to dismantle the protein structure of the hair, resulting in the cleavage of peptide bonds and the liberation of individual amino acids. The resulting breakdown products can be examined and analyzed to gain insights into the hair's composition, characteristics, and properties. Acidic hydrolysis plays a crucial role in scientific research, forensic investigations, and the development of hair care products.

2.11.5 Bacterial Degradation

The bacterial species involved in this process are aerobic, meaning they require oxygen to grow. These bacteria can be cultivated using keratin-rich substances like feathers as a substrate, leading to the complete degradation of keratin protein. The presence of feather powder as a keratin medium significantly enhances the production of keratinolytic protease in B. subtilis, B. pumilis, and B. cereus. Additionally, the production of keratinolytic proteases can be increased in B. subtilis by utilizing casein.

The production of keratinolytic proteases in B. subtilis is inducible, primarily requiring exogenous keratin as an inducer. Three isolates producing keratinolytic proteases were found to be thermophiles. B. subtilis and B. pumilis were capable of growth at 55°C, but the optimal temperature for enzyme production was 40°C. On the other hand, B. cereus could grow at 40°C, with the optimal temperature for enzyme production being 30°C. For B. licheniformis and B. brevis, the best temperature range for keratinolytic protease production in the feather medium was between 40 and 45°C. Staphylococcus sp. could grow at temperatures as high as 50°C, but the most favorable temperature for enzyme synthesis was between 37 and 40°C. Overall, the temperature for maximum enzyme production was slightly lower than the temperature required for bacterial growth in all cases.

2.11.6 Fungal degradation of keratin

Keratinolytic fungi are also responsible for the biodegradation of keratin. The most common fungi involved in this process are Aspergillus, Penicillium, Fusarium, Microsporum, and Trichoderma, which are fungal species commonly found in soil.When hair is inoculated with these keratinolytic fungi, tunnels are formed on the hair strand, and the hyphae of the fungi deepen these tunnels, ultimately perforating the hair strand. Fungal filaments cover the hair tunnel, bundles of hyphae surround the hair strand, and surface erosion takes place. The aerial mycelium strongly adheres to the hair strand. The damage to the cuticle layer can be observed using scanning electron microscopy (SEM).

The hyphae network detaches from the hair surface and attaches to the mantle. The mycelium creates erosion pockets on the hair surface, resulting in the separation of keratin macrofibril bundles. The perforated zone expands, causing the lifting of the cuticle layer, and sleeve-like hyphae encompass the hair strand. These hyphae penetrate the cortex beneath the scale cuticle and lift the scales. Digestion of the cuticle layer occurs, ultimately leading to its removal.

2.11.7 Enzymatic

Papain, also known as papaya proteinase I, is a cysteine protease enzyme found in papaya and mountain papaya. It has various applications in manufacturing, including use in cosmetics, toothpaste, contact lens cleaners, meat tenderizers, and meat products. Recent studies have demonstrated that when a specific protocol is followed, papain is capable of degrading human hair.The outermost layer of the hair is called the epicuticle, which consists of a monolayer of fatty acids, primarily 18-methyleicosanoic acid (18-MEA), bonded to a protein matrix. This structure acts as a barrier, impeding the enzyme's ability to break down the hair.

To overcome this barrier, ethanol and ether extraction methods are employed to remove the protective layers of the hair, rendering it accessible for papain action. Ethanol extraction eliminates cell membrane material, enhancing enzyme access and speeding up hair breakdown. Furthermore, hot ethanol extraction has been shown to eliminate a thin coating of electron-transparent substance from the hair's surface. The root ends of the hair are extracted with diethyl ether in a Soxhlet device for 24 hours and subsequently dried. Continuous hot extraction of the ether degreases the fibers in a Soxhlet device for one week, resulting in ethanol-extracted hair.

Keratinase serves as both a disulfide reductase and a polypeptide hydrolase. The degradation process of keratinase can be divided into three steps: denaturation, hydrolysis, and transamination. In the first step, the disulfide reductase activity of keratinase reduces cystine (-S-S-) to cysteine (-SH), causing the breakdown of the higher-level structure of keratin and resulting in degraded keratin protein. Subsequently, the polypeptide hydrolase activity of keratinase progressively hydrolyzes the degraded keratin protein into polypeptides, oligopeptides, and free amino acids. Finally, through transamination, ammonia and sulfide are produced, leading to the complete hydrolysis of keratin.

The exact mechanism of keratinolysis is still not fully understood. However, it has been hypothesized that deamination, which creates an alkaline environment necessary for substrate swelling, sulfitolysis, and proteolytic breakdown, may be the initial step in keratin degradation.During the microbial degradation of keratin, sulfoxide bonds (S_O) are formed as a result of the breaking of the S-S bonds. The presence of sulfur oxides is crucial for the oxidation of monoxide to dioxide, which then undergoes further oxidation, ultimately leading to the formation of cysteic acid. Various degradation chemicals have been identified, including ammonia, CO_2, sulfur-containing inorganic compounds (SCS, SCO, and H_2S), water, thiols, nitriles, phenol, and 4-methylphenol compounds.

2.12 Soil

Soil is a natural resource that consists of a mixture of minerals, organic matter, water, air, and living organisms.it is composed of mineral particles, such as sand, silt, and clay, which vary in size and texture. It also contains organic matter derived from decaying plant and animal material. The relative proportions of these components determine soil properties like fertility, drainage, and water-holding capacity.

Soil is typically divided into layers or horizons. The top layer is called the topsoil or A horizon, which is rich in organic matter and nutrients. Below that is the subsoil or B horizon, which may contain minerals leached from the topsoil. The lowest layer is the parent material or C horizon, which is less weathered and contains the rock or sediment from which the soil developed. Soil fertility refers to its ability to provide essential nutrients to support plant growth. Fertile soil contains an optimal balance of macronutrients (nitrogen, phosphorus, potassium) and micronutrients required by plants. Human activities, such as agriculture and land use, can affect soil fertility through practices like fertilization and erosion control.

2.12.1 Physicochemical properties of soil

Physic chemical properties of soil refer to the physical and chemical characteristics that influence its behavior and fertility. These properties can vary depending on factors such as soil type, composition, and environmental conditions. soil texture refers to the relative proportions of sand, silt, and clay particles in the soil. It influences water-holding capacity, drainage, aeration, and nutrient availability. Soil texture classes include sandy, loamy, and clayey soils. Soil structure refers to the arrangement and aggregation of soil particles into aggregates or clumps. It affects soil porosity, root penetration, water movement, and air circulation. Desirable soil structures include granular, crumb, and blocky structures.

Soil porosity refers to the amount and arrangement of pore spaces in the soil. It determines water infiltration, drainage, and air exchange within the soil. Well-structured soils have a balance of macro pores (larger spaces for water movement and root penetration) and micro pores (smaller spaces for water retention and nutrient exchange). Soil pH is a measure of the acidity or alkalinity of the soil. It affects nutrient availability and microbial activity. Most plants prefer a slightly acidic to neutral pH range (pH 6 to 7), although some plants have specific pH requirements.

Organic matter content refers to the amount of decomposed plant and animal material in the soil. It contributes to soil fertility, water-holding capacity, nutrient retention, and microbial activity. Soils with higher organic matter content are generally more fertile. Soil water holding capacity is the ability of soil to retain water for plant use. It depends on factors such as soil texture, structure, and organic matter content. Soils with higher clay and organic matter content have higher water holding capacity.

2.12.2 Soil acidity and calcium hydroxide

Soil acidity refers to the pH level of the soil, which indicates its level of acidity or alkalinity. The pH scale ranges from 0 to 14, with values below 7 indicating acidic soil, 7 being neutral, and values above 7 indicating alkaline or basic soil.

Calcium hydroxide, also known as slaked lime or hydrated lime, is a chemical compound with the formula $Ca(OH)_2$. It is commonly used to raise the pH level of acidic soils and neutralize soil acidity. When calcium hydroxide is applied to soil, it reacts with the acidic components, such as hydrogen ions (H+), and increases the soil pH.

The reaction between calcium hydroxide and soil acidity can be summarized as follows:

$$\mathbf{Ca(OH)_2 + 2H+ \text{->} Ca_2+ + 2H_2O}$$

In this reaction, calcium hydroxide ($Ca(OH)_2$) reacts with hydrogen ions (H+) from the acidic soil and forms calcium ions (Ca2+) and water (H_2O). The calcium ions help to reduce soil acidity and raise the pH level.

By increasing the pH level, calcium hydroxide can enhance soil fertility and nutrient availability for plants. It also improves the physical properties of acidic soils, such as soil structure and water-holding capacity. However, it's important to note that the application of calcium hydroxide should be done carefully; taking into consideration the specific soil type, crop requirements, and recommended application rates, as excessive use can lead to over-alkalization and other problems.

2.13 Swiss chard plant

Swiss chard, scientifically known as Beta vulgaris subsp. cicla, is a leafy green vegetable that is highly regarded for its nutritional value and culinary versatility. This plant, which belongs to the same family as beets and spinach, is native to the Mediterranean region but is now cultivated in many parts of the world. Swiss chard is characterized by its large, dark green leaves that are similar in shape to spinach but with prominent ribs that can be white, yellow, or red. The stalks, also known as petioles, are thick and fleshy, and they come in various vibrant colors. The leaves and stalks are both edible and offer different textures and flavors.

One of the key reasons Swiss chard is valued is due to its exceptional nutritional profile. It is an excellent source of vitamins K, A, and C, which are essential for maintaining healthy bones, vision, and a strong immune system. Swiss chard is also rich in minerals like magnesium, potassium, and iron, as well as dietary fiber. Furthermore, it contains antioxidants that help protect the body against oxidative stress and inflammation (BUOL, 2011).In terms of culinary uses, Swiss chard provides a range of possibilities. The leaves can be consumed raw in salads, providing a slightly bitter and earthy taste. Cooking methods such as sautéing, steaming, boiling, or braising can also be applied to the leaves, resulting in a milder flavor and softer texture. The stalks, on the other hand, have a unique crunch and can be cooked separately or used in recipes that call for a firm and colorful vegetable component. Swiss chard pairs well with garlic, lemon, olive oil, and various herbs and spices, allowing for a variety of flavor combinations. When it comes to cultivation, Swiss chard is a relatively easy plant to grow. It is a cool-season crop and can tolerate frost, making it suitable for both spring and fall plantings. It prefers full sun but can tolerate partial shade.

The plant thrives in well-drained soil that is rich in organic matter. Seeds can be sown directly in the garden or started indoors and transplanted. Regular watering and adequate spacing between plants are essential for successful growth. Harvesting Swiss chard can be done at any stage of growth, depending on personal preference (costa, 2019). Individual leaves can be picked when they reach a usable size, allowing the plant to continue producing. Alternatively, the entire plant can be harvested by cutting it off at the base, which encourages new growth. It is important to remove any damaged or wilted leaves during the harvesting process.

For storage, Swiss chard leaves can be kept in the refrigerator for up to a week. It is advisable to remove any excess moisture and store them in a plastic bag or airtight container. The stalks can be stored separately, wrapped in a damp paper towel, and placed in the crisper drawer.

2.14 Researches on utilizing waste human hair as a fertilizer

Quick-release fertilizers use ammonium compounds, (usually ammonium sulfate or ammonium phosphate) and pure urea. These nitrogen forms rapidly dissolve in water and are almost immediately available to the roots. Therefore they produce a rapid, but fairly short lived, green-up response and Slow-release fertilizers contain various forms of modified urea formulated for the roots to absorb slowly. These include sulfur-coated urea, urea form and IBDU. These types of fertilizers are more expensive but less likely to burn the grass, last longer than quick-release and are less likely to leach through the soil (MD.mominue rahman, 2016).

Two researches Se Ok Oh, Aram Yun, and Doo Hyun Park of Korean Society for Biotechnology and Bioengineering studied the Effects of Physicochemically Hydrolyzed Human Hairs on the

Soil Microbial Community and Growth of the Hot Pepper Plant. For this study waste human hairs discarded from beauty shops and barber shops hydrolysed with a mixture of 0.5 N KOH and 0.05 N NA (Gupta, 2014). $(OH)_2$ was heated for 20 min at 120 degree centigrade. Nitrogen, carbon, hydrogen, sulfur, and oxygen contents in the hydrolysate were 13.68, 48.58, 6.46, 3.02, and 28.26%, respectively. The laboratory-level farm field used for the cultivation of hot pepper plants was fertilized with hydrolyzed human hairs in order to estimate the possibility that waste human hair may be a proper material for organic farming plus the effects of human hair hydrolysates on the cell mass and community of bacteria inhabiting hot pepper plant fields, the growth of wilt disease pathogens (R. solanacearum), and the growth of hot pepper plants was evaluated (park, 2011).

From the study it was concluded that Hydrolysate obtained from human hair may be composed of amino acids, peptides, fatty acids, and nucleotides, which together constitute a major nutritional source for the growth of soil bacteria. Soil bacterial community was activated by hair hydrolysates, and an increase in the growth of hot pepper plants was induced by increases in the soil bacterial community. The ultimate goal of fertilization is to increase crop production and protect crops against plant pathogens, and not generally to increase the population of the soil bacterial community. Accordingly, the observed increase in hot pepper plant growth and the existence of hot pepper plants surviving from wilt disease in the fertilized farm field is an indicator for the estimation of successive fertilization (park, 2011).

On 7th of January 2016 a paper was published by four researchers Md. Mominur Rahman1*, Kazi Bayzid Kabir1, Md. Masudur Rahman1 and Zannatul Ferdous of Department of Chemical Engineering, Bangladesh University of Engineering and Technology on Quick Release Nitrogenous Fertilizer from Human Hair. Liquid nitrogenous fertilizer was synthesized using waste human hair as the raw material (MD.mominue rahman, 2016). Potassium hydroxide (KOH) and Tetramethylammonium hydroxide (TMAH) were used as the nonrecoverable solvents for diffusion controlled reductive cleavage of hair protein. Performance of these solvents was analyzed and compared both individually and for different combinations. Thereafter a vegetation pot experiment was established to investigate the performance of the produced liquid fertilizers compared to the commercial Nitrogen-Phosphorus-Potassium, NPK (15-15-15), fertilizer on the growth and yield of a short cycle crop, spinach (Spinacia oleracea L).These Experiments showed that KOH was better for dissolving hair and extraction of nitrogen in the forms of ammonium and nitrate ions compared to TMAH and NPK fertilizers (MD.mominue rahman, 2016).

Recently at 2020 a paper was published by Gayathri Unnikrishnan1,*, Vijayaraghavan Ramasamy on Extraction of Keratin from Human Hair with Production of Biofertilizer from Waste Liquid of Hair Extraction and its Efficient Application on Growth Yield of Abelmoschus esculentus L.

In this paper a convenient extraction procedure of proteins containing keratins from human hair wasters by alkali method was described and the waste water generated after keratin extraction from human hair waste was applied to Okra (Abelmoschus esculentus L.) with five treatment designed to analyze its fertilizing efficiency (ramasamy, 2020). This paper was finalized as Co-digestion of hair waste water after keratin extraction with seedlings of Okra is practically feasible for the generation of organic fertilizers with necessary nutrient content of fertilizing nature (Maharashtra).

Reviewing different articles it is possible to see that Human hair which is considered as a useless entity causing a negative impact on our environment can still be considered worthy of use in different industries but these problems need to be addressed and developed in the regions where their utilization is missing, so in this research it was possible to review that the use of human hair as a green fertilizer. Even though there is adequate information about the use of human hair as a fertilizer either as uncomposted hair form or in a hydrolyzed human hair form there is lack of information in using lime to hydrolyze waste human hair and compare its performance with the worldwide highly used commercial DAP fertilizer.

3 MATERIALS AND METHODS

3.1 Materials and chemicals

3.1.1 Equipment and instruments

While performing the experiment different equipment was used from preparation of raw materials until characterizing of the end product. Based on the experimental path materials used will be mentioned with their respective use age. Electric thermostatic heated dry box was used to dry the raw material and prepare it for the following experimental procedure. Coffee motor was used to reduce the size of the dried raw materials and Sieve with a mesh size of 200 was used to differentiate the oversized. Measuring balance was used to measure the accurate amount of raw material and chemicals needed for the experiment as a whole .Conical flasks was used to prepare the solvent solution and auto clave was used to carry out high-pressure and high-temperature reactions. A centrifuge was used to separate solid and liquid components based on their density differences. A PH meter was used to monitor the acidity or alkalinity of the hydrolysis solution. FTIR analyzer is used to find out the elemental composition of waste human hair. Tensiometers was used to measure the moisture content of soil. Kjeldahl Digestion Apparatus was used to measure total nitrogen content in a soil .available potassium and phosphors was measured by using UV spectrophotometer. Moisture balance was used to measure moisture content in the plant. muffle furnace Crucibles and Desiccator was used to measure to ash content . crude protein, crude fat, and crude fiber was measured by Kjeldahl Apparatus, Soxhlet Extractor and Fiber Extraction System respectively. Since the experiment include vegetation pot experiment too same sized pots was used to plant the hurt plant

3.1.2 Chemicals

All chemicals used in this study are analytical grade. Calcium hydroxide is used (CAOH) was used for hydrolysis reaction Sulfuric Acid (H_2SO_4), Sodium or Potassium Sulfate (Na_2SO_4 or K_2SO_4) , Boric Acid (H_3BO_3) and Sodium Hydroxide (NaOH) was used to determine nitrogen test by Kjeldahl Method. Ammonium Fluoride (NH_4F), Sulfuric Acid (H_2SO_4), Ammonium Molybdate, Ascorbic Acid or Sodium Ascorbate and Antimony Potassium Tartrate were used to perform soil phosphorus tests. Nitric acid and argon acid was used to determine the elemental composition of human hair.

3.2 Methods

The sample needed for this research was collected around kotoba wereda 12. Based on the information collected from the government officials there is assurance that in this area people from different regional state of Ethiopia do live plus KOTOBE METROPOLITIAN UNIVERSITY where students from every side of Ethiopia come and learn is located in that area so having this in mind its possible to conclude that the collected sample hair can designate most Ethiopian's hair.

Many Ethiopians have coily hair characterized by tight curls or coils that can vary in size and pattern. This hair type is often referred to as afro-textured or type 4 hair. It tends to have less natural moisture and can be prone to dryness

3.2.1 Experimental methods and procedure

In kotebe wereda 12 area there are hundred plus beauty salon based on my review .For this research hair sample was collected only form male barber shop the reason behind this is women mostly apply heat on their natural hair when heat is applied to hair, it can have both reversible and irreversible effects on the protein structure. The reversible effects occur when heat temporarily alters the hydrogen bonds within the hair, causing the hair to change shape However, excessive or prolonged heat exposure can cause irreversible damage to the protein structure of the hair. High temperatures can break down the protein bonds, leading to the loss of amino acids and protein degradation.so questioner was distributed to hundred male barber shops

መጠይቅ

1. በቀን ምን ያህል የሰው ጸጉር ትቆርጣህ/ሽ?

2. በወር በአማካኝ ምን ያህል ጸጉር ትቆርጣለህ/ሽ?

3 አንድ ሰው በምን ያህል ጊዜ ጸጉር ሊቆረጥ ይችላል?

4 የተቆረጠው ጸጉር ለምን ያህል ጊዜ ሳይወገድ እናተ ጋር ይቆያል?

5 የተቆረጠው ቆሻሻ ጸጉር ሳይወገድ በመቀመጡ ምን አይነት ችግሮች ታስተናግዳላቹ?

6 የተቆረጠው ጸጉር በምን አይነት መልኩ ታስውግዱታላቹ?

Figure 4 questioner

3.2.2 Sample collection

Waste human hair was collected from different male barber shops using a woven bag. The collected waste human hair had many tissue paper, dust particle and thin unwanted materials in it the collected waste human hair was sorted to remove any unwanted particles until the wanted human hair is left

Figure 5 collected waste human hair

Figure 6 sorting of waste human hair

Figure 7 sorted waste human hair

3.2.3 Sample preparation

The sorted waste human hair was washed to remove the sticky dust particles in it and left to air dry for a single day and this sample hair is analyzed for its elemental composition using CHNS/O analyzer.

Figure 8 washing of waste human hair **Figure 9 air dried waste human hair**

3.2.4 Sample pretreatment

To remove any unwanted moisture from measured amount of waste human hair sample was dried in an Electric thermostatic heated dry box for 24 hr at 105 degree centigrade. This procedure is followed by mechanical per treatment for size reduction so the dried waste human was milled using an electric motor and the end product was sieved to remove the oversized using a 200 mesh size sieve.

Figure 10 cleaned and hair

Figure 11 pretreated waste human hair

3.3 Preparation of solvent solution or limewater

For this experiment alkaline hydrolysis was chosen as an experimental method so for the hydrolysis experiment to take place solvent solution was prepared with different concentration. The alkaline solute used to prepare the solution was calcium hydroxide. Calcium hydroxide is a strong base, and when dissolved in water, it increases the concentration of hydroxide ions (OH-) in the solution. This results in an alkaline pH, typically around 12-13. Aside to this CAOH sparingly soluble in water. As a result, the concentration of the dissolved calcium hydroxide varies depending on the amount of solid added and the temperature of the solution. At room temperature, the solubility of calcium hydroxide is approximately 1.17 g/ calcium hydroxide has low solubility capacity as the amount of solid content increases. For this experiment 0.1, 0.5,1 gram of calcium hydroxide was dissolved with 250 ml of water. This dissolution of calcium hydroxide in water is an exothermic process, meaning it release heat and the solution appears in cloudy or have a milky appearance but if left for some minute the un dissolved calcium hydroxide will settle down then filter paper was used to filter out the solution. This solution is mostly termed as lime water.

3.4 Performing the experiment

The experiment was performed based on the design expert analysis in randomized order. Randomizing is a crucial step in conducting experiments to ensure unbiased and reliable results. It involves assigning participants or subjects to different groups or conditions in a random manner. Randomization helps reduce the impact of confounding variables and ensures that the groups being compared are as similar as possible. Three factors were considered in this experiment those were temperature, CAOH concentration and hair mass.

Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:lime loading g/ml	Factor 3 C:hair mass gram	Response 1 hydrolizing tim mintues
1	9	Block 1	100	0.1	2	
2	23	Block 1	110	0.1	2	
3	20	Block 1	120	0.1	2	
4	26	Block 1	100	0.5	2	
5	27	Block 1	110	0.5	2	
6	19	Block 1	120	0.5	2	
7	10	Block 1	100	1	2	
8	4	Block 1	110	1	2	
9	16	Block 1	120	1	2	
10	8	Block 1	100	0.1	4	
11	14	Block 1	110	0.1	4	
12	13	Block 1	120	0.1	4	
13	17	Block 1	100	0.5	4	
14	3	Block 1	110	0.5	4	
15	15	Block 1	120	0.5	4	
16	24	Block 1	100	1	4	
17	1	Block 1	110	1	4	
18	25	Block 1	120	1	4	
19	7	Block 1	100	0.1	6	
20	6	Block 1	110	0.1	6	
21	21	Block 1	120	0.1	6	
22	22	Block 1	100	0.5	6	
23	5	Block 1	110	0.5	6	
24	2	Block 1	120	0.5	6	
25	12	Block 1	100	1	6	
26	18	Block 1	110	1	6	

Table 4 experimental steps

3.5 Hydrolysis of waste human hair

After the lime water was prepared, different amount of well-prepared waste human hair was measured to perform the hydrolysis reaction. For this experiment 2,4,6 gram of waste human hair was measured and soaked in the prepared lime water solution and was stirred for 20 minutes Stirring helps to ensure uniform distribution of reactants throughout the solution. This promotes more efficient contact between the substrate and the hydrolytic agents, increasing the likelihood of successful hydrolysis .After the stirring process ceased the solution was transferred in to conical flask and inserted in to an autoclave for the hydrolysis reaction to take place, water was added in the autoclave for steam production to control temperature during hydrolysis. The hydrolysis reaction was performed at different temperature level .the chosen temperature level for this experiment was 100,110,120 degree centigrade. After this the autoclave was closed carefully and power was supplied to the autoclave. The autoclave was operating at a specific temperature and pressure. For certainty the same experiment was performed using water bath too.

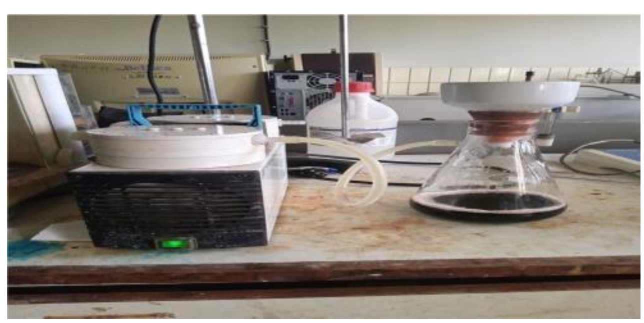
Figure 12 stirring the solution

Figure 13 autoclave and water bath for hydrolysis

Figure 14 hydrolyzed waste human hair

3.6 Fertilizer preparation

After the hydrolysis experiment was performed the hydrolsate sample was centrifuged to isolate left un hydrolyzed hair compontes and the sample was filtered paper using filter paper. Finally the sample was checked for its PH value to make sure it's in the wanted range.



Total nitrogen content of the fertilizer

The kjeldahl procedure is based on the principle that the organic matter is oxidized by treating soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted in to ammonium sulphate during the oxidation. the acids trapes NH_4^+ ions in the soil which are librated by distilling with NAOH. The librated NH_4^+ is absorbed in boric acid and back titrated with standard H2so4. Potassium Sulfate is added to raise the boiling point of the mixture during digestion and copper sulfate and copper sulfate and selenium powder mixture is added as a catalyst

.

3.7 Vegetation pot experiment

The main objective of a vegetation pot experiment is to study and understand various aspects of plant growth, development, and responses to different treatments or conditions. for this experiment the main aim of vegetation pot experiment was to evaluate the response of a Swiss chard to different treatments.

3.7.1 Soil sampling and preparation

The soil sample was selected based on the most common type of soil used in the agriculture area. To prepare the soil for the experiment first the top layer of the soil was excavated (0-15 cm) in the excavation process unwanted objects such as stones,derbies were discarded the reason behind this is, removing stones and debris from the soil creates a more favorable environment for root growth. Rocks and debris can impede root penetration, causing root deformation or restricted growth. By clearing the soil, plants can establish a healthier and more extensive root system, which is essential for nutrient uptake, water absorption, and overall plant growth. After obtaining clear soil sample soil was transported to the laboratory located at Ethiopian construction design supervision works corporation and checked for soil PH, texture, field capacity ,organic carbon ,total nitrogen available phosphorus and available potassium.

3.7.2 Pre-preparation of pot Experiment

For the pot experiment, pots with a size of 20.40 and with the capacity of holding two liter was prepared. All the pots chosen were fitted with an experimental soil, for free air and moisture movement the pots were pierced at the bottom and placed at a tray to capture any excess water escaping from the pots. Then water was added to all the pots until it much with the soil's field capacity and was allowed to settle for 48 hrs this can be important because. When soil is initially added to a pot, it may be loose and have air pockets. Allowing the soil to settle for a few hours helps gravity and natural compaction forces to work, causing the soil particles to settle and fill in these gaps. This settling process ensures better contact between soil particles, reducing air pockets and promoting stability.

Figure 15 soil preparation

3.7.3 Seed sowing

On the soil selected for experimental procedure the seed was sown. Seed sowing has its own procedure from choosing the optimal sowing time depending the plant spices to creating furrows or holes based on the seed size and space requirement. The plant species selected for this experiment was Swiss chard. Swiss chard which is known as Beta vulgaris subsp s a leafy green vegetable which is highly nutritious and is an excellent source of vitamins A, C, and K. swiss chard relatively small in size compared to some other vegetable seeds. They are usually about 3-5 millimeters in diameter and typically the seeds are round and slightly oval in shape with dark brown or black color.

Swiss chard seeds was sown on the soil prepared by removing any weeds, rocks, or debris. After the sowing process was completed the seeds were gently covered with soil use a rack and the seed was watered to initiate the germination process and provides the necessary moisture for seedling development.

Figure 16 seed sowing and germination stage

3.7.4 Seedling transplantation

Before seedling transplanting different treatment was applied to the pots using Sprayer or Sprinkle on the soil based on the recommended dose of nitrogen for Swiss chard plant which is around 10 -15 %. The treatments types are treatment one (T1) synthesized fertilizer from waste human hair,(T2) commercial fertilizer DAP and (T3) is no application of fertilize. After the treatments were applied the soil's physiochemical properties were analyzed.Under good environmental condition the time taken for Swiss chard soil to germinate is 7-14 days. After germination the seedlings were transplanted to experimental pots where different treatment are applied the pots were regularly watered to maintain their water content within the field capacity levels throughout the duration of the experiment to ensure maximum growth of the crop and the pots were moved around randomly with in a five days gap to minimize the effect of climate.

3.7.5Swiss chard plant harvesting

Swiss chard plants can be harvested at baby leaf stage or Mature Leaf Harvest the difference between them is baby leaf can be harvested after 28-35 days from sowing seed and mature leaf can be harvested around 49-60 days from sowing. Before harvesting treatment of each type was applied for 3 days' time gap difference .due to the time given to complete the research in this experiment Swiss chard plant was harvested at baby leaf stage.

Figure 17 harvesting of Swiss chard plant

3.8 Recording and measurement

The number of leaves and stem height was recorded for each treatment at the end of each week .after harvesting different parameters was measured too. The parameters measured were fresh and dry weight of the edible parts.

3.9 Characterization

Proximate analysis

Proximate analysis is a laboratory technique used to determine the approximate composition or nutritional profile of a food or agricultural sample. It involves the quantitative analysis of various components or proximate nutrients present in the sample.

3.9. 1.Moisture content

It is the amount of moisture or water found in an agriculture sample. It is a significant parameter because it affects the quality, stability, and shelf life of a product. Five grams of Swiss chard was measured and heated in an oven for two hours at 105degree centigrade this process removes the moisture away from the sample. After the heating process ceased the sample was allowed to cool in a desiccators for 40 minutes to prevent the sample from absorbing any moisture from the environment. The cooled sample was reweighed. And moisture content was calculated with a formula.

$$\textbf{Moisture content \%} = \frac{\textbf{[(initial weight – final weight)]}}{\textbf{Initial weight}} \textbf{*100\%}$$

3.9.2 Ash content

Refers to the inorganic residue left behind after the complete combustion of a sample. It provides information about the mineral content or non-combustible materials present in the sample. 5 grams of the sample was accurately weighed using analytical balance. Then the measured sample was subjected to high temperature in a muffle furnace at 500 degree centigrade for 5 hours. The heated sample was allowed to cool in the desiccators to attain room temperature and reweighed. Ash content was calculated with a formula.

Ash Percent % = (Weight of Ash / Initial Weight of Sample) x 100

3.9.3 Crude protein

Refers to estimating the protein content in a sample. It indicates the nitrogenous compounds present in the sample being analyzed.5 grams of the sample was weighed using analytical balance, them the most commonly used nitrogen determination method which is Kjeldahl method was used to determine nitrogen content. The sample was digested using concentrated sulfuric acid which have an ability to convert the nitrogen present in the sample in to ammonium sulfate. Then the obtained ammonium sulfate was treated with an alkali to liberate ammonia. Ammonia was titrated in an acidic solution to determine the amount of nitrogen present in the sample The nitrogen content obtained from the titration is multiplied by a conversion factor to estimate the crude protein content. The conversion factor used depends on the type of sample being analyzed. For most common food and feed materials, the conversion factor is typically around 6.25. However, this factor can vary for specific materials, such as soybean meal, where a conversion factor of 5.70 is commonly used.

Crude Protein (%) = Nitrogen Content (%) x Conversion Factor

3.9.4 Crude fat

Refers to the amount of lipid or fat present in a sample helps to determine composition of a food.5 grams of the sample was weighted using analytical balance. The weighted sample was subjected to fat extraction using hexane as a solvent. Then the remaining sample was dried at 105 degree centigrade to remove any trace of solvent in it until constant weight is achieved. The above process was followed by weighting the extracted fat and the dried sample carefully using accurate measurement. The calculate the crude fat with a formula

Crude Fat (%) = (Weight of extracted fat / Weight of the sample) x 100

3.9.5Crude fiber

Crude fiber specifically refers to the indigestible portion of plant material, consisting mainly of cellulose, hemicellulose, and lignin. It represents the structural and insoluble components of plant cell walls. The calculation of crude fiber in proximate analysis involves determining the weight of the residue obtained after the extraction and expressing it as a percentage of the initial sample weight.

$$\textbf{Crude Fiber (\%)} = \mathbf{(WF / W1) \times 100}.$$

4 Result and Discussion

4.1 Discussion on the questioners reply

The number of customers a barber can cut hair per day can vary based on various factors including the barber's skill level, the complexity of the haircuts requested, the time required for each haircut, and the barber's schedule.A skilled and experienced barber can typically handle anywhere between 8 to 20 haircuts per day. To estimate this value per month Determine the average number of working days in a month which is 26 excluding Sundays and an average to 10 people in a day a well skilled barber cuts 260 customers per month. A single customer could get a haircut with in time difference of three to four weeks but this depends on the nature of the hair type.so single hair cut can generate approximately 25 grams to 50 grams of hair waste under considering hair density, length. Calculating .the hair waste generated per day by 100barbershop would be 30000 grams or 30kg taking the average value of number of customer and amount of waste per each cut 10 customers and 30 grams respectively. Converting it in a month value it was 900 kg. This data gave me an insight that human hair does exist as a potential waste and this waste human hair could stay for about four of five days in the trash been before being collected by municipality cleaners this accumulation contribute to clogging of the plumbing system and provides a food source for pests and encourages their infestation, if not collected by the municipality cleaners all the barbers could do is discard it in the environment. So based on the reply's from the distributed questioner it was concluded that human hair does really exist in a plenty amount which could be enough to use it in production of valuable product like fertilizer.

4.2 Elemental composition of hair

The analysis conducted using the CHNS/O elemental analyzer revealed the following composition percentages in the hair sample: 12.00% Nitrogen (N), 32.32% Carbon (C), 5.47% Hydrogen (H), and 2.8% Sulfur (S) and the exist small amount of Trace Elements such as calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), and others. The composition of might differ based on individual genetics, diet, and environmental factors.

4.3 Experimental lay out

Experiments could be divided as comparative experiment, screening experiment, characterizing experiment, modeling experiments and optimizing experiment each has there on distinct features. Comparative experiment is an experimental design that aims to compare and evaluate the differences or similarities between two or more treatments, conditions, or variables. Screening experiment aims to identify the key factors or variables that have a significant impact on the performance or outcome of a system, process, or material. Characterizing experiment aim to quantify the effects of the identified factors, assesses their interactions, and generates more detailed data for modeling and optimization purposes. Modeling experiment involves using mathematical or computational models to analyze and understand complex systems, processes, or phenomena. Optimizing experiments conducted with the goal of finding the optimal set of conditions, parameters, or variables that maximize or minimize a specific objective or performance metric.

The chosen type of experiment for this research was characterizing and optimizing experiment. The experiment was analyzed using design expert general factorial design. Three factors were studied temperature, CAOH concentration and hair mass.

Tabel Expermintal points of design factors

Factor	Name	Units	Type	Low Actual	High Actual
A	temprature	degree centigra	Numeric	100.00	120.00
B	lime loading	g/ml	Numeric	0.100	1.00
C	hair mass	gram	Numeric	2.00	6.00

Table 5 experimental points of design factor

4.4 Experimental results obtained from laboratory

The randomized experiment obtained from the design was performed in ADDIS ABEBA INSTITUE OF TECHNOLOGY at thermal laboratory. Based the lay out given temperature, CAOH concentration and hair mass was studied at different points. Temperature was studied at three points which were 100℃, 110 ℃,120 ℃ . The other factor CAOH concentration was also studied at three points which were 0.1g/ml, 0.5g/ml,1g/ml. The third factor hair mass were also studied at three different points which were 2gm,4gm and 6gm. Design expert was used to analyze the data obtained from the laboratory experiment.

Results obtained from laboratory experiemnt

	Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:lime loading g/ml	Factor 3 C:hair mass gram	Response 1 hydrolizing time mintues
	1	3	Block 1	100	0.1	2	720
	2	13	Block 1	110	0.1	2	699
	3	19	Block 1	120	0.1	2	660
	4	22	Block 1	100	0.5	2	705
	5	7	Block 1	110	0.5	2	690
	6	5	Block 1	120	0.5	2	645
	7	18	Block 1	100	1	2	645
	8	8	Block 1	110	1	2	630
	9	25	Block 1	120	1	2	600
	10	16	Block 1	100	0.1	4	720
	11	1	Block 1	110	0.1	4	705
	12	20	Block 1	120	0.1	4	660
	13	12	Block 1	100	0.5	4	705
	14	23	Block 1	110	0.5	4	690
	15	24	Block 1	120	0.5	4	645
	16	17	Block 1	100	1	4	660
	17	21	Block 1	110	1	4	630
	18	6	Block 1	120	1	4	600
	19	14	Block 1	100	0.1	6	720
	20	9	Block 1	110	0.1	6	660
	21	11	Block 1	120	0.1	6	645
	22	2	Block 1	100	0.5	6	645
	23	15	Block 1	110	0.5	6	630
	24	27	Block 1	120	0.5	6	618
	25	4	Block 1	100	1	6	645
	26	10	Block 1	110	1	6	630

Table 6 results obtained from laboratory work

4.5 Experimental analysis

Laboratory results were analyzed using Analysis of Variance (ANOVA). ANOVA assess the significance of different factors and interactions in the experimental data. It helps determine which factors have a significant impact on the response variable and allows for the identification of important main effects and interaction effects. Three factors were considered in the experiment these factors might have significant or non –significant effect the response variable hydrolyzing time. The level of significance (α which is a parameter used in hypothesis testing to determine the threshold for accepting or rejecting a null hypothesis was (0.05) or 5% .significance or non-significance depends on the fact that if the probability value is greater than α value then the factor has no significant effect on the response variable where as if the probability value has is less than α value then the factor has significant effect on the response variable .based on the table was obtained from ANOVA

Response: **hydrolizing time**

ANOVA for Response Surface Linear Model

Analysis of variance table [Partial sum of squares]

Source		Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model		32632.66	3	10877.55	49.39	< 0.0001	significant
	A	*13448.00*	*1*	*13448.00*	*61.06*	*< 0.0001*	
	B	*16940.16*	*1*	*16940.16*	*76.92*	*< 0.0001*	
	C	*2244.50*	*1*	*2244.50*	*10.19*	*0.0041*	
Residual		5065.34	23	220.23			
Cor Total		37698.00	26				

Table 7 ANOVA Table

The table given above shows that the selected model was linear and the model was significant. This proves that the model was accepted. From the table given above temperature had a p-value of < 0.0001 which is lesser than alpha value this means that temperature had a significant effect on the response variable. The concentration of calcium hydroxide had a p-value of <0.0001 which is lesser than the alpha value again this proves that CAOH concentration had significant effect on hydrolyzing time of waste human hair. Hair mass had a p –value of 0.0041 which is lower than alpha value proving the significant effect of hair mass on response variable. Comparing the sum of squares value it's possible to predict that concentration of calcium hydroxide had higher effect among the two factors with a sum of squares value of 16940.16. following CAOH concentration it's possible to predict the effect of temperature on the response variable is high with sum of squares value of 13448.00.lastly it is possible to predict the effect of hair mass is much lower with a sum squares value of 2244.50.From the ANOVA table it was observed that there exist no interaction effect among the factors.

4.6 Effect of factors on hydrolyzing time

The three factors which are temperature, CAOH concentration and hair mass had an effect on hydrolyzing time this were proven by comparing level of significance and probability value of each factor. Based on this the effect of each factor was analyzed and discussed.

4.6.1 Effect of temperature on hydrolyzing time

The effect of temperature on hydrolyzing time was observed by altering CAOH concentration and hair mass at a high level and low level value. So at a high level value of CAOH concentration and hair mass temperature has positive effect as temperature increases hydrolyzing time decreases. The reason behind this was higher lime loading typically increase the reaction rate by providing more hydroxide ions (OH-) that can participate in the hydrolysis process and increasing temperature provide more energy to the reactant molecules, increasing their kinetic energy and collision frequency. The following figure shows the relationship between temperature and hydrolyzing time at high level value of CAOH concentration and hair mass

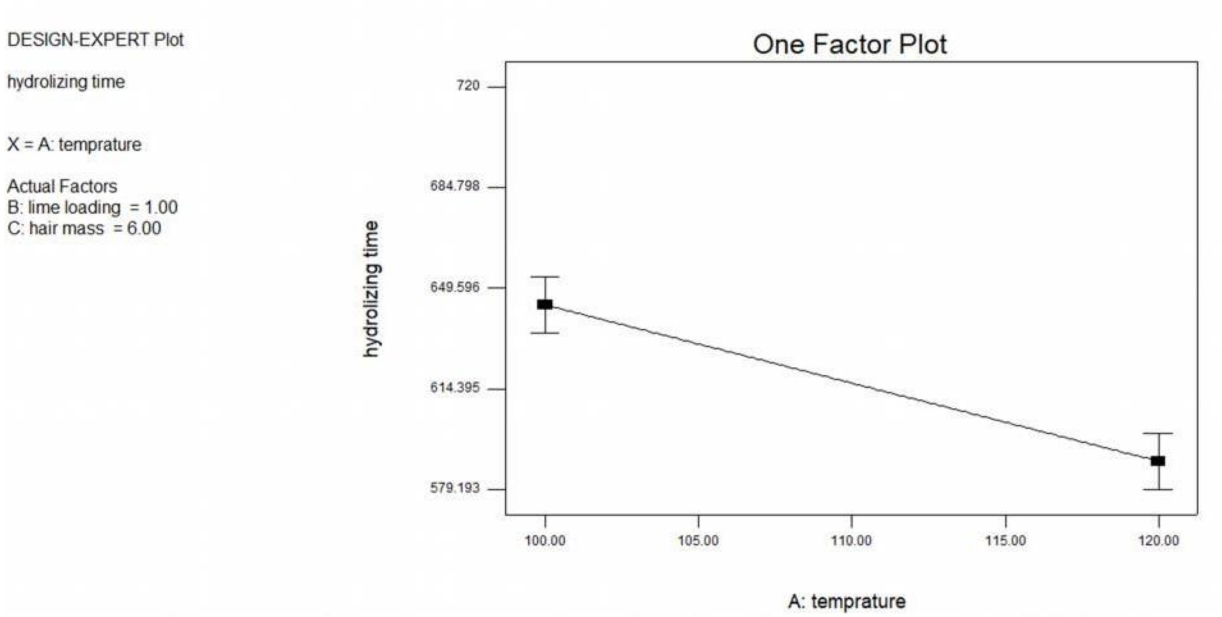


Figure 18 effect of temperature on hydrolyzing time at higher lime loading and hair mass

The observed effect of temperature at a low level of CAOH concentration and hair mass showed that the minimum temperature point used in this experiment took longer time to hydrolyze waste human hair compared to that point at high level points of calcium hydroxide and hair mass. As temperature value increased the time taken to hydrolyze the waste human hair was longer than. This happening was because enough amounts of OH ions weren't involved in breaking of the bonds which caused lower successful collisions. The following figure shows the relationship between temperature and hydrolyzing time with lower value of CAOH concentration and hair mass.

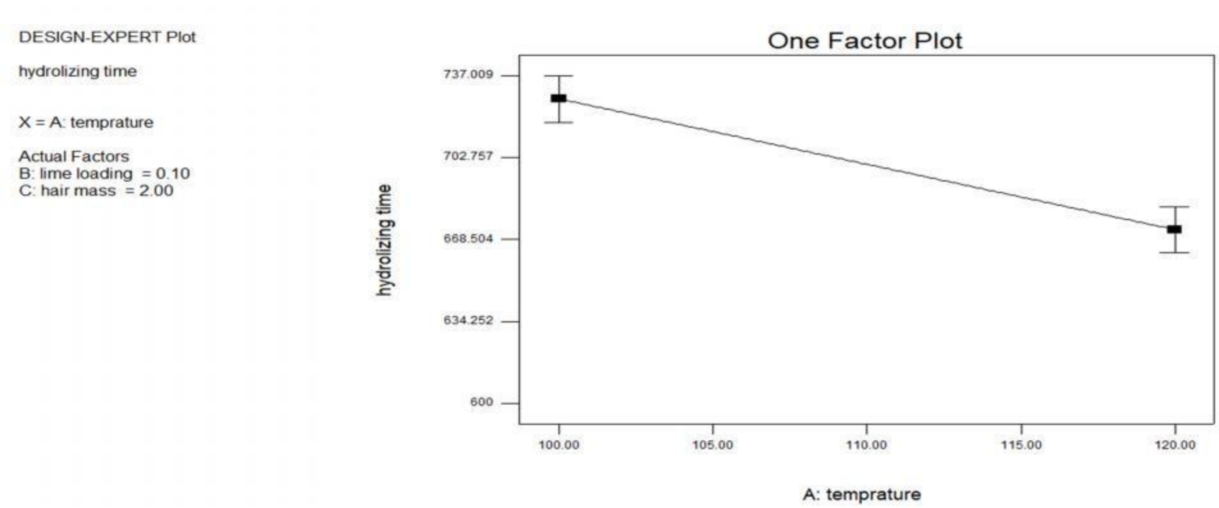


Figure 19effect of temperature on hydrolyzing time at low level of lime loading and hair mass

4.6.2 Effect of CAOH concentration on hydrolyzing time

The effect of CAOH concentration on the response variable hydrolyzing time was highly dependent on the chemical characteristics of calcium hydroxide. Calcium hydroxide is partially soluble in water it better dissolves in a high amount compared to its low amount, aside to this the dissolution of calcium hydroxide in water is an exothermic process, which means it release heat from the surroundings. So observing the effect of CAOH concentration on hydrolyzing time of waste human hair at a high level value of temperature and hair mass, CAOH concentration had positive effect on hydrolyzing time as concentration of CAOH increased hydrolyzing time decreased. This is illustrated in the following figure below.

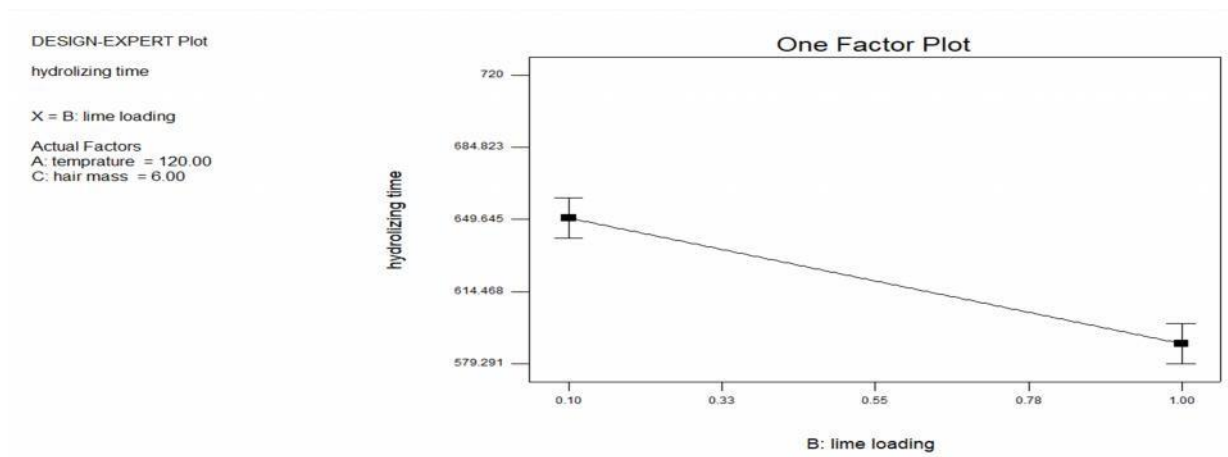


Figure 20effect of lime loading at a higher level of temperature and hair mass

The observed effect CAOH concentration on hydrolyzing time of waste human hair at a low level value of the other two variables was negative. Complete hydrolysis reaction took longer amount of time with increasing lime loading. This happening is illustrated in the figure below.

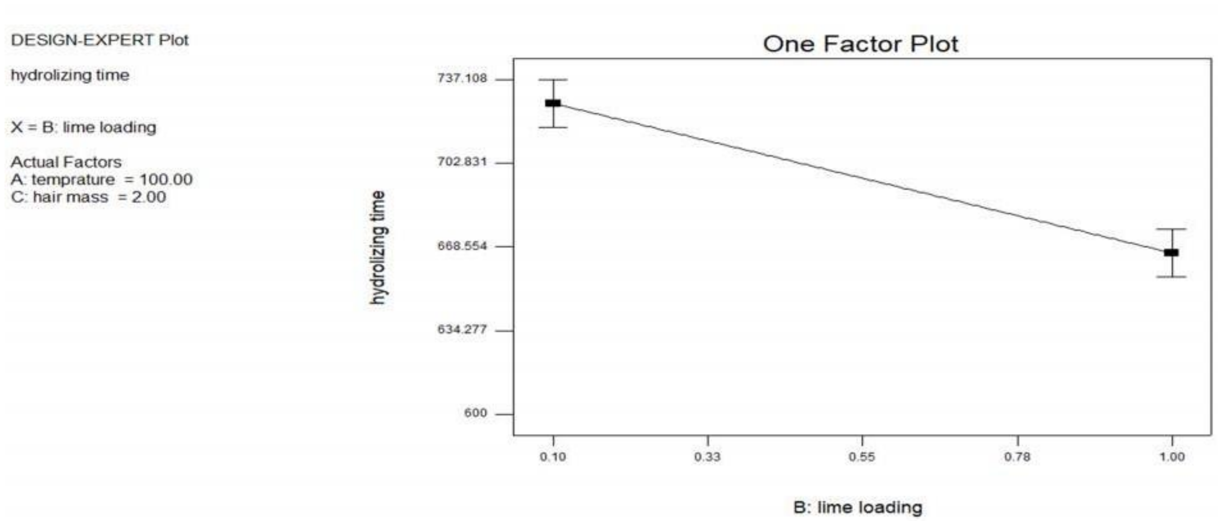


Figure 21effect of lime loading at a lower value of temperature and hair mass

4.6.3 Effect hair mass on hydrolyzing time

Based on the analyzed data hair mass amount does not highly contribute on hydrolyzing time. The hydrolyzing time obtained on both high and low level points of lime loading and temperature were nearly the same. This result gave an insight that hydrolyzing time was highly affected by temperature and lime loading. The following phenomenon is illustrated in the figure below.

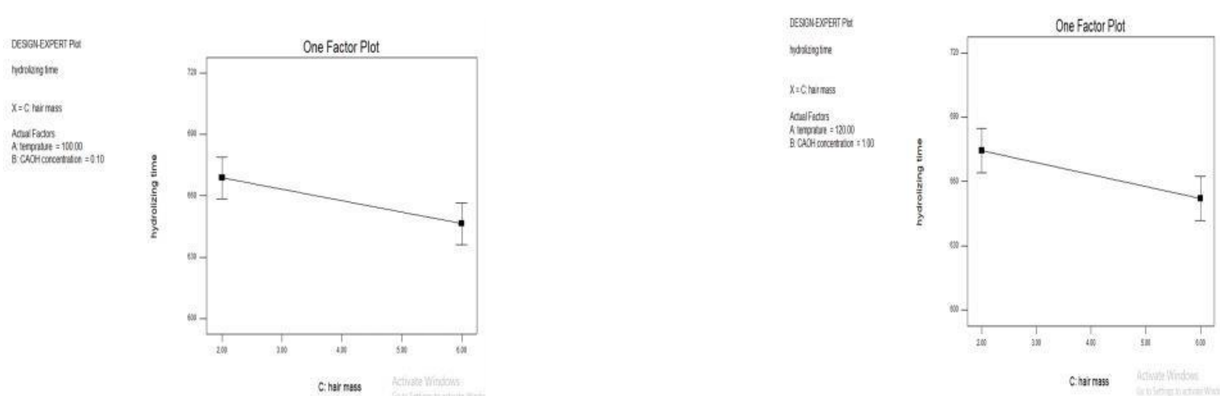


Figure 22effect of hair mass on hydrolyzing time

4.7 Model equation analyzed by design expert soft ware

The model equation is used to describe the relationship between a dependent variable and the independent variables or factors in a designed experiment. Coefficients in the model equation estimate the effect of each predictor variable on the response variable. The model equation was developed based on significant factors from the experiment and analyzed by ANOVA software.

Factor	Coefficient Estimate	DF	Standard Error	95% CI Low	95% CI High	VIF
Intercept	658.20	1	2.86	652.29	664.11	
A-temprature	-27.33	1	3.50	-34.57	-20.10	1.00
B-lime loading	-30.61	1	3.49	-37.84	-23.39	1.00
C-hair mass	-11.17	1	3.50	-18.40	-3.93	1.00

Figure 23coefficients estimation table

The coefficient of temperature was found to be -27.33, the coefficient of lime loading was -30.61and hair mass coefficient was -11.17.based on the coefficient the slope of all the three factors was found to be negative these implied us, as the value of the independent variable increases from lower value to higher value the dependent variable decrease. Fitting this logic in this research as the value of temperature and lime loading increases from lower value to higher value hydrolyzing time decreases. The model equation was represented as :-

$$hydrolizing\ time = -27.33 * A - 30.61 * B - 11.17 * C$$

4.7.1 The actual and predicted values

The value of (R^2) is an important statistical measure used to assess the goodness of fit of a model to the experimental data.it provides an indication of how well the model explains the variability in the response variable.

Std. Dev.	5.87	R-Squared	0.9875
Mean	670.59	Adj R-Squared	0.9809
C.V.	0.88	Pred R-Squared	0.9658
PRESS	1607.39	Adeq Precision	37.242

Figure 24table of actual and predicted value

predicted versus actual value graph, is a useful graphical tool to assess the performance of a model and the accuracy of its predictions. This plot compares the predicted values from the model with the corresponding actual values from the experimental data .In this experiment the points in the plot was closely aligned along a diagonal line, which indicates a strong agreement between the predicted and actual values.

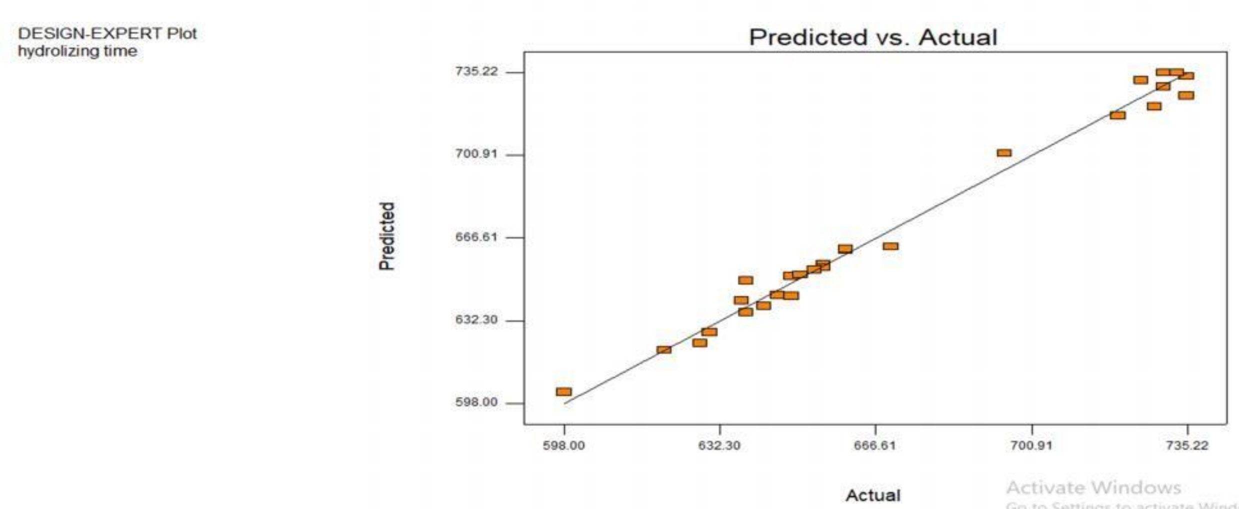


Figure 25predicted vs actual graph

Normal plot of residual

A graphical tool used to assess the normality assumption of the residuals in a statistical model. It compares the observed residuals against the expected values under the assumption of normality.in this experiment the points on the normal plot of residuals formed a straight line. Which indicates that the residuals are normally distributed, supporting the assumption of normality.

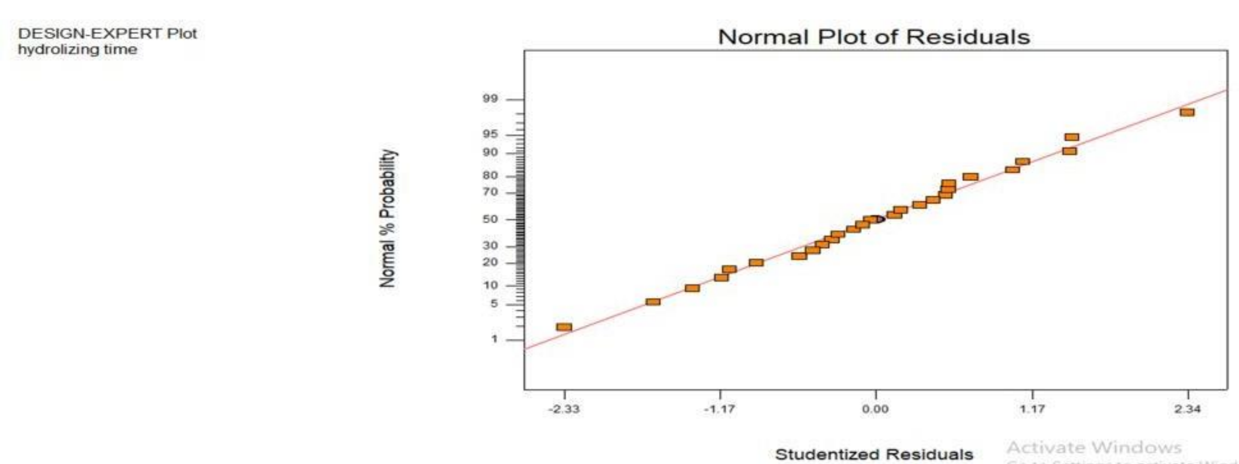


Figure 26 Normal plot of residuals

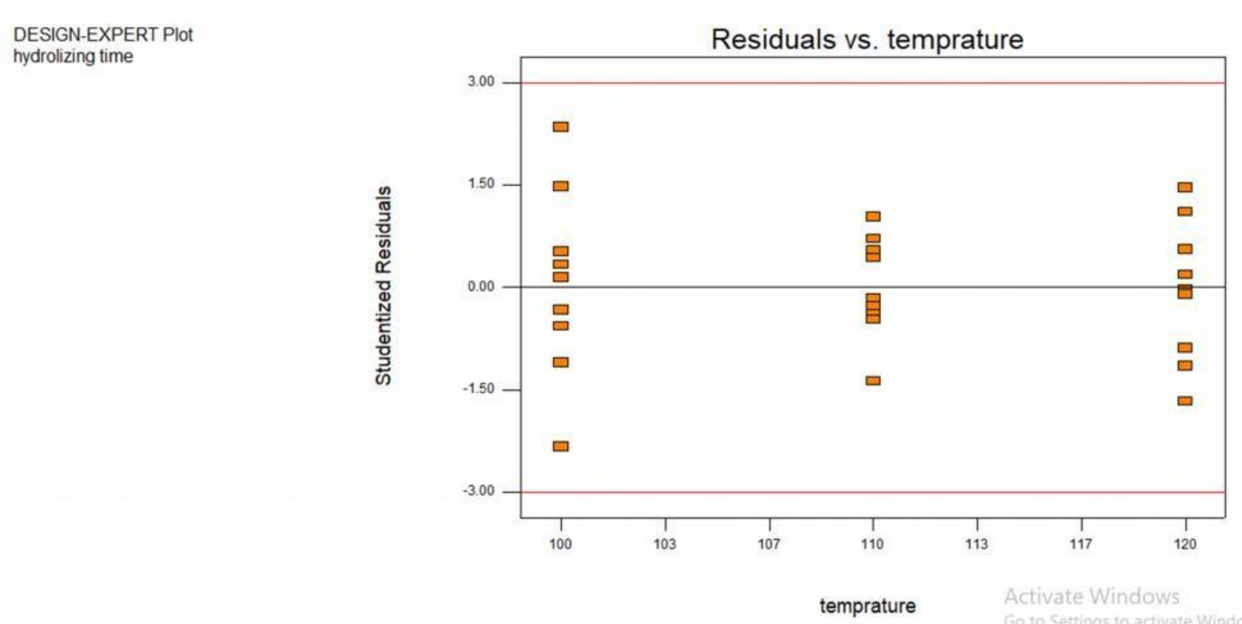


Figure 27Residual vs temperature

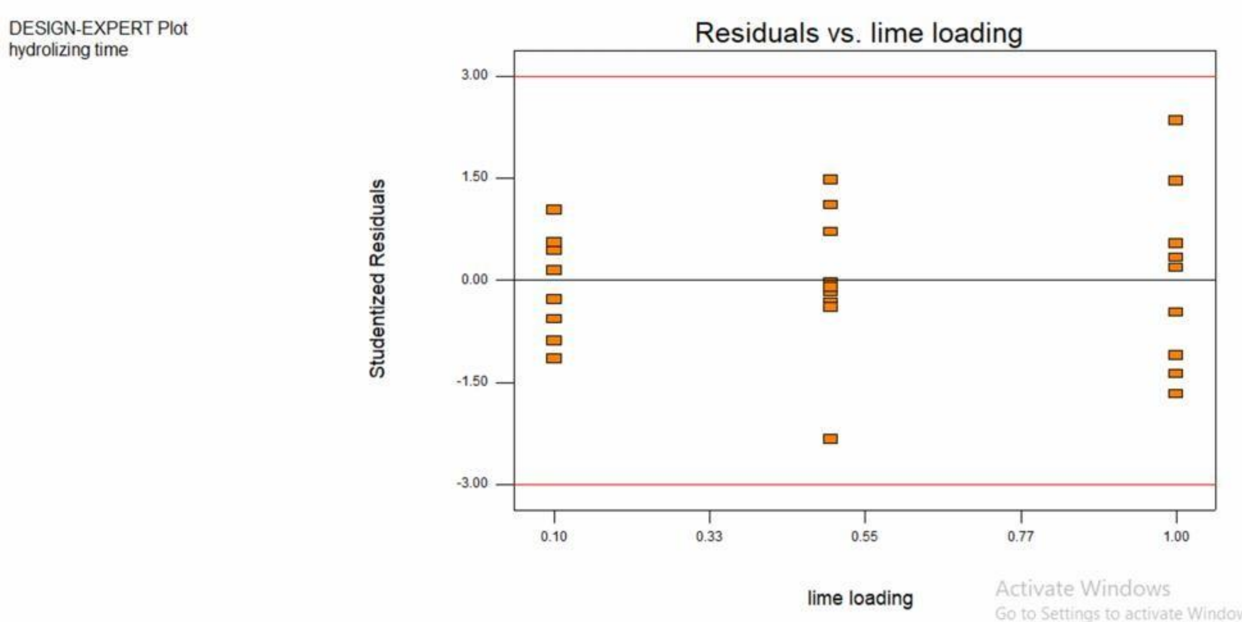


Figure 28Residual versus lime loading

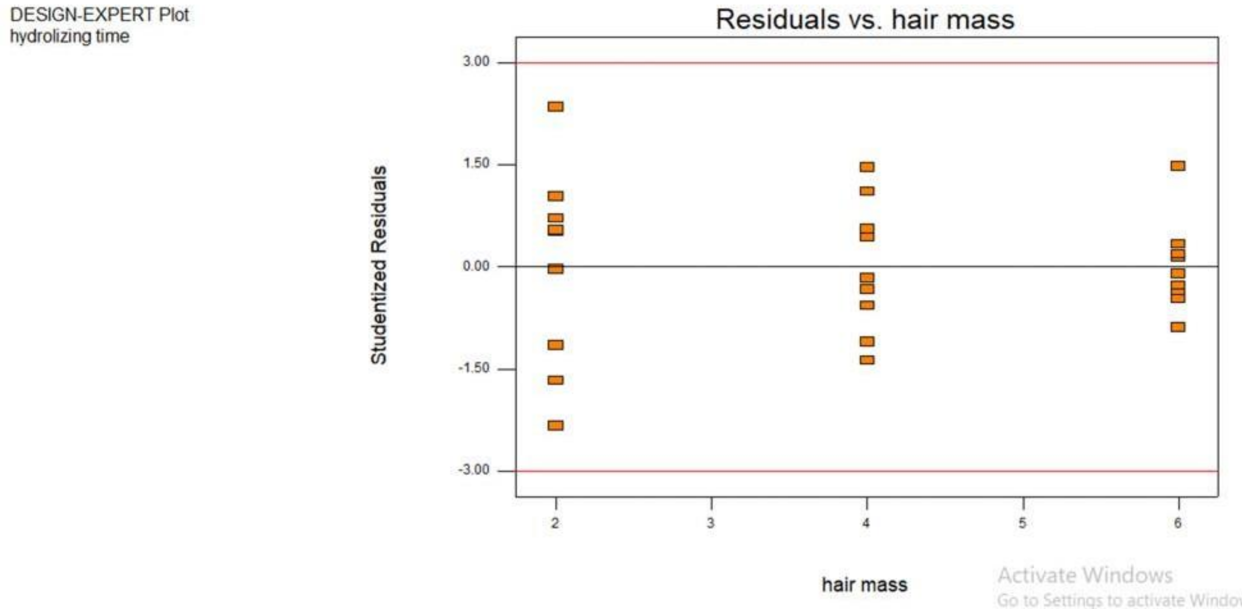
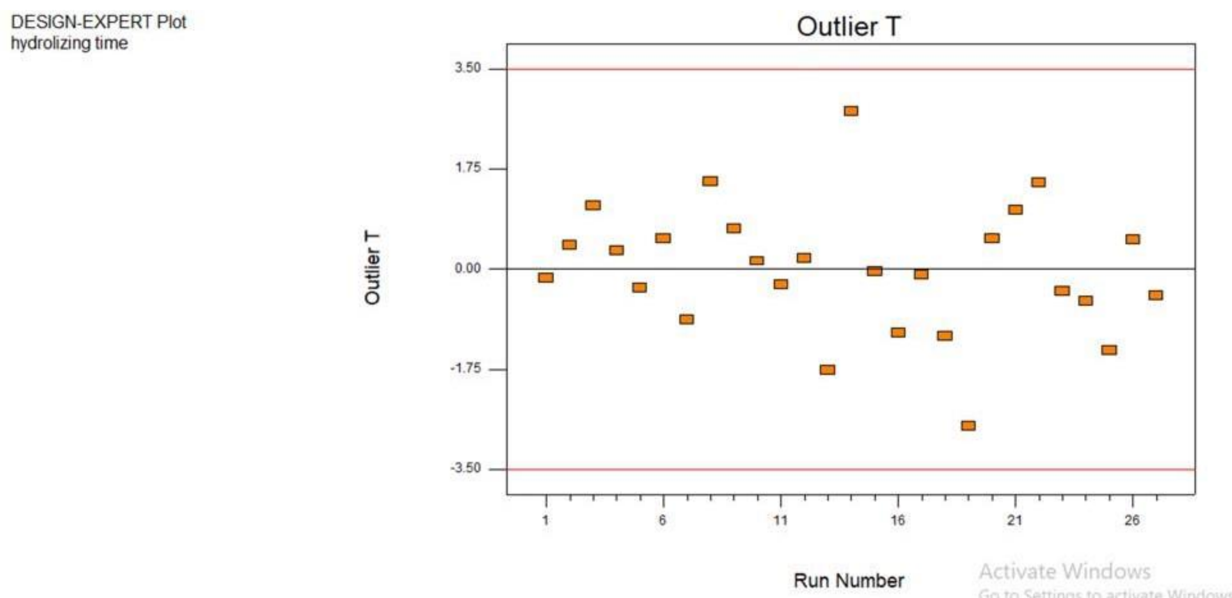


Figure 29eResidual versus hair mass



4.8 Determining optimum process parameters for hydrolysis reaction

Optimum value refers to combination of factors that maximize or minimize a response variable based on the goals of the experiment or study. The optimum process parameters for temperature, lime loading and hydrolyzing time were determined by box-behnken method. To perform the analysis the factors were kept in a range and total nitrogen content was kept at maximum the table below exhibits the desired combinations of process parameters that would provide the highest total nitrogen content value by using numerical optimization. Numerical optimization was used to optimize any combination of one or more goals.

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
temprature	is in range	100	120	1	1	3
hydrolizing time	is in range	10	12	1	1	3
lime loading	is in range	0.1	1	1	1	3
total nitrogn con	maximize	5	9.5	1	1	3

Table 8

Box behken experimental lay out

Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:hydrolizing ti hr	Factor 3 C:lime loading g/ml	Response 1 total nitrogn co percent
1	6	Block 1	100.00	10.00	0.55	
2	4	Block 1	120.00	10.00	0.55	
3	3	Block 1	100.00	12.00	0.55	
4	1	Block 1	120.00	12.00	0.55	
5	9	Block 1	100.00	11.00	0.10	
6	2	Block 1	120.00	11.00	0.10	
7	16	Block 1	100.00	11.00	1.00	
8	13	Block 1	120.00	11.00	1.00	
9	5	Block 1	110.00	10.00	0.10	
10	7	Block 1	110.00	12.00	0.10	
11	10	Block 1	110.00	10.00	1.00	
12	12	Block 1	110.00	12.00	1.00	
13	17	Block 1	110.00	11.00	0.55	
14	14	Block 1	110.00	11.00	0.55	
15	15	Block 1	110.00	11.00	0.55	
16	11	Block 1	110.00	11.00	0.55	
17	8	Block 1	110.00	11.00	0.55	

Experimental results

	Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:hydrolizing ti hr	Factor 3 C:lime loading g/ml	Response 1 total nitrogn co percent
	1	6	Block 1	100.00	10.00	0.55	5
	2	4	Block 1	120.00	10.00	0.55	5
	3	3	Block 1	100.00	12.00	0.55	5
	4	1	Block 1	120.00	12.00	0.55	8
	5	9	Block 1	100.00	11.00	0.10	6
	6	2	Block 1	120.00	11.00	0.10	6
	7	16	Block 1	100.00	11.00	1.00	6
	8	13	Block 1	120.00	11.00	1.00	8
	9	5	Block 1	110.00	10.00	0.10	5
	10	7	Block 1	110.00	12.00	0.10	7
	11	10	Block 1	110.00	10.00	1.00	7
	12	12	Block 1	110.00	12.00	1.00	8
	13	17	Block 1	110.00	11.00	0.55	9.5
	14	14	Block 1	110.00	11.00	0.55	9
	15	15	Block 1	110.00	11.00	0.55	9.2
	16	11	Block 1	110.00	11.00	0.55	9.1
	17	8	Block 1	110.00	11.00	0.55	9.4

optimization criteria

The numerical analysis from Box-behnken gives ten (10) possible solutions. All possible solutions were given in table below. The maximum total nitrogen content was obtained at a temperature of 112.3 degree centigrade with a lime loading of 0.72g/ml and in 11:27hr

Solutions

Number	temprature	hydrolizing tim	lime loading	total nitrogn cc	Desirability	
1	113.01	11.21	0.82	9.51551	1.000	
2	112.07	11.27	0.74	9.53884	1.000	
3	112.37	11.27	0.72	9.54666	1.000	Selected
4	112.68	11.35	0.78	9.52431	1.000	
5	112.84	11.26	0.81	9.52082	1.000	
6	113.38	11.15	0.73	9.51611	1.000	
7	112.17	11.33	0.77	9.52515	1.000	
8	112.55	11.14	0.72	9.52392	1.000	
9	112.97	11.34	0.75	9.53832	1.000	
10	113.19	11.20	0.79	9.52631	1.000	

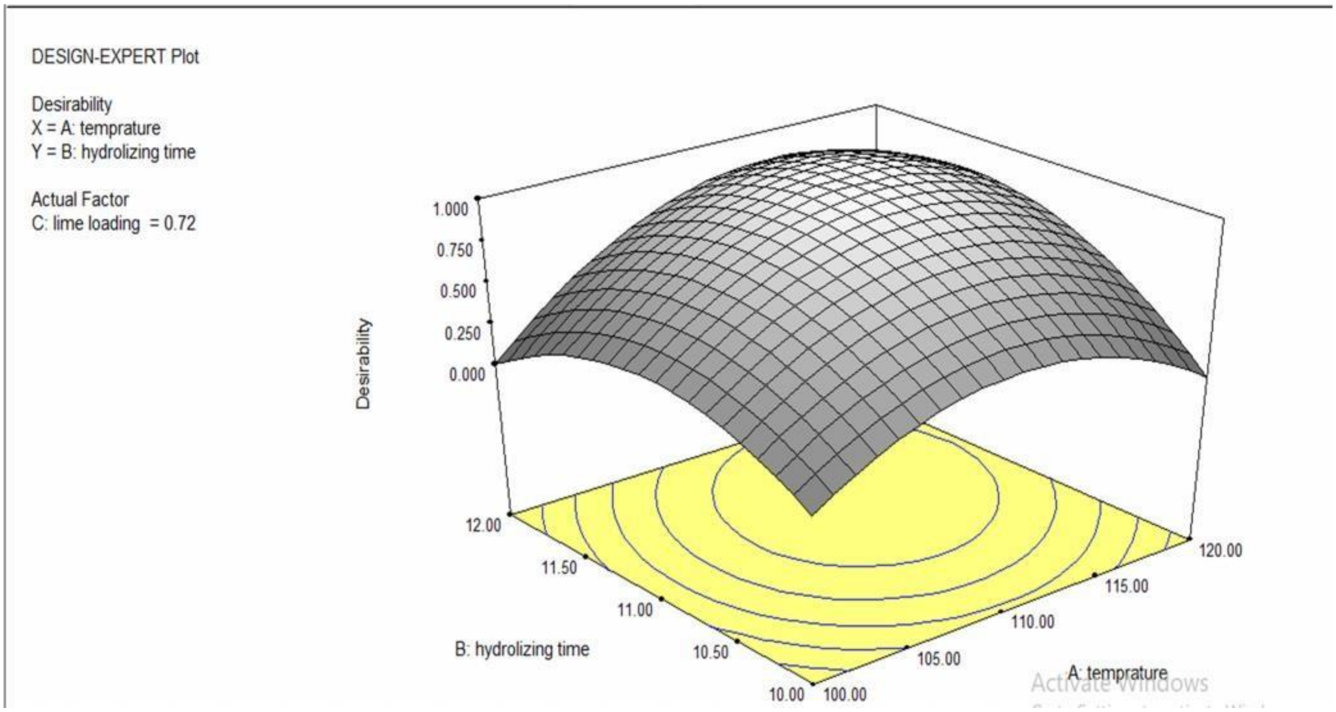


Figure 303-D surface graph of solution

4.9 Soil physiochemical characteristics

The result showed that the soil content with hair hydrolsate fertilizer have better nitrogen content and well adjusted PH

Soil physiochemical characteristic	Without fertilizer application	With hair hydroslate fertilizer application
PH	4	7.2
Texture	Clay	Clay
Field capacity %	14.2	14.3
Total nitrogen %	0.12	1.9
Available phosphorous mg/Kg	12	12
Available potassium mg/Kg	12.9	12.9

table 9soil physiochemical characteristics

4.10 Characterization of Swiss chard leaf

4.10 .1 Proximate analysis

The outcome of analyzing the Swiss chard plant with hair hydrolysate and DAP fertilizer treatments reveals different concentrations and proportions of biochemical and other substances. The moisture content of the Swiss chard exhibits a significant difference between the hair hydrolysate and DAP fertilizer treatments. The Swiss chard treated with hair hydrolysate fertilizer showed a higher moisture content percentage (92.6%), while the Swiss chard treated with DAP fertilizer had a lower moisture content percentage (90.02%).higher moisture content in plants offers several advantages compared to low moisture content. some of the advantages could be Improved Photosynthesis, facilitates the absorption of essential nutrients, maintaining turgidity and regulate temperature through transpiration.

The inorganic mineral residue left behind after the organic matter in the leaf which is ash content was compared for both hair hydro lysate fertilizer and dap fertilizer and the obtained result showed that Swiss chard treated with hair hydrolysate fertilizer exhibits a higher total ash content of this (9.01%) compared to the ash content of Swiss chard treated with DAP which was this (8.67%). This result proved that Swiss chard plant treated with hair hydro lysate fertilizer had abundant essential minerals such as calcium, potassium, magnesium, phosphorus, and trace elements like iron, zinc, and manganese.

Total protein content in Swiss chard plant which is crude protein was studied for both Swiss chard plant treated with hair hydrolsate fertilizer and the commercial fertilizer DAP. The result obtained were Swiss chard treated with hair hydrolsate fertilizer had a protein content of 2.5 % and the plant treated with DAP fertilizer had a 2% of protein content. This phenomena is a result of absorbing more nitrogenous fertilizer from the hair hydrolsate fertilizer.Having higher crude protein content showed that the plant can provide more essential amino acids and may exhibit faster and more robust growth, resulting in larger and healthier plant structures, such as leaves, stems, and roots.

Swiss chard being a leafy vegetable had insignificant amount of fat in it. Comparison was made by applying both fertilizer but the result obtained was nearly the same the amount of crude fat in Swiss chard leaf was below one (1%).Swiss chard contains dietary fiber that contributes to its nutritional value. Typically Swiss chard plant fiber content is (1.80 g per 100 g) of raw chard which lower than the average amount found in raw vegetables (2.43 g per 100 g). Comparing the leaf of Swiss chard plant’s fiber content based on application of hair hydrolsate fertilizer and DAP fertilizer did show that much of a difference so it was negligible.

4.11 Physical analysis of Swiss chard plant

4.11.1 Morphological characteristics

Characteristics are used to describe and categorize different aspects of a plants's external appearance and structure. Mostly morphological characteristics are physical traits and features of a plant. Comparing the morphological characteristics of Swiss chard plant with hair hydrolsate fertilizer and DAP fertilizer showed in a table given below

Morphological characteristics	Swiss Chard with hair hydrolsate fertilizer	Swiss Chard with DAP Fertilizer
Leaf Size	Larger leaves	Comparatively smaller leaves
Leaf color	Deep, vibrant color	Deep, vibrant color
Petiole thickness	Thick enough	Thick enough
Petiole color	White	White
Root development	Well-developed root system	Well-developed root system
Plant height	Longer height	Shorter height

4.11.2Number of leaves and Plant height

Measuring the height of Swiss chard plants providing information about their growth and development. Based on this comparing the height of the Swiss chard plant with hair hydrolsate fertilizer application and DAP fertilizer application there existed a visible amount of difference. Swiss chard plant with hair hydrolsate fertilizer measured around 35cm from the base of the plant to the tip of the highest leaf at the last week whereas Swiss chard plant with DAP fertilizer application measured around 30 cm this proved that the application of nitrogen rich fertilizer promotes vegetative growth and result in increased plant height. Number of leaves of the Swiss chard plant was also compared for the two fertilizers and by the end of the fourth week the Swiss chard with a hair hydrolsate fertilizer applied on had 9 number of leaves whereas DAP fertilized one had 7 number of leaves so abundant foliage was obtained with hair hydrolsate fertilizer application.

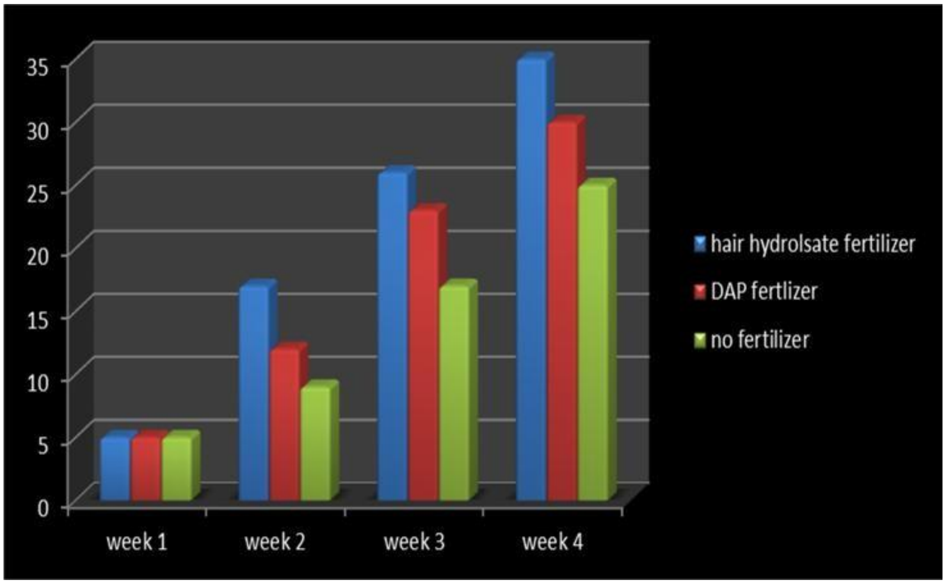


Figure 31comparison of height of Swiss chard plant

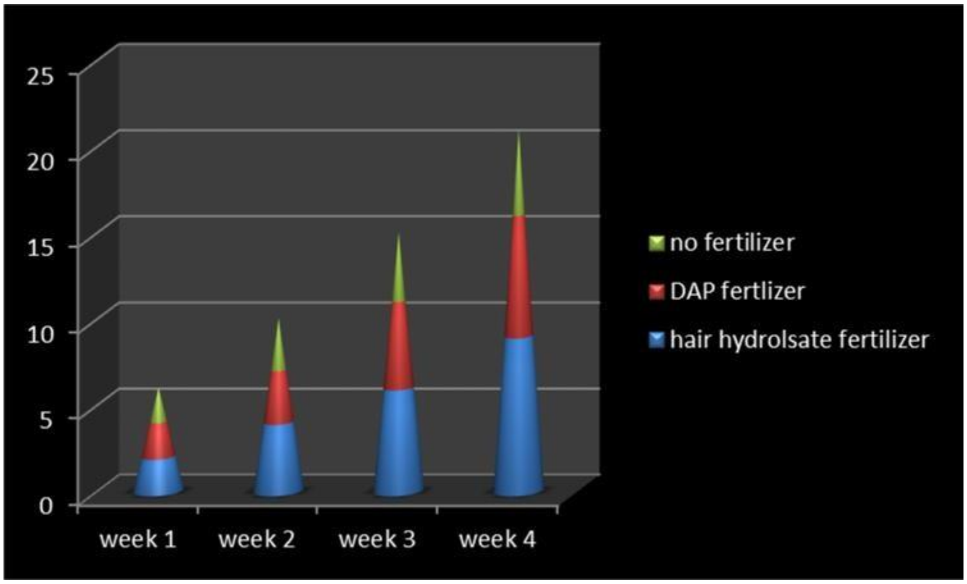


Figure 32comparison of number of leaves

4.11.3 Biomass Analysis

Biomass of Swiss chard plants involves measuring the fresh weight and dry weight of different plant parts, such as leaves, stems, and roots. This analysis provides insights into the plant's productivity and allocation of resources.

Fresh weight of the Swiss chard plant with different treatment application was measured with its own steps at a young Swiss chard plant and mature Swiss chard plant. The Swiss chard plant with hair hydro lysate fertilizer application on had a fresh weight of 90 gram on average .for the Swiss chard plant with DAP fertilizer the obtained result were 82 gram on average. The obtained results showed that Swiss chard plant with hair fertilizer application on had higher cellular hydration level and potentially more active metabolic processes compared to both DAP fertilizer applied one and the swiss chard with no fertilizer application

Dry weight, the weight measured after the removal of moisture was a parameter to be compared for the different treatments and the obtained result were. For the Swiss chard plant where hair hydrolsate fertilizer was applied on the dry weight was measured to be around 25g on average and the dry weight mass for the application of DAP fertilizer were 19.5 g on average . the obtained result illustrates that Swiss chard plant with an application of hair hyrolysate fertilizer had greater amount of plant material without the presence of water.

5 Recommendation and conclusion

5.1 Conclusion

To sum up, the utilization of lime treatment on waste human hair to create nitrogenous fertilizer presents a promising and sustainable solution for waste management and agriculture. This research has successfully demonstrated that lime treatment effectively breaks down the keratin structure of waste human hair, releasing nitrogen compounds that can be harnessed as a valuable resource for plant growth. By carefully optimizing lime dosage and temperature, the resulting nitrogenous fertilizer exhibits favorable nutrient content and agronomic advantages. This environmentally friendly approach offers a dual benefit by reducing waste and providing a nutrient-rich fertilizer that can enhance soil fertility, improve crop productivity, and address soil acidity. The utilization of waste human hair for nitrogenous fertilizer production aligns with the principles of the circular economy, transforming waste into a valuable resource in the agricultural sector. This approach not only addresses the pressing issue of waste management but also contributes to sustainable agricultural practices and the efficient utilization of organic waste resources.

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5.2 Recommendation

The findings of this study clearly demonstrate that waste human hair can serve as a valuable nitrogenous fertilizer source for agricultural crop production. As a result, it is highly recommended for individuals involved in municipal solid waste management systems and those interested in establishing small-scale enterprises to convert waste human hair into organic fertilizers. Given that waste hair generation occurs at specific locations, such as barber shops, implementing a waste hair collection system can be relatively easy. By utilizing calcium hydroxide solution, the hair can be processed into fertilizer, creating a potential source of income. This organic (amino acid) fertilizer can be marketed for gardening and short-term vegetable cultivation, thereby assisting in municipal solid waste management efforts. Due to the hair hydrolysate's effectiveness in promoting plant growth and its high content of essential macromolecules and nutrients, it is also recommended to utilize hair hydrolysate fertilizers to maintain soil fertility and cultivate short-term vegetables.

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APPENDIX

	Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:lime loading g/ml	Factor 3 C:hair mass gram	Response 1 hydrolizing time mintues
	1	3	Block 1	100	0.1	2	720
	2	13	Block 1	110	0.1	2	699
	3	19	Block 1	120	0.1	2	660
	4	22	Block 1	100	0.5	2	705
	5	7	Block 1	110	0.5	2	690
	6	5	Block 1	120	0.5	2	645
	7	18	Block 1	100	1	2	645
	8	8	Block 1	110	1	2	630
	9	25	Block 1	120	1	2	600
	10	16	Block 1	100	0.1	4	720
	11	1	Block 1	110	0.1	4	705
	12	20	Block 1	120	0.1	4	660
	13	12	Block 1	100	0.5	4	705
	14	23	Block 1	110	0.5	4	690
	15	24	Block 1	120	0.5	4	645
	16	17	Block 1	100	1	4	660
	17	21	Block 1	110	1	4	630
	18	6	Block 1	120	1	4	600
	19	14	Block 1	100	0.1	6	720
	20	9	Block 1	110	0.1	6	660
	21	11	Block 1	120	0.1	6	645
	22	2	Block 1	100	0.5	6	645
	23	15	Block 1	110	0.5	6	630
	24	27	Block 1	120	0.5	6	618
	25	4	Block 1	100	1	6	645
	26	10	Block 1	110	1	6	630

Hydrolyzing time of waste human hair with the factors temperature lime loading and hair mass.

Total nitrogen content in the fertilizer

Std	Run	Block	Factor 1 A:temprature degree centigr	Factor 2 B:hydrolizing ti hr	Factor 3 C:lime loading g/ml	Response 1 total nitrogn co percent
1	6	Block 1	100.00	10.00	0.55	5
2	4	Block 1	120.00	10.00	0.55	5
3	3	Block 1	100.00	12.00	0.55	5
4	1	Block 1	120.00	12.00	0.55	8
5	9	Block 1	100.00	11.00	0.10	6
6	2	Block 1	120.00	11.00	0.10	6
7	16	Block 1	100.00	11.00	1.00	6
8	13	Block 1	120.00	11.00	1.00	8
9	5	Block 1	110.00	10.00	0.10	5
10	7	Block 1	110.00	12.00	0.10	7
11	10	Block 1	110.00	10.00	1.00	7
12	12	Block 1	110.00	12.00	1.00	8
13	17	Block 1	110.00	11.00	0.55	9.5
14	14	Block 1	110.00	11.00	0.55	9
15	15	Block 1	110.00	11.00	0.55	9.2
16	11	Block 1	110.00	11.00	0.55	9.1
17	8	Block 1	110.00	11.00	0.55	9.4


COMMERCIAL
FERTILIZER
APPLICATION


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