Final Feasibility Study Report

Leather Solid Byproduct Transformation into Valuable Products for MSMEs and Tanneries in Modjo and Around Modjo Area, Ethiopia

Client:
SOLIDARIDAD ETHIOPIA

Prepared By:
KIND SOLUTION & CONSULTANCY PLC

Kind Solution & Consultancy PLC

Office: Megenagna Metebaber Edget Building Office Number 609,

Yeka Subcity, Addis Ababa, Ethiopia; P.O.Box: 20642

Tel +251-974-01-22-01; +251-964-08-88-88; +251-974-01-33-01;

Email: kindsolution2022@gmail.com;

Website: www.kindplc.com

General Manager: Tesfaye Gabriel Dalalo (PhD)

Oct, 2023

Addis Ababa, Ethiopia

Contents

List of Table

List of Figure

Acronyms and Abbreviations

EIA- Environmental Impact Assessment

EIC- Ethiopia Investment Commission

ELIA- Ethiopian Leather Industries Association

EPA- Environmental Protection Authorities

FDRE- Federal Democratic Republic of Ethiopia

GDP – Gross Domestic Product

GMIA-Gelatin Manufactures Institute of America

GTP- Growth and Transformation Plan

LISEC - Leather Initiative for Sustainable Employment Creation in Ethiopia

LLPI-RDC –Leather and Leather Products Industry Research and Development Center

MoI- Ministry of Industry

Acknowledgments

Kind Solution & Consultancy PLC is grateful for the opportunity to take part in this intriguing project and for the ongoing assistance provided by the SOLIDARIDAD-Ethiopia team during the project's duration. We also want to express our gratitude to the Leather and Leather Products Industry Research and Development Center's top management and to every member of the research team for their unreserved assistance. Additionally, we owe a debt of gratitude to the tanneries in the area of Modjo who graciously offered us access to their facilities as well as time for repeated data gathering activities and conversations. Lastly, we would like to thank the Modjo City Administration for their assistance and contributions on the socioeconomic effects of the leather industry.

Executive Summary

The tanning industry generates a large amount of waste, which should be managed following the principles of the circular economy. The aim of this feasibility study is to study the production of different valuable products such as (biogas, chicken feed, tallow oil, gelatin, biopolymer, keratin, adsorbent, bio-stimulant and binder sot match making, and wool fat) from tannery solid waste generated by industries located specifically at Modjo and surrounding areas. So to conduct this study both qualitative and quantitative data collection method basically literature review, stakeholder consultation and field visit were used. From the above ten products, production of chicken feed from raw trimming wastes and production of gelatin from lime trimmings and splitting wastes are technically feasible so that the detail financial, economic and environmental feasibility for the two products are presented on the paper. While Binder sot match making is addressed by LLPIRDC and Solidaridad, conducting the feasibility study for binder is just duplication of effort. The rest seven products evaluated based on a number of reasons that render them unfeasible for practical implementation. These reasons range from technical limitations, availability of raw materials and economic constraints. Regarding minimizing the environmental impact it is crucial to produce chicken feed and gelatin on sustainable way. This done by regular monitoring, reporting, and keeping compliance with environmental laws and regulations ensure that the production process aligns with best practices. Overall, based on the market feasibility analysis, it can be concluded that establishing a chicken feed and gelatin production plant using leather solid waste as a raw material offers significant potential for success and profitability as well as it will have contribution to the sustainable development of the country. Collaboration among stakeholders, government support, and industry-wide initiatives will be crucial in realizing these projects in Ethiopia.

Key Words: Leather Industry, Waste, valuable products and feasibility

1. Introduction

Solid residues are by-products from human and industrial activities, associated with negative impacts on human beings and the environment when disposed of incorrectly. The reduction of the generation of this waste and its proper management, therefore, become imminent challenges for governmental and non-governmental organizations (Rigueto et al., 2020). The tanning industry generates a large amount of waste, which should be managed following the principles of the circular economy. It is estimated that leather processing produces 200 times more waste than total product output (Chojnacka et al., 2021). The leather-making operation is conducted in a tannery and consists of converting the raw skin or hide, which is a highly putrescible material, into leather, a stable material that can be used in the manufacture of a wide range of products (Framis, 2018). During the process of leather processing, substantial amounts of solid and liquid by-products are generated. The various solid byproducts generated from tanneries are hair, wool, raw trimming and fleshing, wet blue shavings and splits, crust trimmings, buffing dust, and sludge.

The Ethiopian leather industry has gained momentum of growth over the last several years. The number of tanning industries that were a handful ten years ago has now risen to 29+ with more under formation. The soaking capacity of each leather company is estimated to be around 1.3 million pieces of hide and 32 million pieces of skin per year which means 10,325 pieces of hide and 179,650 pieces of skin per day. Most of them are located in Addis Ababa-Modgo and their surroundings. According to the Ethiopian investment commission, Ethiopia has the largest livestock population in Africa, measured at around 53 million cattle and it is the 10^{th} largest producer in the world. Unfortunately, only 50 % of the hide and skin potential is currently being utilized.

The leather industry has been considered as one of the highly polluting industries. In Ethiopia, the large production of leather presents a considerable challenge to the industry taking into account the adverse nature of most of the chemicals used during the process. A huge amount of liquid and solid wastes are generated as long as gases such as H_2S, NH_3 and CO_2. Very obnoxious smell is emitted because of a degradation of proteinous material of skin. Therefore, all of these wastes need to be analysed and treated. The tannery solids wastes contain different chemicals according to the distinct mechanical and chemical processes applied to the hides and skins. They are mainly shacked salt, raw trimmings, hair waste, fleshings, splitting waste, chrome shavings and buffing dusts. An accumulation or a non-properly disposal of them might cause environmental problems.

Leather industries generate chromium-based waste such as chromium sludge, chrome-tanned leather shavings (CTLS), and chrome leather trimmings. This creates serious environmental challenges in leather industry. The indirect use of CTLS through recovery of chromium and protein hydrolysate from CTLS has been well established for application in various industries. The possibility of transforming recovered materials from CTLS wastes into feed protein. Hydrolyzed protein, because of its high nitrogen content, has potential applications as animal feed additive, which provides food supplement amino acids. Its amino acid pattern is of a better quality than feather meal and is equal to meat meal and soybean meal with regard to cost competitiveness. The hydrolysates of CTLS were used as leather meal, which is hydrolyzed in a similar manner to poultry feathers and used as a supplemental protein source for livestock. Alkaline protein hydrolysate is preferred to be neutralized with phosphoric acid because of the equivalence of calcium phosphates to bone meal (Chaudhary and Pati, 2016).

Waste animal fats are regarded as effective feedstock in view of their easy availability, no food over fuel conflicts and serious concerns regarding their effects on environment. Technically, animal fats are made up of highly saturated fatty acids than oils; thereby contributing a significant role in developing high quality biofuel upon trans-esterification. Moreover, waste fats are rendered from fleshing and meat processing wastes collected from tanneries and slaughter houses, respectively. Each ton of raw hides yield approximately 70–230 kg of fleshing wastes with more than 1–2% (on dry weight basis) fat in them; whereas, nearly 4% (on average) of bovine live-stock weight is distributed as its fatty tissues, with most of it being inedible. Consequently, these data fairly briefs out about the sufficient availability of these waste fat that can be processed into sustaining high energy density biodiesel (Jambulingam et al., 2020).

Gelatin is an important biopolymer that has found widespread use in food technical and pharmaceutical industries. Gelatin is used in food industry as gelling agent, stabilizer, and thickener, texturizer in gelatin desserts, ham coating, fruit toppings, instant sauces, soups, marshmallows and gummy candies. It is also used as binding and glazing agents in meats and aspics, fining agent for a beverage, fruit and vegetable juice. In the pharmaceutical health industry, gelatin is used to make the shells of hard and soft capsules for medicines, capsules (vitamin supplement), dietary/ health supplements, syrups, etc. Due to the good film-forming property, inherent biodegradability, and universality, gelatin has attracted considerable interest from widespread areas, including food packaging, bone-tissue engineering, and soft electronics, etc. Most recently, gelatin-based films have been produced for the requirement of food preservation as food packaging (Elsayed et al., 2021).

The use of leather waste (hides and skins) as raw materials to obtain biopolymer-based fertilizers is an excellent example of a circular economy. This allows the recovery of a large quantity of the tanning agent in the case of tanned wastes, as well as the valorization of significant quantities of waste that would be otherwise disposed of by landfilling. The composition of organic biopolymers obtained from leather waste is a rich source of macronutrients (nitrogen, calcium, magnesium, sodium, potassium), and micronutrients (boron, chloride, copper, iron, manganese, molybdenum, nickel and zinc), necessary to improve the composition of agricultural soils, and to remediate the degraded soils. This enhances plant growth ensuring better crops (Stefan et al., 2022).

The use of hide waste to produce composite polymers that are further transformed in smart fertilizers. Hide waste contains mostly protein (collagen that is a natural polymer), that is extracted to be used in the cross-linking with water soluble copolymers to obtain the hydrogels which are further valorised as smart fertilizers. Smart fertilizers are a new class of fertilizers which allow the controlled release of the nutrients in synchronization with the plant's demands (Stefan et al., 2021).

Keratin is the most abundant structural fibrous protein of hair, skins, bristles, horns, hooves, and bird feathers. Millions tonnes of keratinous wastes are generated annually globally, especially in wool textile industry and in poultry slaughterhouses. Keratin-based materials are suitable for biomedical, cosmetically and agricultural applications. Due to biodegradability and high mechanical strength, keratin materials have a promising potential for biodegradable packaging production (Sinkiewicz et al., 2017)

Besides chromium, shaving is mainly consisted of collagen containing amino, carboxyl and other hydrophilic/hydrophobic functionalities which provide adequate sites for adsorption of transition metal cations and organic molecules. Few studies about use of tannery wastes as adsorbent exist

in literature. These studies highlighted the ability of these wastes to adsorb oil, aromatic organic acids, dyes, tannins, surfactants [19], As(V) and Cr (VI) (Onenc et al., 2011).

Feasibility study includes but not limited to the following:

- Technical feasibility for all possible valuable products from the mentioned solid wastes (are they easy for operation by unemployed youth and women with minimum academic background, are they environmentally friendly and socially acceptable)
- Financial feasibility - are these initiatives financially feasible (could be initiated with minimum capital and return on investment),
- Market linkage; do these initiatives have sustainable market
- Are the initiatives best fit to Micro, Small, and Medium Enterprises modality or tannery?
- Successfulness of the business cases by MSMEs/tanneries in other countries
- Pros and cons of the cases with respect to the environmental and social aspects with its mitigations

1.1. Leather Waste Management Practices in Ethiopia

Ethiopian tanneries for the last long years producing their products just utilizing the raw hides and skins as input and produce the required products by using conventional chemicals and machinery and end up with the output and generate wastes and discharge the liquid wastes to the surrounding river without any treatment and damp solid wastes together with all the municipal wastes at open damping sites.

Tannery solid waste represents one of the burdensome environmental problems owing to the large quantities of discarded material. Tanneries in Ethiopia as a general, are characterized by their unpleasant smell and polluting behaviors which is due to uncontrolled and desegregated disposal of tannery solid waste. Lack of waste-to-wealth approaches and secured landfill makes the segregation and disposal of tannery solid waste much more difficult. Segregation must be performed by separating various solid wastes based on their property. For better utilization of tannery solid wastes generated along the unit operations, there must be best practices to be implemented by each tanneries so as to improve their environmental performance. Detail best practices to be implemented for each type of solid wastes generated is indicated under Annex IV.

Tannery wastes have historically been discharged into rivers, landfill waste sites and the air with little if any purification. Even though it is evident that improper management of the waste from the tanning industry is full of risk to human and environmental health, presently almost all of the leftovers from leather product industries in Ethiopia and elsewhere are sent to the land as waste. Most of the factories do not possess well-established treatment plants for their wastes and simply dump their waste into the rivers nearby. This dumping to the river causes a serious pollution problem to the habitats near the tanneries. Due to the huge discharge of chemical containing wastes from tannery and improper management practice of such toxic wastes by the private tanneries, there is full of risk to the human that is living the vicinity of the industry and creates environmental health.

1.2. LISEC Project and SOLIDARIDAD's Work Component

The LISEC project aims to strengthen social cohesion by supporting local economies and social development initiatives, especially for women and youth living in Modjo areas; and enhancing industrial and labor relations in the Modjo Leather City. The project is coordinated by consortium which People in need (PIN) is the organizing body where Solidaridad, IRC, UNIDO are implementing entities with clear mandates. In this regard, Solidaridad is responsible for environmental and social responsibilities of the tanning industries and basically focusing on tannery solid waste management.

This project is the extension of efforts done by Solidaridad and Leather and leather products industry research and development center (LLPIRDC) on utilization of tannery sloid waste whereby six projects such as utilization of de-dusted salt, production of protein hydrolysate from chrome containing waste, Glue production form raw trimmings, leather board preparation from buffing dusts, preparation of bricks from tannery sludge and organic compost production from fleshing waste.

Since tanning industry generates huge amount of wastes having different characteristics so that solidaridad is interested to conduct feasibility study for production of ten different products from tannery solid wastes as indicated in Fig-1 below

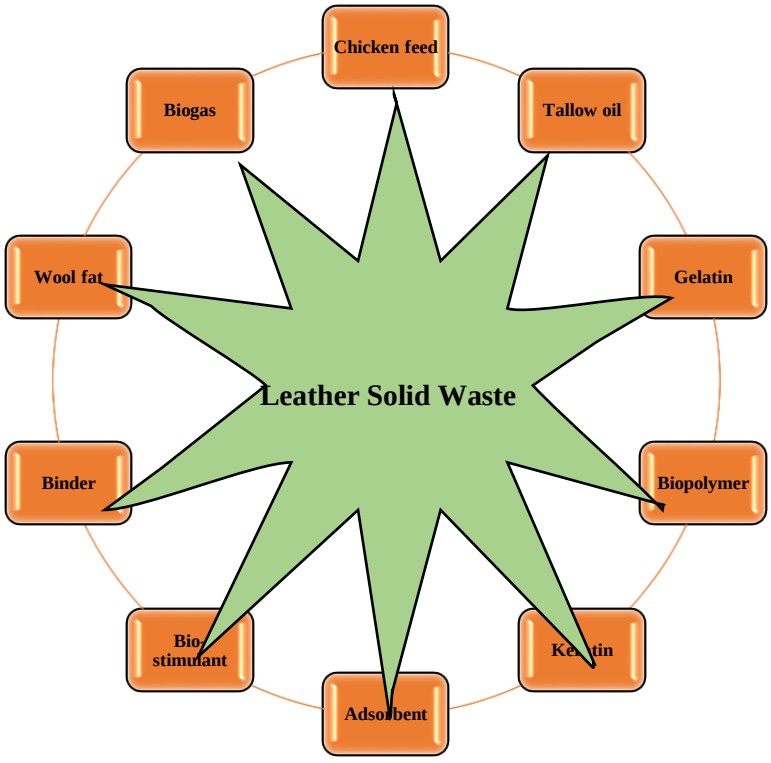

Figure 1 The suggested products to be produced from various tannery wastes

Table 1 Type of products and the relevant waste for production of the above products

Project Areas (10)	Suggested waste sources for the indicated products	Available extraction methods	Possible Application areas	Reference
Project Area 1: Production of biogas from leather solid waste	Chrome-tanned leather waste, Fleshing wastes integrated with toilet wastes, biological treatment outlets or combination	Anaerobic digestion	heating, power generation, fuel, and raw materials for further processing and production of sustainable chemicals including hydrogen, and carbon dioxide and biofuels	(Priebe et al., 2016)
Project Area 2: Production of chicken feed from leather solid waste	Raw trimmings, lime trimmings, protein hydrolysate derived from chrome-tanned leather solid waste	Separating protein hydrolysate and chromium, followed by protein purification	Animal feed	(Chaudhary and Pati, 2016)
Project Area 3: Production of tallow oil from leather solid waste	Discarded fleshing waste and raw trimmings, lime trimmings/splits,	Co-solvent based transesterification	For biodiesel, fat liquor	(Jambulingam et al., 2020)
Project Area 4: Production of gelatin from leather solid waste	Rejected raw hides and skins, raw trimmings, lime trimmings/splits	Swelling and extraction; Acid or alkaline hydrolysis	For cosmetics and pharmaceutical applications as binder, adhesives, gelling agent, suspending agent, etc	(Elsayed et al., 2021)
Project Area 5: Production of biopolymer from leather solid waste	Lime trimmings/splits, chrome shavings, buffing's, crust trimmings,	Hydrolysis and double cross-linking	As fertilizer, retanning and finishing agent in leather industries	(Stefan et al., 2021)

Project Area 6: Production of keratin from leather solid waste	Hair wastes, or combining with other keratinous wastes such as chicken feather etc.	Hydrolysis: Hydrothermal, Microbial, Enzymatic, Chemical methods	Drug delivery system, Hydrogel, Tissue engineering and wound healing, as retanning agent in leather industry	(Hussain et al., 2020; Sinkiewicz et al., 2017)
Project Area 7: Production of adsorbent from leather solid waste	Fleshing wastes, lime trimmings/fleshing's, raw	Chemical activation	Industrial waste water treatment, heavy metal impurities removal	(Onenc et al., 2011)
Project Area 8: Production of bio-stimulant from leather solid waste	Raw trimmings	Hydrolyzation and enrichment with P and K and Stabilization	Plant growth promoter	(Sundar, 2023; Xu and Geelen, 2018)
Project Area 9: Production of binder sot match making from leather solid waste	Raw/lime trimmings, fleshing wastes	Hydrolysis	Adhesive	(Pahlawan et al., 2019)
Project Area 10: Production of wool fat from leather solid waste	Sheep or goat wool	Scouring with chemicals, and then centrifugation	Ointment base for pharmaceutical application	(Chojnacka et al., 2021)

2. Objective

2.1. General objective

- To conduct feasibility study of transforming leather solid by-products (for all tannery solid wastes (hair/wool, raw trimming, fleshing, lime trimming, shaving, wet blue trimming, crust and finished leather trimmings, buffing dust, lime and chrome sludge) into valuable products (such as biogas, chicken feed, tallow oil, gelatin, biopolymer, keratin, adsorbent, bio-stimulant and binder sot match making, and wool fat), considering the availability of raw materials, production processes, and technology requirements, specifically in the context of Modjo and surrounding areas.

2.2. Specific Objectives

- To conduct a comprehensive feasibility study on the transformation of lesser sold waste materials into valuable products for MSMEs and Tanneries in Mojo.
- To identify the technical, economic, environmental, and social feasibility of producing the selected products from waste materials.
- To analyze the market demand and potential for the selected products in Mojo and beyond.
- To develop a business model and financial analysis for each product to determine its profitability and viability.
- To assess the environmental impact of the proposed production processes and recommend measures to mitigate any negative effects.
- To provide recommendations and an implementation plan with timelines for the establishment of a sustainable waste-to-product system in Mojo.
- To create awareness among stakeholders about the benefits of waste-to-product initiatives and promote sustainable development in the region.
- To establish partnerships and networks among MSMEs, Tanneries, and other relevant stakeholders to facilitate the establishment of a sustainable waste-to-product system in Mojo.

3. Scope

- The feasibility study is focused on the transformation of lesser sold waste materials into the following products: chicken feed, tallow oil, gelatin, biopolymer, keratin, absorbent, bio-stimulant, binder, wool fat, and biogas (as indicated in the figure below).
- The study covered the technical, economic, environmental, and social aspects of the production of the selected products.
- The study analyzed the market potential and demand for the selected products in Mojo and the surrounding region.
- The studies develop a business model and financial analysis for each product to determine its profitability and viability.

4. Methodology

4.1. Study Area

Mojo is a town in central Ethiopia, named after the nearby Modjo River. Located in the East Shewa Zone of the Oromia Region, it has a latitude and longitude of 8.65°N, 39.08333°W with an elevation between 1788 and 1825 meters above sea level.

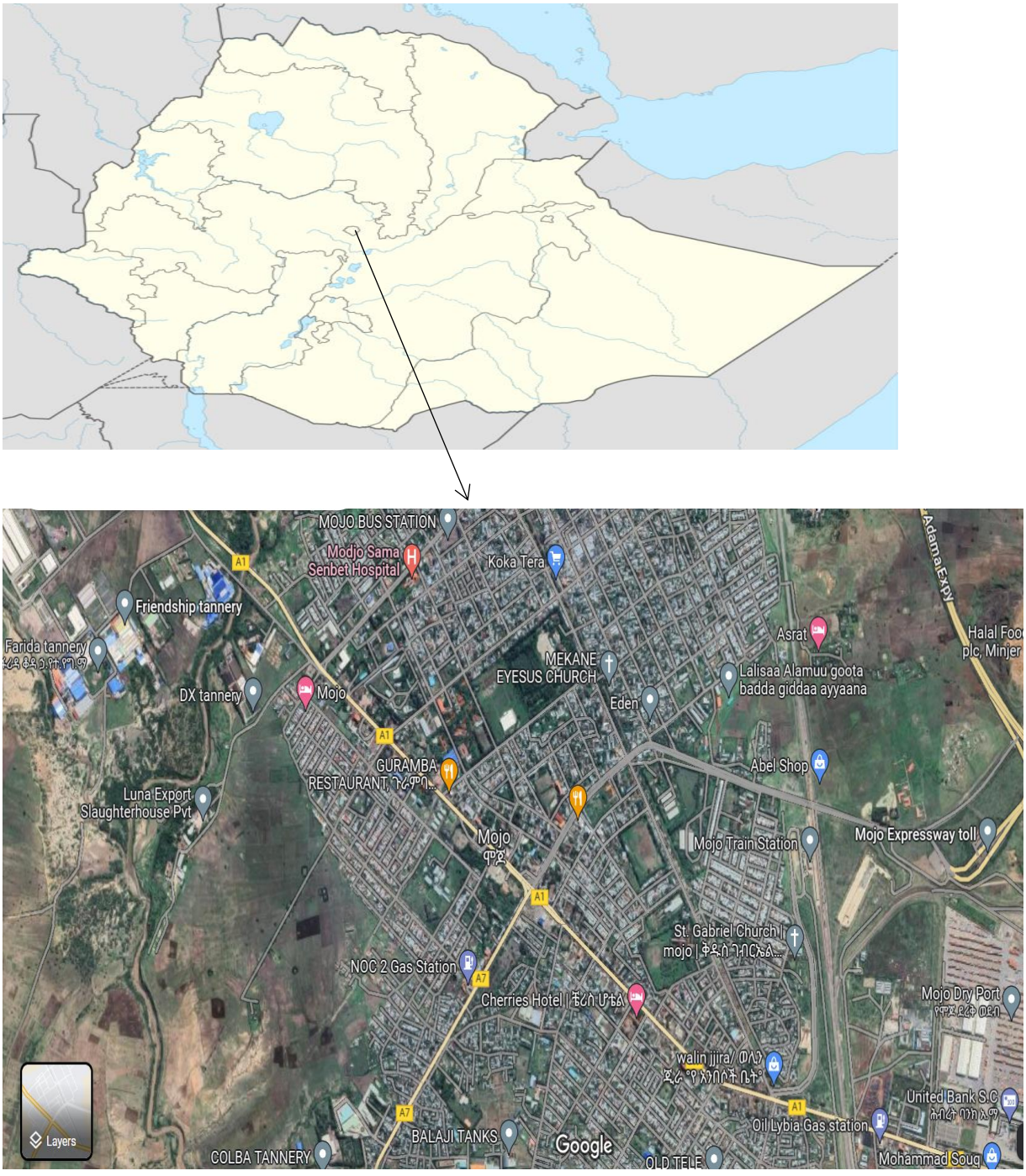

Figure 2 Map of Mojo Town

4.2.Method

The feasibility study was conducted using a range of research methods, including literature reviews, stakeholder consultations, field visits, and data analysis. The following section outlines the methodology to be used in this study:

- **Literature Reviews:** The study will involve a comprehensive review of relevant literature, including academic publications, reports, and online resources, to gather information on waste management practices, the production of the selected products, market demand, and regulatory frameworks.
- **Stakeholder Consultations**: The study will involve consultations with relevant stakeholders, including MSMEs, Tanneries, waste collectors, government agencies, and other actors involved in waste management and product production. The consultations will be conducted through interviews, surveys, and focus group discussions to gather information on the challenges and opportunities of waste-to-product initiatives.
- **Field Visits**: The study will involve field visits to waste disposal sites, MSMEs, and Tanneries to collect data on waste generation, disposal practices, and product production processes. The field visits will also provide an opportunity to observe the production processes and assess the environmental impact of the waste-to-product system.
- **Data Analysis:** The study will involve data analysis to quantify the technical, economic, and environmental feasibility of the selected products. The data analysis will include cost-benefit analysis, financial modeling, and environmental impact assessment.

The methodology will be implemented through a collaborative approach involving the project team, stakeholders, and technical experts. The study will follow ethical guidelines and protocols to ensure the confidentiality, accuracy, and reliability of the data collected. The findings of the study will be validated through peer review and feedback from stakeholders.

5. Technical Feasibility Studies for the Ten Products

5.1. Production of Chicken Feed From Tannery Solid Wastes

Chicken feed is a kind of feed prepared for poultry farm. It contains protein, minerals and other nutrients which are useful for egg production as well as survival and growth of the chicken. This feed can be prepared from lime pelt and lime split waste and it can be mixed with oil cakes, agro - residues, flour, cereals, molasses, minerals and vitamins etc. The major chicken feed consumers are large and small scale poultry organization and farmers.

Selection of the tannery waste is important for production of chicken feed and it is not recommended to use waste that contains heavy metals and other toxic chemicals which have bioaccumulation and bio-magnification potential, in this case, only pre-tanning wastes such as raw trimming, lime trimmings, and lime splitting wastes are preferable for production of chicken feed. And hence chrome containing wastes are not preferable and is excluded from the production of chicken feed.

The total hide lime pelt trimming and lime split waste generated from the tanneries around the Modjo area is 2,179,785 kg per year. Among this Xiang Zing tannery produce 837,475kg per year and is utilized for gelatin production. The balance will be 1,342,310 kg available per year and which is the total lime pelt trimming and lime split waste generated for our study.

In previous projects conducted by LIDI and Solidaridad, cow hide lime trimmings were assumed to be utilized for production of Glue and currently Solidaridad is supporting the implementation of pilot scale production in selected tanneries at Modjo. And it was estimated that 700,000Kg of waste can be generated per year. From such volume if 40% is not collected for glue production due to many reasons it is possible to get approximately 385,385kg of cow lime trimming waste per year and this can be utilized for production of chicken feed. Therefore, from these data, it can be concluded that there will not be a problem of raw material supply. In addition to that chicken feed can be produced at small scale by developing small capacity machineries and equipment's and hence the product is technically feasible to engage the MSMEs at around Modjo town that will create social cohesion with the surrounding community.

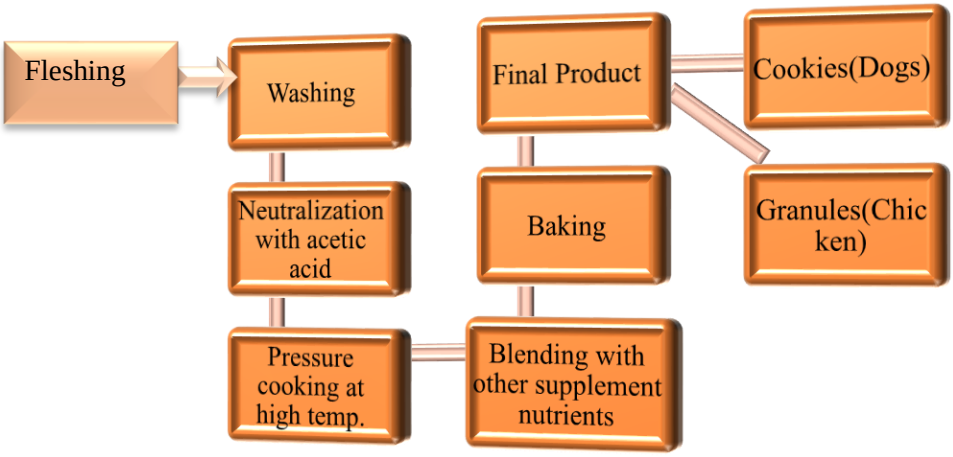

Figure 3 Flow diagram for production of chicken feed from untanned tannery solid wastes

5.2. Production of Gelatin from Leather Solid Waste

Gelatin is defined as a "product obtained from partial hydrolysis of collagen derived from natural sources such as skin, connective tissue, and bones of animals." It is an easily digestible protein that contains all the essential amino acids except tryptophan. Gelatin is NOT a chemical or chemically modified substance. Gelatin is produced by subjecting the skin, bone, and connective tissues of animals such as pigs, cattle, and very few fishes to certain production processes. The basic raw material of the gelatin planned to be produced in the facility subject to feasibility is animal bovine bones. Gelatin is a protein substance found in the tissues of mammals, in the parts binding muscles to bones, bones to each other and other organs, and skin, and is extracted from collagen, a protein. When boiled with water, collagen in the skin, bones, and connective tissues of animals (mostly cattle and pigs) turns into a water-soluble protein known as gelatin. When cooled, the solution does not turn into collagen; but it turns into a gel. Gelatin is used in many sectors due to its properties such as strong shaping ability, transparent gel forming, flexible film, easy to digest, melting in hot water and easy to shape; it is used in many areas especially in food production.

Gelatin molecules, like those of other proteins, are large and complex. Values for the average molecular weight range from 15,000 to 250,000. Gelatin is composed of about 18 different amino acid radicals which are linked together in an ordered fashion. These amino acids obtained by the complete hydrolysis of gelatin, are listed in table below. Gelatin analyses in terms of the elements 50.5% carbon; 6.8% hydrogen; 17% nitrogen and 25.2% oxygen.

The main raw material in producing Gelatin is Rawhide trimming waste. In addition to raw trimming waste hide pelt trimming and limed splits can be used as raw materials for gelatin production but these wastes are already proposed for glue production. The chemicals like lime, sulfide, wetting agent, acid, Sodium hydro sulfite, Charcoal, and others are used as essential in the gelatin production process.

The total annual cost of raw materials is estimated at Birr 2,674,000.00 by considering the 300kg of net gelatin production capacity per day. Gelatin has good market demand and it can be produced raw trimmings lime trimmings and lime splits and the tanned solid waste is not recommended for production of gelatin since gelatin is mostly applicable in food and pharmaceutical industries the raw material should not contain heavy metals and some recalcitrant chemicals which will have toxic effect to human

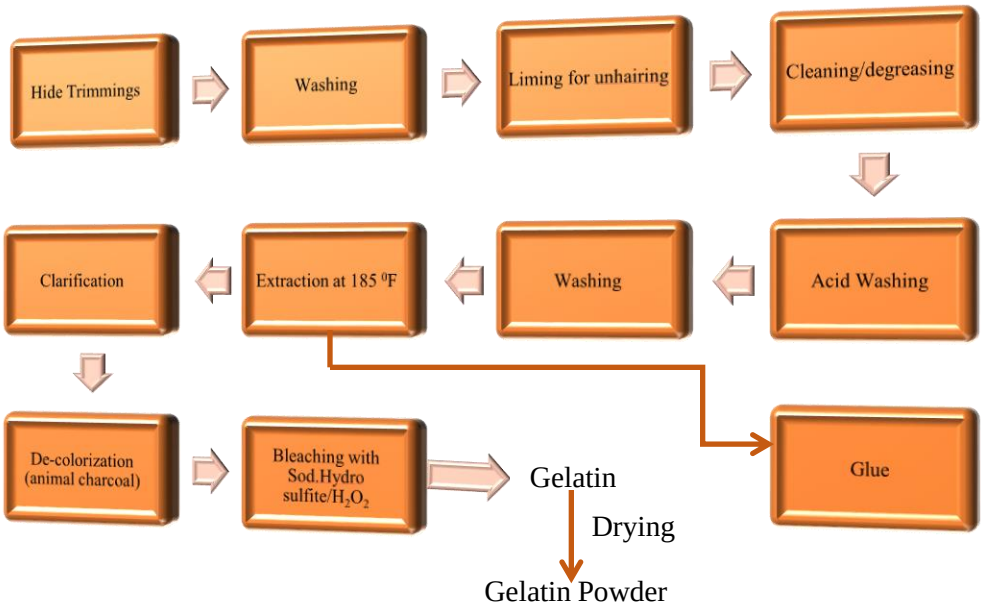

Figure 4 Process diagram for gelatin production

5.3. Production of Bio-gas from Leather Solid Waste

For production of bio gas methane generation is important and for generation of methane there should be decomposition of organic matter need to be facilitated. From all the tannery wastes, ideal waste for production of bio gas is fleshing waste since it is removed from flesh layer of the hide it contains fat mater and other organic contents. Conventionally before the fleshing operations the liming operation is usually done by use of lime and sodium sulphide and hence some amount of lime and sulphide is remained in the fleshing waste that affect the decomposition of the wastes this in turn hinders the generation of methane gas. This is the main challenges of bio-gas production from tannery solid wastes. Since the tanneries at Modjo are scattered and there is no cluster of tanneries so the amount of fleshing waste generated is not sufficient to generate sufficient amount of methane and the complete decomposition of the waste is also not easy compared with municipal wastes.

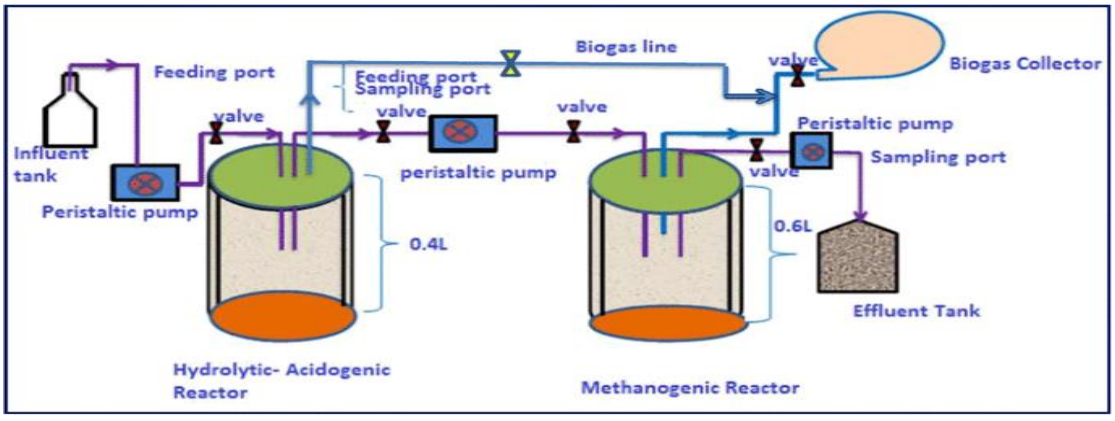

Figure 5 Flow diagram for production of bio gas from tannery wastes

The production of biogas requires a steady supply of organic waste, such as agricultural residues or food waste. However, the availability of such feedstock may be limited, making it difficult to sustain biogas production on a large scale. On the other side before the fleshing operations the liming operation is usually done by use of lime and sodium sulphide and hence some amount of lime and sulphide is remained in the fleshing waste that affect the decomposition of the wastes this in turn hinders the generation of methane gas. In addition to that the limed fleshing waste has a low C: N (3.2) and an alkaline pH of 11.4. This is a major disadvantage for anaerobic digestion due to ammonia toxicity for methanogenesis.

Regarding cost, establishing biogas production facilities requires significant capital investment, including anaerobic digesters, storage tanks, and gas purification systems. The high upfront costs make biogas projects financially challenging, particularly in regions with limited financial resources.

So, for the technical feasibility of bio-gas production there must be cluster of tanneries to get more organic wastes and the tannery waste need to be integrated with municipal wastes which have more decomposable organic matter so as to get sufficient production of methane, it requires chemical free solid waste without fulfilling these production conditions of bio-gas from tannery waste by alone is not technically feasible.

5.4. Production of Tallow Oil from Leather Solid Waste

Tallow oil is animal oil obtained by pressing tallow and used chiefly as a lubricant especially when mixed with mineral oils. Tallow oil can be applicable for production of biodiesel and fat liqour synthesis. From the wastes generated from leather industries mainly fleshing wastes contain animal fat which is the main source for tallow oil. In Ethiopia all tanneries use conventional liming operation and the type of fleshing is lime fleshing only and the there is no green fleshing (to be conducted immediately after soaking operations). Therefore, the lime fleshing waste contain organic matter (flesh layer), lime, sulphide and other trace chemicals and it is important to remove all chemicals prior to extraction of tallow oil from the fleshing waste which can be done by using mild acids and the smell of sulphide also another problem in cleaning and purification of waste. The cleaned fleshing waste contains fat and protenious matter so to extract the tallow oil it is essential to separate the fat component and protein component using thermal hydrolysis. Which incurs additional cost.

Different studies show that percentage of fat obtained from green fleshing is higher than lime fleshing suggesting that the $Ca(OH)_2$ present in limed pelt acts like a cement, reducing the effect of the thermal treatment and /or the extraction by solvent(A.F.Cunha,2020).

Tallow oil is derived from animal fats, primarily from cattle. However, the availability of such feedstock is limited and subject to market fluctuations, which can hinder consistent production of tallow oil. Based on research findings from leather industry development institute, Ethiopian hides and skins have low fat content compared with international raw materials and reported that the fat content is 3 to 13 percent which indicates that the fat is not significant and this makes Ethiopian leather have high tensile and tear strength but other countries such as Australian hides and skins have fat content of 30 to 40 percent. So this fat content is not sufficient to produce tallow oil. Due to the reasons mentioned above, the production of tallow oil from tannery fleshing waste is not technically feasible.

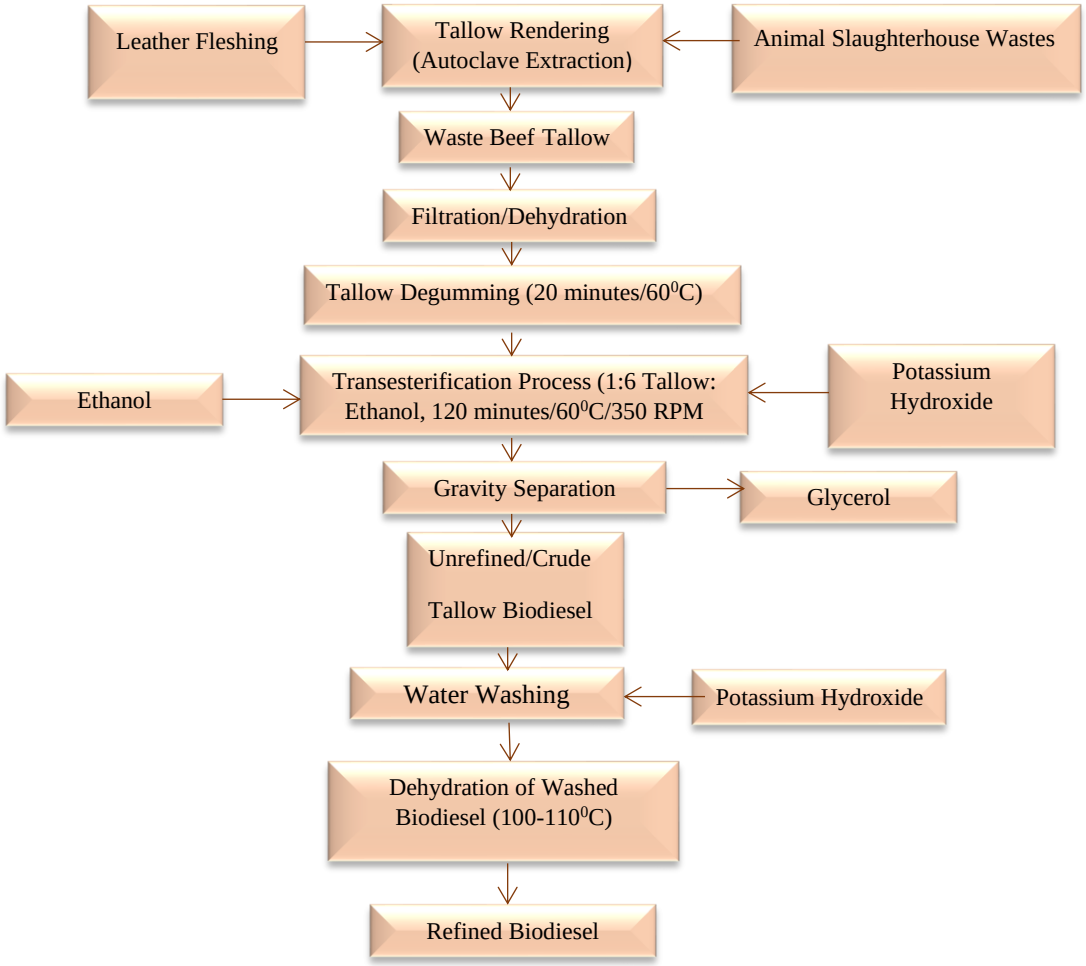

Figure 6 Process flow diagram for production of tallow oil from tannery fleshing waste

5.5. Production of Biopolymers from Leather Solid Waste

Biopolymers are polymers produced from natural sources either chemically synthesized from a biological material or entirely biosynthesized by living organisms. The use of biopolymers from different sources has been investigated for many years for pharmaceutical and biomedical applications. Studies show that tannery waste from leather processing can be valorized to tailor made collagen biopolymers with diverse shapes (fibers, films and sponges) the obtained biopolymers have been conveniently modified using various methodologies including crosslinking with various compounds with the aim of generating waste driven renewable biopolymers with enhanced properties which can have important and promising applications in the field of cosmetics, medicine or veterinary. For application of tannery waste for biopolymer production, the waste needed to be free from any chemicals which might have adverse effect on human health.

Most of the collagen based bio polymers are applicable in food, pharmaceutical and cosmetic industries, tannery wastes are not recommended because the wastes are chemically contaminated. On the other hand even if biopolymers offer the advantage of being derived from renewable resources, their production faces technical challenges. These include scalability issues, limited mechanical properties compared to conventional plastics, and high production costs due to the complexity of the manufacturing processes. The market for biopolymers is currently dominated by petroleum-based plastics, which are more cost-effective and offer superior performance characteristics. As a result, the demand for biopolymers is relatively low, limiting their economic feasibility. In Ethiopian context based on the main objective of the project, production of biopolymer from tannery waste is not technically feasible.

5.6. Production of Keratin from Tannery Hair Waste

Keratin, a protein found in animal hair and feathers, has limited commercial applications. One of the major wastes from tannery is hair waste generated during the liming operations. Tannery hair wastes are obtained as a byproduct from the tanneries during hair shaving paint un-hairing process and it is estimated that about 5% of dry hair is recovered based on rawhide weight. Tannery sheep hair waste shares 20-30% based on the wet salted weight of sheepskin depending on the breed types and climatic conditions. Studies show that keratin can be produced from tannery hair waste for different applications. But still, most of the tanneries are following a hair-burning type of unhairing which destroys the hair completely and contribute to high COD, BOD, TDS, etc. loads in the effluent.

Keratin has potential uses in cosmetics, wound dressings, and biomedical materials, its widespread implementation faces challenges due to its limited versatility and high production costs. In Ethiopia Leather manufacturing industries, obtaining keratin in large quantities is difficult due to the tanneries bad practice of hair burning system which dissolves the hair in the liming drum itself this makes collection of hair difficult and hair is dissolved with the lime liquor and discharged to effluent treatment plant.

Ethiopian tanneries cannot meet environmental discharge parameters such as COD, BOD and TDS and also cannot produce valuable products from hair waste if life as usual way of hair burning method of liming techniques continues. To mitigate the adverse environmental effect due to hair waste it is recommended for tanneries to implement hair saving way of lime sulphide unhairing practices or enzyme assisted hair saving methods.

5.7. Production of Wool Fat from Leather Solid Waste

The hair waste generated from tannery contains wool fat and keratin mainly. Wool fat or wool grease is a wax secreted by the sebaceous glands of wool-bearing animals a yellow viscous animal oil extracted from wool; a mixture of fatty acids and esters; used in some ointments and cosmetics.

The demand for wool as a textile material has declined in recent years due to the availability of more affordable synthetic alternatives. The limited market demand and competition from synthetic fibers make large-scale wool production economically unfeasible.

By similar reason mentioned in the case of keratin production from hair waste due to tanneries hair burning techniques hair will be completely dissolved in the drum itself so that production of wool

fat from hair waste cannot be technically feasible. If the practice is changed it might be feasible based on the amount of wool fat contained as per the weight of the hair waste.

5.8. Production of Adsorbent from Leather Fleshing Waste

Tannery fleshing waste can be utilized for adsorption of effluents containing dyes and heavy metals such as chrome. And different studies have been conducted that pre tanning wastes such as fleshing wastes can be utilized for preparation of activated carbon with high adsorption capacity due to its high surface area to volume ratio.

Since there is no proper solid waste management practice in Ethiopia, removal of toxic wastes using adsorption technique is not technically feasible because at the end of the day all the wastes are dumped at open disposing area. For example in the case of tanning industry fleshing wastes, chrome containing wastes, raw/wet blue/crust/finished leather trimmings all are dumped on open solid waste disposing site therefore proper design and construction of secure land fill is critical for management of leftover wastes after conducting different treatment techniques.

Tanneries are scattered transportation of the fleshing waste from tanneries is very difficult due to the nature of wastes containing more than 80% of the moisture.

Adsorbents, used for removing pollutants from air or water, often have limited efficiency and selectivity. Developing adsorbents that can effectively capture specific pollutants without interference from other compounds is a significant technical challenge, rendering them unfeasible for certain applications.
Implementing adsorbent-based systems can be costly, requiring regular maintenance and replacement of the adsorbent materials. The associated expenses and logistical considerations make adsorbents less viable compared to alternative pollution control methods.

In addition to that the amount of fleshing waste generated per year from all tanneries at modjo is estimated to be 2.5 million kg per year. And the solid content will be 10% that means 250000kg per annum will be the solid content per annum and if we consider total working day of 180days, the amount of waste available for adsorbent production will be 1388kg which is insignificant at large scale.

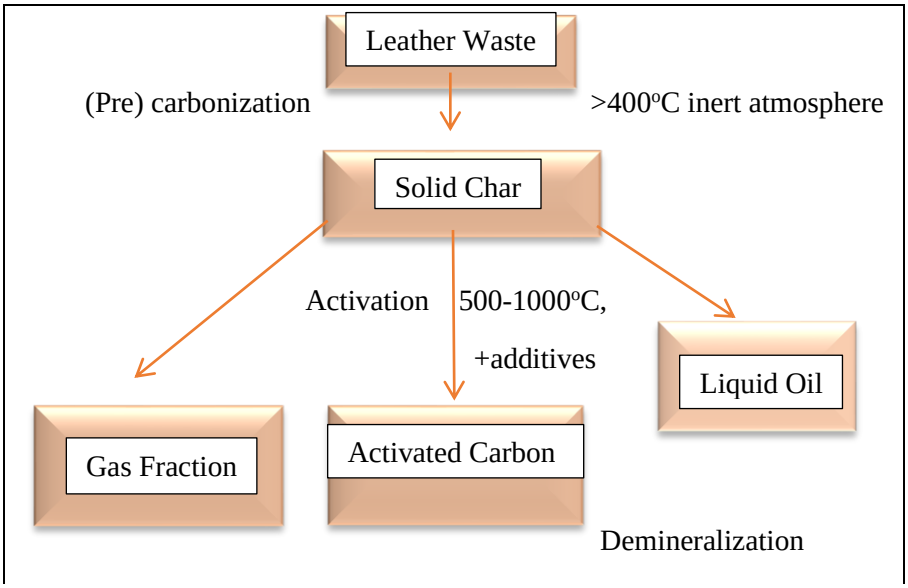

Figure 7 Process flow diagram for production of adsorbent from tannery fleshing waste

5.9. Production of Bio-Stimulant from Tannery Solid Waste

In modern agriculture, seeking eco-friendly ways to promote plant growth and enhance crop productivity is of priority. Bio stimulants are a group of substances from natural origin that contribute to boosting plant yield and nutrient uptake, while reducing the dependency on chemical fertilizers. The criteria to select designated by-products for valorizing as bio-stimulant are: absence of pesticide residue, high organic content, low cost of collection and storage, sufficient supply and synergy with other valorization paths. Except the green fleshing wastes other tannery wastes cannot be directly utilized for preparation of bio stimulants because they contain impurities and need further treatments.

Since the tanneries are scattered, transportation of the fleshing waste from tanneries is very difficult due to the nature of wastes containing more than 80% of the moisture. Additionally, implementing adsorbent-based systems can be costly, requiring regular maintenance and replacement of the adsorbent materials. The associated expenses and logistical considerations make adsorbents less viable compared to alternative pollution control methods.
The efficacy of bio-stimulants and binders in enhancing plant growth or improving soil properties varies greatly depending on environmental factors and specific plant species. Their inconsistent performance limits their reliability, making them unfeasible for widespread agricultural applications. The product face stiff competition from conventional agricultural practices and chemical fertilizers, which are often more cost-effective and deliver predictable results. Their higher costs and uncertain benefits make them less attractive to farmers.

Therefore, in the case of Ethiopian leather industry, production of bio stimulant is not technically feasible due to the absence of chemical free wastes to be utilized directly and cost of transportation of wastes from different tanneries for further treatment since the tanneries are not in the form of cluster to get sufficient organic wastes for further treatments.

5.10. Production of Binder Sot Match Making from Leather Solid Waste

Production of glue from lime trimming has been technically proved by leather and leather products industry research and development center and Solidaridad has been involved on the feasibility study and transfer of the technology is going on to the selected industries. Therefore, the production of binder sot for match making is just production of bio based adhesives for binding and it is very similar with the organic glue developed so far and conducting the feasibility study for binder is just duplication of effort and there is no separate product for the specified purpose so the glue developed can be directly utilized.

Table 2 Recommendations and mitigation mechanism for unfeasible projects

s/no	Name of projects	Comparison of projects viability status					Overall feasibility of projects	Further Recommendations/mitigation strategies
		Technical	financial	economic	Social	environmental		
1	production of gelatin from Leather Solid Waste							only pre tanning wastes need to be utilized and chrome containing wastes must be avoided because complete removal of chromium is not possible. since the gelatin produced is industrial grade it is most recommended for industrial application.
2	production of chicken feed from tannery solid wastes							To avoid chemical and microbial contamination, the wastes need to be Free from chrome containing solid and liquid wastes and the chicken production unit must be isolated and decontaminated
3	Biogas production from fleshing waste							The optimum conditions were found by blending the waste with municipal waste that provided C: N of 15 and pH of 6.5 and the cumulative biogas yield increased from 560 mL using LF fraction alone, to 6518 mL with optimum blend. Therefore production of biogas will be feasible if we integrate the fleshing waste with different wastes having high carbon content

4	Keratin production from hair waste							conventionally almost all Ethiopian tanneries are hair destructive way of un-haring system that dissolves the hair and it makes collection of hair difficult so to get sufficient amount of hair for extraction of keratin it is recommended to follow cleaner production options such as hair saving, enzyme assisted hair saving methods and installing hair filtration system on liming drum that allows for easy of collection of more hair wastes.
5	Production of wool fat from hair waste							since wool fat is obtained from the hair recommendations given for keratin production holds true
6	Production of bio stimulant from tannery solid waste						NF	It is recommended to use tannery wastes that do not contain chromium and other heavy metals. In different countries fleshing wastes are utilized by blending them with other ingredients that have chemical ingredients of potassium and phosphorus. In some literature plant growth promoters have been developed by blending fleshing wastes with plant leaves, china clay and sand in order to increase the yield and its stability. Since the three are major plant growth promotors including nitrogen which will be obtained from fleshing waste. Therefore for the production of bio stimulant to be feasible, there should be use of another wastes to blend and further characterization of product need to be conducted at research level to see whether it is commercially viable or not.

7	Production of binder sot for match making from tannery solid wastes							Feasibility study has been conducted and approved for production of glue lime trimmings so the production of binder sot is just similar with production of organic glue. The difference is just on purpose of application. Therefore, it is possible to directly utilize the previous studies done by another consultant.
8	Production of adsorbent from fleshing wastes							Further studies need to be conducted to see the commercial viability of tannery solid waste for each type of wastes generated along the unit operations. Integrating the wastes with those wastes that have more carbon content such as agricultural wastes is recommended to maximize the yield as well as to optimize the cost of production.
9	Production of tallow oil from fleshing waste							since the amount of fat content for Ethiopian hide and skin is very less approx. 3-5% so the fat extraction yield is very so tallow production is not feasible at all

In the above table feasibility of projects have evaluated with respect to various dimensions of feasibility such as technical, environmental, financial, social and economic aspects and the overall feasibility of each product is indicated with different colors such as green, yellow and red colors. Those products that have indicated with **green colors** are considered as feasible. For technical details the project feasibility evaluating factors such as IRR, payback period are indicated for chicken feed production plant and for gelatin production plant.

Those projects where the overall feasibilities are indicating with yellow color can be feasible if there will be some process modification in tanneries towards waste management by using different cleaner production options. For example, for production of keratin and wool fat if the conventional lime sulphide unhairing system which is hair burning method is replaced by hair saving techniques as well as low sulphide enzyme assisted liming unharing techniques, the amount of hair to be collected will be sufficient and free of contamination. So the projects will be feasible if there is just slight process optimization. In addition to that the production of binder sot for match making

is just similar to production of glue for binding purpose so it is just assessing the market demand for such product. Since the production of glue is feasible from the study conducted by solidaridad and LLPIRDC during the first round.

Overall Feasibility of Projects such as Biogas production from fleshing waste, production of bio-stimulant from fleshing waste, production of adsorbent from fleshing waste and production of tallow oil from fleshing waste are evaluated with respect to various dimension of feasibility such as technical, financial, environmental, social and economic aspect and the projects cannot be feasible at the moment and overall feasibility for all the four projects indicated with '**Red' color** . that means the projects cannot be feasible by utilizing only the tannery wastes since the respective yield for each product is very low as well as the environmental performance of all tanneries in handling fleshing waste is very poor and this waste is usually mixed with other wastes containing heavy metals such as chrome. Due to this handling as well as segregation and cleaning practice of the fleshing waste is very poor.

6. Feasible Projects

In general, from the above ten products production of chicken feed from raw trimming wastes and production of gelatin from lime trimmings and splitting wastes are technically feasible so that the detail financial, economic and environmental feasibility for the two products are presented as follows

6.1. Project 1: Production of Chicken Feed from Leather Solid Waste

Leather waste is a significant environmental concern in the leather industry. Traditional manufacturing processes result in the production of bad smells, organic and inorganic waste, and high water consumption. Despite the potential for being an environmentally friendly industry by utilizing waste products from meat production, the leather industry has often been perceived as polluting.

From every tons of raw hides, approximately 240 kg of leather, up to 600 kg of solid waste (such as shaving, trimming, fleshing, and dust), and about 20,000 liters of liquid effluents are produced. Wastewater, specifically, is a major contributor to pollution, followed by solid wastes and by-products generated throughout the various production steps.

For the sustainability of leather industry, recently the concept of circular economy which is a strategy towards optimum utilization of resource and recaptures wastes as a resource to produce new products has been initiated and successfully practiced in tanneries across the globe.

Despite the environmental challenges associated with leather waste, there are promising opportunities for its sustainable utilization. One such opportunity lies in the production of chicken feed. The increasing trend of intensification in poultry production in Ethiopia has created a growing demand for chicken feeds. This demand, coupled with the marked increase in consumer demand for chicken products, presents an attractive investment opportunity.

Chicken feed, essential for poultry farms, contains protein, minerals, and other vital nutrients that support egg production, as well as the growth and survival of chickens. Utilizing leather waste in the production of chicken feed can be an innovative solution to mitigate environmental pollution while meeting the rising demand for quality feed.

However, it is crucial to select tannery waste that does not contain heavy metals or toxic chemicals with bioaccumulation potential. Waste materials such as raw trimming, lime trimmings, and lime splitting wastes are preferable for chicken feed production, while chrome-containing wastes should be excluded due to their potential harmful effects.

Investment incentives, including duty-free feed machinery and necessary equipment, land availability, free consultancy and training, investment facilitation, market promotion services, and access to credit through lease financing, are offered to attract potential investors in the chicken feed production industry.

To establish a successful chicken feed production plant, a suitable location is essential. Modjo Industrial area, in proximity to the majority of tanneries, provides convenient access to raw materials. Additionally, the area offers necessary infrastructure such as roads, electricity, telecommunications, and water supply. By utilizing tannery waste in a sustainable manner, investors can contribute to a greener and more efficient production process while tapping into a lucrative market.

6.1.1. Current Scenario

Ethiopia has 18 operational tanneries, with most of them located around Mojo town. These tanneries have the capacity to produce 2.5 million pieces of hides and 35.3 million pieces of skins annually. Ethiopia also has a substantial livestock population, including cattle, sheep, goats, horses, and camels. Leather processing produces significant amounts of liquid and solid waste, with wastewater being the primary source of pollution. Approximately 240 kg of leather, 600 kg of solid wastes (shaving, trimming, fleshing, and dust), and about 20,000 liters of liquid effluents are generated from one tonne of raw hides.

6.1.2. Investment Opportunities

There are several investment opportunities in the production of chicken feed from leather solid waste in Ethiopia, including:

1. High livestock population and diverse agro-ecologies.
2. Increasing trend of intensification of poultry production, leading to higher demand for chicken feeds.
3. Growing commercial orientation of poultry production in Ethiopia.
4. Price increment of chicken feed over time.
5. Prospects of increased consumer demand for chicken products.

Incentives:

Investors in the chicken feed production industry can benefit from various incentives, including:

1. Duty-free feed machinery and necessary equipment.
2. Land availability.
3. Free consultancy, training, investment facilitation, market promotion services, and credit access through lease financing.

6.1.3. Product Description and Application

Chicken feed is a specially formulated feed designed for poultry farms. It contains protein, minerals, and other essential nutrients required for egg production, as well as the growth and survival of chickens. Chicken feed can be prepared by utilizing lime pelt and lime split waste and mixing them with oil cakes, agro-residues, flour, cereals, molasses, minerals, and vitamins. The main consumers of chicken feed are large and small-scale poultry organizations and farmers. It is crucial to select tannery waste that does not contain heavy metals or toxic chemicals with bioaccumulation potential. Pre-tanning waste such as raw trimming, lime trimmings, and lime splitting wastes are suitable for chicken feed production, while chrome-containing waste is excluded.

6.1.4. Project Location

The proposed location for the chicken feed production plant is Modjo Industrial area, near the majority of tanneries. This proximity ensures a sufficient supply of raw materials from the tanneries. Modjo Industrial area offers suitable infrastructure, including road access, electricity, telecommunications, and water supply.

6.1.5. Land Requirement and Building Construction

For the integrated production facilities, an estimated land area of 2,000m² is required, which can be obtained through an 80-year lease with a payment period of 40 years. The land cost is approximately 520,000.00 ETB. Out of the total land area, 1,000m² will be utilized for building construction. The estimated cost for building and civil works is around Birr 3.5 million, considering a rate of Birr 3,500 per m².

6.1.6. Machinery Requirement and Cost

To ensure the appropriate production purpose, the project requires carefully selected machinery. This machinery can be purchased from local and international suppliers but in this feasibility study the global price of machines is considered to calculate the cost production. Factors such as durability, suitability, price, availability of spare parts, energy efficiency, advanced technology, and supplier experience should be considered during the selection process. The production of chicken feed from leather solid waste in Ethiopia presents a significant opportunity for investment, given the country's large livestock population, increasing poultry production, and growing demand for chicken products. Proper utilization of tannery waste can help mitigate pollution and promote sustainable practices within the leather industry. With the right incentives, suitable project location, and necessary infrastructure, investors can contribute to the development of the chicken feed production sector while benefiting from the market demand and favorable business environment.

The total cost of machineries is estimated to be 8,610,000.00 **ETB**

Table 3 Total cost of machineries

Machineries	**set**	**quantity**	**Single Price USD**	**Total Price USD**	**Total Price ETB**
Tank and silo for raw and auxiliary material	set	1	21000	21000	1,050,000.00
Metal screen and shaker	set	1	21000	21000	1,134,000.00
Extractor	set	1	19000	19000	1,026,000.00
Mixer	set	1	21000	21000	1,134,000.00
Hammer mill (crusher)	set	1	23000	23000	1,242,000.00
Bagging machine	set	1	23000	23000	1,242,000.00
Product tan	set	1	15000	15000	810,000.00
Other accessories	set	1	18000	18000	972,000.00
Total					8,610,000.00

6.1.7. Equipment and Tools Requirement

The cost of equipment and tools required for the chicken feed production was obtained from the local market and from the quotation of the alibaba.com site. The total cost of the equipment and tools is **1,957,400.00 ETB**

Table 4 Equipment and Tools Requirement

S.No	Name of equipment or tools	Quantity	unit cost (USD)	Total cost (USD)	total cost (ETB)
1	Hand Cart	1	50.00	50.00	2,700.00
2	Hydraulic Trolley	1	500.00	500.00	27,000.00
3	Knifes	5	10.00	50.00	2,700.00
4	weighing machine	1	2,000.00	2,000.00	110,000.00
5	digital balance weighing	1	1,000.00	1,000.00	55,000.00
6	Isuzu car for RM transportation	1	32,000.00	32,000.00	1,760,000.00
	Total		**35,560.00**	**35,600.00**	**1,957,400.00**

For this study cow pelt trimming is one of the raw materials in producing chicken feed. Chemicals like acetic acid are very important for the extraction of chicken feed from pelt-trimming waste.

The total annual cost of raw materials is estimated at Birr **2,118,462.50** by considering the 650kg of net chicken feed production capacity per day.

Table 5 Annual raw material requirement for the production of the specified quantity of product

Type of Raw Materials	Unit price ETB/kg	Qty kg/day	Qty kg/yr	Total cost ETB /day	Total ETB cost/year
Pelt trimming and split waste	2.5	1300	385,385	3,250.00	963,462.50
Deliming agent	85	32	7,000	2,720.00	595,000.00
Acetic acide	80	20	7,000	1,600.00	560,000.00
TOTAL			**399,385**	**7,570.00**	**2,118,462.50**

6.1.8. Chicken Feed Production Formulas:

The chicken feed production formula for day-old chicks to 22 days of age includes a mixture of lime pelt and lime split waste (30%), oil cakes (20%), agro-residues (20%), flour (15%), cereals (10%), and minerals/vitamins (5%). The waste materials are collected from tanneries, ground into fine particles, and blended with other ingredients to create a nutritious feed for young chickens.

For chickens older than 22 days and egg-laying chickens, the formula includes pre-tanning waste materials (40%), oil cakes (15%), agro-residues (10%), flour (10%), cereals (10%), molasses (10%), and minerals/vitamins (5%). The pre-tanning waste is ground and mixed with other ingredients to produce a feed suitable for older chickens and those that are laying eggs.

It is important to ensure that the feed is of high quality, free from contaminants, and meets the specific nutritional needs of each age group or type of chicken. Regular testing and monitoring should be conducted to maintain the nutritional balance and safety of the feed. Detail formulation for chicken feed production with respect to their age is indicated in table as follows

Table 6 Detail formulation for chicken feed production with respect to their age

s/no	Ingredients	Mixing Proportion (in %) for egg laying chickens(<=22days)	Mixing Proportion (in %) for older egg laying chickens(>22days)
1	Raw trimming, Lime pelt and lime split waste from tanneries (pre-tanning waste only)	30	40
2	Oil cakes	20	15
3	Agro-residues	20	10
4	Flour	15	10
5	Cereals	10	10
6	Molasses	0	10
7	Minerals and vitamins	5	5

The ingredients for chicken feed preparation are properly mixed as per the formulation indicated in the above table and grinded to have uniform size.

6.1.9. Production Capacity

The proposed chicken feed production plant has a specific plant capacity of 1300kg/day by considering that 20% is converted into chicken feed from the selected tannery wastes. Therefore, to produce 1300kg/day of chicken feed 6500kg of waste is required per day. Generally, it is estimated that from one tone of waste 200kg of chicken feed can be produced that means about 20% is converted into chicken feed.

The total amount of hide lime pelt trimming and lime split waste generated from the tanneries in the Modjo area is approximately 2,179,785 kg per year. In addition to that huge amount of raw trimmings and low quality raw hides and skins can be generated and utilized for chicken feed production.

Therefore, based on this data, it can be concluded that there will not be a shortage of raw materials for the production of chicken feed. By using the available raw material, it is possible to produce bulk quantity of chicken feed based on the market demand.

The production program is based on the plant operating for 8 hours per shift, one shift per day, and operating for 280 days per year.

6.1.10. Production Program

The planned daily production capacity of chicken feed is 1300kg/day by assuming the plant is performing at its maximum capacity. But it is ideal for a given plant to use its maximum capacity at the beginning of the production. Therefore, the following assumptions have been made regarding the production capacity utilization rate and the corresponding daily production of chicken feed in kilograms.

Table 7 Production Program and Capacity Utilization Rate:

Item	**Year**				
	1	2	3	4	5
Capacity Utilization Rate, (%)	50	60	75	85	90
Production, of chicken feed kg/day	650	780	975	1105	1170

According to the table, in the first year, the plant is expected to operate at a capacity utilization rate of 50% and produce approximately 650 kg of chicken feed per day. As the plant progresses into subsequent years, the capacity utilization rate increases gradually, reaching 90% by the fifth year. Consequently, the daily production of chicken feed also increases, with an estimated output of around 1170 kg per day in the fifth year.

These projections provide an overview of the anticipated production levels and capacity utilization rates for the chicken feed production plant over the next five years. However, it is important to note that these figures are subject to change based on various factors such as market demand, operational efficiency, and any potential adjustments in production strategies. Regular monitoring and evaluation will be necessary to ensure optimal production performance

6.1.11. Human Requirement

The project will generate direct and indirect employment opportunities for creative youth and females local societies. This labor force is managed in modern management with defined organization structure and management. An organizational structure consists of activities such as task allocation, coordination and supervision, which are directed towards the achievement of organizational aims.

At the beginning of its operation 22 employees will be required to meet the demands of the projected market over the next five years in the areas of both direct production areas and supporting staff.

6.1.12. Financial feasibility

The financial feasibility analysis is an essential aspect of evaluating the viability and profitability of a business venture, in this case, the production of chicken feed from leather solid waste. It involves a comprehensive assessment of the project's financial aspects, including costs, revenues, cash flows, and potential returns on investment.

In the context of the chicken feed production plant, the financial feasibility analysis aims to determine whether the project is financially viable and can generate sustainable profits over time. It involves evaluating various factors, such as capital investment requirements, operating costs, pricing strategy, revenue projections, and potential risks.

Key components of the financial feasibility analysis include:

1. **Capital Investment:** Assessing the initial investment required to establish the plant, including costs for land, buildings, machinery, equipment, and other essential assets.
2. **Operating Costs:** Identifying and estimating the ongoing expenses associated with the production process, including raw materials, labor, utilities, maintenance, marketing, and administrative expenses.
3. **Revenue Projections:** Estimating the potential sales revenue based on market demand, pricing strategy, production capacity, and projected sales volumes.
4. **Cash Flow Analysis:** Evaluating the inflows and outflows of cash throughout the project's life cycle to determine the project's financial sustainability, liquidity, and potential for reinvestment.
5. **Profitability Analysis:** Assessing the project's profitability by analyzing key financial indicators such as gross profit margin, net profit margin, return on investment (ROI), payback period, and break-even point.
6. **Risk Assessment:** Identifying and evaluating potential risks and uncertainties that may impact the project's financial performance, including market volatility, regulatory changes, raw material price fluctuations, and competitive factors.

By conducting a thorough financial feasibility analysis, stakeholders can gain insights into the project's financial viability, potential profitability, and the overall feasibility of investing in the chicken feed production plant. This analysis serves as a crucial tool for decision-making, helping to determine the project's viability, attract investors, secure financing, and develop an effective financial plan for the venture's success.

Financial Analysis and Revenue Calculation:

Based on the provided information, we can conduct a financial analysis and calculate the revenue for each year, considering a 1 kg price of chicken feed at 45 ETB for the first year, with an estimated 10% price increment over five years. The production program and capacity utilization rates are as follows:

Capacity Utilization Rate: Year 1: 50% (650 kg/day) Year 2: 60% (780 kg/day) Year 3: 75% (975 kg/day) Year 4: 85% (1105 kg/day) Year 5: 90% (1170 kg/day)

To calculate the revenue, we multiply the daily production capacity by the price per kilogram and then multiply by the number of working days in a year (280 days).

Year 1: Revenue = (650 kg/day) * (45 ETB/kg) * (280 days) = 8,190,000 ETB

Year 2: Revenue = (780 kg/day) * (45 ETB/kg * 1.1) * (280 days) = 10,315,200 ETB

Year 3: Revenue = (975 kg/day) * (45 ETB/kg * 1.1^2) * (280 days) = 12,894,840 ETB

Year 4: Revenue = (1105 kg/day) * (45 ETB/kg * 1.1^3) * (280 days) = 14,575,656 ETB

Year 5: Revenue = (1170 kg/day) * (45 ETB/kg * 1.1^4) * (280 days) = 15,431,064 ETB

Please note that the price increment of 10% per year has been applied to calculate the revenue for each subsequent year. The total expenses for the project are 14,303,862.50 ETB, with a significant portion of 8,610,000.00 ETB occurring in the first year.

It's important to consider other factors such as operating costs, overhead expenses, and market fluctuations when conducting a comprehensive financial analysis. These figures provide an estimate of the revenue potential based on the given parameters, but it's advised to perform a more detailed analysis to accurately assess the financial viability of the project

To analyze the financial aspects of the chicken feed production plant, we will calculate the revenue for each year based on the given production program and capacity utilization rates. The price of 1 kg of chicken feed is 45 ETB for the first year, with an estimated price increment of 10% over the five-year period.

Capacity Utilization Rate: The plant's capacity utilization rate is initially set at 50% of 1300 kg/day and gradually increases over the years as follows:

Profit calculation

Based on the provided information, here is the table showing the production capacity rate, revenue, expense, and profit for each year, deducting the one-time machinery cost of 8,610,000 ETB from the total expenses of 14,303,862.50 ETB starting from year 2 to year 5:

Table 8 Production capacity rate, revenue, expense, and profit for each year

Year	Capacity Utilization Rate	Revenue	Expense	Profit
1	50%	8,190,000 ETB	14,303,862.50 ETB	-6,113,862.50 ETB
2	60%	10,315,200 ETB	5,693,862.50 ETB	4,621,337.50 ETB
3	75%	12,894,840 ETB	5,693,862.50 ETB	7,200,977.50 ETB
4	85%	14,575,656 ETB	5,693,862.50 ETB	8,881,793.50 ETB
5	90%	15,431,064 ETB	5,693,862.50 ETB	9,737,201.50 ETB

Please note that the profit has been calculated by deducting the expense from the revenue for each year. The one-time machinery cost of 8,610,000 ETB has been excluded from the expense starting from year 2 to year 5

ROI and Payback period

To calculate the Return on Investment (ROI) and Payback Period, we need to consider the total initial investment and the cash flows generated by the project. In this case, the total initial investment is 14,303,862.50 ETB.

To calculate the Payback Period, we determine the time it takes for the initial investment to be recovered from the project's cash flows.

To calculate ROI, we divide the profit generated by the project by the initial investment and express it as a percentage.

Assuming the profit is the positive cash flows generated by the project (excluding the initial investment):

Payback Period: Year 2: Initial investment - Year 2 profit = 14,303,862.50 ETB - 4,621,337.50 ETB = 9,682,525.00 ETB remaining Year 3: Remaining amount - Year 3 profit = 9,682,525.00 ETB - 7,200,977.50 ETB = 2,481,547.50 ETB remaining Year 4: Remaining amount - Year 4 profit = 2,481,547.50 ETB - 8,881,793.50 ETB = -6,400,246.00 ETB remaining

The Payback Period is between Year 3 and Year 4, as the remaining amount becomes negative. Therefore, the Payback Period is around 3 years.

ROI: Profit over 5 years: 4,621,337.50 ETB + 7,200,977.50 ETB + 8,881,793.50 ETB + 9,737,201.50 ETB = 30,441,310.00 ETB

ROI = (Profit / Initial Investment) * 100 ROI = (30,441,310.00 ETB / 14,303,862.50 ETB) * 100 ≈ 213.01%

The Return on Investment (ROI) is approximately 213.01%.

Please note that these calculations are based on the provided information and assumptions. Additional factors and financial considerations may need to be taken into account for a comprehensive analysis of the project's financial performance.

6.1.13. Market Analysis

This market feasibility report provides an overview of the chicken feed market in Ethiopia. The report aims to assess the potential for establishing a chicken feed production business in the country.

Ethiopia has witnessed a significant increase in poultry production, driven by factors such as population growth, urbanization, rising disposable incomes, and changing dietary preferences. As a result, there is a growing demand for high-quality and nutritious chicken feed to support the expanding poultry industry.

The market feasibility analysis will evaluate the current market trends, growth drivers, competitive landscape, and customer demand for chicken feed. It will also consider factors such as market size, pricing strategies, distribution channels, and regulatory environment.

By understanding the market dynamics and assessing the viability of the chicken feed production business, this report aims to provide valuable insights for potential investors or entrepreneurs looking to enter the market. It will help them make informed decisions regarding investment, production capacity, pricing, marketing strategies, and risk mitigation.

The findings of this market feasibility analysis will guide stakeholders in identifying market opportunities, understanding customer needs, and developing a competitive edge in the chicken feed industry in Ethiopia.

Please note that this is a brief introduction to the market feasibility report for the chicken feed market in Ethiopia. A comprehensive analysis would delve deeper into the various aspects of the market, providing detailed insights and recommendations for potential investors or entrepreneurs.

The chicken feed market in Ethiopia is experiencing significant growth and presents a promising opportunity for investors. This section provides an overview of the current trends, growth drivers, and market size in the chicken feed industry.

1. **Current Trends:** The poultry industry in Ethiopia is witnessing an intensification of production, with a shift towards commercial orientation. This trend is driven by factors such as increasing urbanization, rising disposable incomes, and changing dietary preferences. As a result, the demand for chicken products, including eggs and meat, is on the rise. This creates a corresponding need for high-quality and nutritious chicken feed.
2. **Growth Drivers:** Several factors are driving the growth of the chicken feed market in Ethiopia:
    - Population Growth: Ethiopia has a growing population, which translates into a larger consumer base and increased demand for poultry products.
    - Urbanization: As more people migrate to urban areas, the demand for processed and convenient food, including chicken products, is increasing.
    - Rising Disposable Incomes: With improving economic conditions, consumers have more purchasing power, leading to increased consumption of protein-rich foods like chicken.
    - Health Consciousness: Consumers are becoming more health-conscious and are seeking out poultry products as a source of lean protein. This drives the demand for chicken feed that ensures healthy and high-quality poultry production.
3. **Market Size:** The chicken feed market in Ethiopia is sizable and has significant potential for further growth. With the country's large livestock population, including millions of cattle, sheep, and goats, there is a continuous demand for poultry feed to support the growing poultry industry. Additionally, the commercialization of poultry production and the increasing number of large and small-scale poultry organizations contribute to the expanding market size.
4. **Commercial Orientation of Poultry Production**: Ethiopia is witnessing a shift from traditional, subsistence-based poultry farming to a more commercial-oriented approach. Poultry producers are adopting modern techniques, improved breeds, and better management practices to enhance productivity and meet the rising demand. This commercial orientation emphasizes the importance of high-quality chicken feed to achieve optimal growth, health, and egg production.

The chicken feed market in Ethiopia is experiencing significant growth driven by the intensification of poultry production, rising consumer demand for chicken products, and the commercial orientation of the poultry industry. As the demand for chicken products continues to

rise, the need for nutritious and quality chicken feed becomes paramount. This presents an attractive opportunity for investors in the chicken feed production sector to meet the growing market demand and capitalize on the evolving poultry industry landscape in Ethiopia.

Competitive Analysis

The competitive analysis of the chicken feed market in Ethiopia focuses on evaluating the existing players and their strategies. It aims to assess their market share, product offerings, pricing strategies, distribution channels, and customer base. Despite the presence of established competitors, there are opportunities for new entrants, especially those utilizing innovative raw materials like leather and solid waste.

Currently, several companies dominate the chicken feed market in Ethiopia. These established players have built strong brand recognition and customer loyalty over the years. They offer a wide range of chicken feed products catering to different age groups and nutritional requirements of poultry.

The market leaders have established distribution networks that ensure a wide reach across the country. They employ various distribution channels, including direct sales to large poultry organizations, partnerships with feed retailers, and engagement with small-scale farmers. This extensive distribution network enables them to effectively penetrate the market and meet customer demand.

Product offerings in the chicken feed market vary in terms of formulation, ingredients, and nutritional composition. Established players invest in research and development to continuously innovate their products, ensuring optimal growth, health, and productivity of poultry. They emphasize quality and compliance with industry standards to maintain a competitive edge.

Pricing strategies employed by existing players consider factors such as production costs, market demand, and competition. They aim to strike a balance between profitability and customer affordability. Pricing may vary based on the target market segment, product differentiation, and added value.

While the chicken feed market in Ethiopia is currently dominated by established players, there is room for new entrants to capitalize on the growing demand for innovative and sustainable feed solutions. Utilizing raw materials like leather and solid waste presents an opportunity to differentiate from competitors and address environmental concerns.

New entrants can leverage technological advancements and research to develop unique feed formulations that provide enhanced nutrition and support sustainable poultry production. By emphasizing the utilization of eco-friendly raw materials, they can appeal to environmentally conscious consumers and contribute to the circular economy.

The competitive analysis reveals that the chicken feed market in Ethiopia is currently dominated by established players. However, there is potential for new entrants, particularly those offering innovative feed solutions utilizing raw materials like leather and solid waste.

Customer Analysis

The customer analysis segment of this report focuses on identifying the target customers for the chicken feed produced from leather solid waste. By understanding the needs and preferences of these customers, the project can tailor its product offering to effectively meet their requirements.

1. Large-Scale Poultry Organizations: Large-scale poultry organizations form a significant customer segment in the chicken feed market. These organizations typically have large poultry farms with a substantial number of chickens. They require a steady and reliable supply of high-quality feed to support the growth, health, and productivity of their poultry. The feed produced from leather solid waste can be positioned as a sustainable and eco-friendly option, which may resonate with these organizations' values and environmental goals.
2. Small-Scale Poultry Farmers: Small-scale poultry farmers, including individual farmers and cooperatives, are an important customer segment to consider. These farmers often have smaller flocks of chickens and may focus on backyard or village-level poultry production. They require feed that is affordable, easily accessible, and provides optimal nutrition for their chickens. By offering competitively priced chicken feed produced from leather solid waste, the project can cater to the needs of small-scale farmers and help them improve their poultry production.
3. Farmers with Integrated Livestock Production: Many farmers in Ethiopia engage in integrated livestock production, where they have both cattle and poultry on their farms. These farmers can benefit from utilizing the chicken feed produced from leather solid waste as it provides a value-added use for the waste generated from their livestock activities. Positioning the feed as a resourceful and sustainable option can resonate with these farmers and encourage them to adopt the product.
4. Potential Customers in Other Industries: Apart from poultry organizations and farmers, there may be potential customers in other industries or sectors that can benefit from the chicken feed produced from leather solid waste. For example, animal feed manufacturers who produce feed for other livestock species like pigs or fish might be interested in incorporating this innovative feed ingredient into their formulations. Exploring collaborations and partnerships with such entities can open up additional market opportunities.

Understanding the specific needs and preferences of these customer segments is crucial for the project's success. Conducting market research and engaging with customers directly can provide insights into their feed preferences, nutritional requirements, packaging preferences, and desired price points. By tailoring the product offering to meet these customer requirements effectively, the project can position itself as a trusted and preferred supplier in the market.

Finally, the customer analysis highlights the importance of identifying and understanding the target customers for the chicken feed produced from leather solid waste. Large-scale poultry organizations, small-scale poultry farmers, farmers with integrated livestock production, and potential customers in other industries represent key customer segments. By addressing their unique needs and preferences, the project can develop a product offering that meets their requirements and positions itself as a reliable and sustainable solution in the chicken feed market

Market Potential and Demand Analysis Report

The market potential and demand analysis in this report focuses on assessing the market potential and demand for chicken feed in Ethiopia. By considering various factors such as population growth, the increasing trend of poultry production, and the growing consumer demand for chicken products, the analysis reveals a substantial market potential and a rising demand for quality chicken feed.

1. **Population Growth**: Ethiopia has a rapidly growing population, which directly translates into an increased demand for food products, including poultry products. As the population continues to expand, so does the potential market for chicken feed. The growing consumer base provides a strong foundation for the chicken feed industry to thrive.
2. **Increasing Trend of Poultry Production**: There is a noticeable trend towards intensification and commercialization of poultry production in Ethiopia. Poultry farmers are adopting modern techniques, improved breeds, and better management practices to enhance productivity. This trend further drives the demand for high-quality chicken feed that meets the nutritional needs of poultry at different stages of growth.
3. **Growing Consumer Demand for Chicken Products:** Consumer demand for chicken products, including meat and eggs, is on the rise in Ethiopia. Factors such as urbanization, rising disposable incomes, and changing dietary preferences contribute to this growing demand. As consumers seek healthy and affordable protein sources, the poultry industry experiences a surge in demand. This, in turn, fuels the need for quality chicken feed to support the optimal growth and health of poultry.
4. **Potential Market Size:** Considering the population size and the increasing trend of poultry production, the potential market size for chicken feed in Ethiopia is significant. With millions of chickens raised across the country, there is a constant demand for nutritious and balanced feed. This market size provides ample opportunities for new entrants and existing players to capture a significant share and meet the growing demand.
5. **Quality Considerations:** As the demand for chicken products continues to rise, there is an increasing emphasis on quality. Consumers are becoming more conscious of the source and quality of the poultry products they consume. This includes the feed given to the chickens. Consequently, there is a growing demand for high-quality chicken feed that ensures healthy growth, optimal egg production, and the overall well-being of poultry.

The market potential and demand analysis reveal a substantial market potential for chicken feed in Ethiopia. Factors such as population growth, the increasing trend of poultry production, and the growing consumer demand for chicken products contribute to the positive outlook for the industry. The analysis indicates that there is a rising demand for quality chicken feed that meets the nutritional requirements of poultry at different stages of growth. This presents an opportunity for both new entrants and existing players to capitalize on the growing market and cater to the evolving needs of the poultry industry in Ethiopia

Pricing Strategy

The pricing strategy section of this report delves into the pricing considerations for the chicken feed produced from leather solid waste. It takes into account various factors, including production costs, competitive pricing, and customer affordability. The suggested pricing strategy aims to strike a balance between profitability and market competitiveness.

1. **Production Costs:** One of the key factors to consider when determining the pricing of the chicken feed is the production costs. This includes the costs associated with sourcing and processing the leather solid waste, as well as other ingredients, labor, packaging, and overhead expenses. By carefully analyzing the production costs, the project can establish a baseline for pricing that ensures profitability.
2. **Competitive Pricing:** Competitive pricing plays a vital role in the success of any product in the market. It is important to evaluate the pricing strategies employed by existing players in the chicken feed market. By understanding the prevailing market prices and the pricing strategies of competitors, the project can position its product competitively. The pricing strategy should aim to offer value to customers while remaining attractive compared to other alternatives available in the market.
3. **Customer Affordability:** Customer affordability is a crucial consideration when determining the pricing strategy. It is essential to understand the target customers' purchasing power and their willingness to pay for chicken feed. Conducting market research and understanding the price sensitivity of customers can help in setting a price point that is within their affordability range. This ensures that the product remains accessible and attractive to the target market segment.
4. **Value Proposition:** The pricing strategy should align with the value proposition of the chicken feed produced from leather solid waste. Highlighting the unique selling points of the product, such as its sustainability, eco-friendliness, and high nutritional value, can justify a slightly higher price point compared to conventional chicken feed. Communicating the value proposition effectively can help customers understand the benefits they receive by choosing the product, which can influence their perception of the pricing.
5. **Market Competitiveness:** While profitability is an important consideration, it is equally crucial to remain competitive in the market. The pricing strategy should strike a balance between profitability and market competitiveness. Setting excessively high prices may deter potential customers, while setting excessively low prices may impact profitability. Regular monitoring of the market, competitor prices, and customer feedback can help in making necessary adjustments to maintain competitiveness.

So the pricing strategy for the chicken feed produced from leather solid waste should consider production costs, competitive pricing, customer affordability, and the value proposition of the product. Striking a balance between profitability and market competitiveness is crucial. By carefully analyzing these factors and monitoring the market dynamics, the project can set an optimal price that attracts customers, ensures profitability, and positions the product effectively in the chicken feed market.

Marketing and Distribution Channels

The marketing and distribution channels section of this report outlines the proposed strategies to create awareness, promote the chicken feed produced from leather solid waste, and effectively reach the target customers. The report suggests utilizing a combination of traditional and digital marketing channels, along with collaborations with poultry organizations and partnerships with retailers.

1. **Traditional Marketing Channels:** Traditional marketing channels play a crucial role in reaching customers in Ethiopia. These channels include:
    a. Print Advertising: Utilize print media such as newspapers and magazines to advertise the chicken feed product. Target poultry industry publications and agricultural magazines to reach the relevant audience.
    b. Trade Shows and Exhibitions: Participate in industry-specific trade shows and exhibitions to showcase the product, engage with potential customers, and generate leads.
    c. Direct Sales Team: Employ a dedicated sales team to directly approach large-scale poultry organizations, small-scale farmers, and other potential customers. This allows for personalized interactions and relationship building.
2. **Digital Marketing Channels:** Digital marketing channels are increasingly important in today's connected world. Leverage digital platforms to create awareness and reach a wider audience. Strategies include:
    a. Website and Online Presence: Develop a professional website that showcases the product, its benefits, and company information. Optimize the website for search engines to improve online visibility.
    b. Social Media Marketing: Utilize popular social media platforms such as Facebook, Twitter, and Instagram to engage with the target audience, share informative content, and run targeted advertising campaigns.
    c. Content Marketing: Create valuable and educational content related to poultry nutrition, best practices, and the benefits of the chicken feed produced from leather solid waste. Publish blog articles, videos, and infographics to establish thought leadership and attract potential customers.
3. **Collaboration with Poultry Organizations:** Collaborating with existing poultry organizations can significantly enhance the reach and credibility of the product. Establish partnerships with poultry associations, industry groups, and research institutions to gain access to their networks and leverage their expertise. This collaboration can involve joint marketing initiatives, knowledge sharing, and product endorsements.
4. **Partnerships with Retailers:** Partnering with retailers, both offline and online, can facilitate wider product distribution. Identify reputable retailers specializing in agricultural products and negotiate partnerships to stock and promote the chicken feed. Online marketplaces and e-commerce platforms can also serve as effective distribution channels, allowing for easy access and nationwide reach.
5. **Customer Engagement and Education:** Emphasize customer engagement and education to create brand loyalty and trust. Conduct workshops, training sessions, and farm visits to

educate customers on the benefits of the chicken feed and provide guidance on its proper usage. Foster two-way communication channels to address customer queries, feedback, and concerns promptly.

Generally, the proposed marketing and distribution channels for the chicken feed produced from leather solid waste involve a combination of traditional and digital marketing strategies. By leveraging both online and offline channels, collaborating with poultry organizations, and forming partnerships with retailers, the project can effectively create awareness, promote the product, and reach the target customers. Customer engagement, education, and personalized interactions will play a key role in building brand loyalty and driving sales. Regular monitoring and evaluation of marketing efforts will help refine strategies and ensure their effectiveness in the evolving chicken feed market.

6.1.14. Risk Analysis Report

The risk analysis section of this report assesses the potential risks and challenges associated with the chicken feed production project. It identifies various factors, such as raw material availability, regulatory compliance, market competition, and pricing volatility, that pose potential risks to the project's success. Additionally, mitigation strategies and contingency plans are proposed to address and minimize these risks.

1. Raw Material Availability: One of the key risks in the production of chicken feed from leather solid waste is the availability of raw materials. The project relies on a steady supply of leather solid waste, which can be influenced by factors such as tannery operations, waste management practices, and potential fluctuations in the availability of hides and skins. To mitigate this risk, the project should establish long-term agreements with tanneries and explore alternative sources of raw materials, such as partnerships with other waste management entities or suppliers.
2. Regulatory Compliance: Compliance with regulatory requirements is essential to ensure the legality and sustainability of the project. The production and distribution of chicken feed may be subject to various regulations, including those related to food safety, waste management, environmental impact, and labeling. It is crucial to stay updated with the evolving regulatory landscape and implement necessary measures to comply with the applicable laws and standards. Engaging with regulatory authorities, conducting regular audits, and investing in quality control systems can help mitigate this risk.
3. Market Competition: The chicken feed market in Ethiopia is competitive, with established players already catering to the demand. New entrants may face challenges in penetrating the market and gaining market share. It is important to conduct a thorough market analysis, identify unique selling points, and develop a strong value proposition that differentiates the product. Building strong relationships with customers, offering superior product quality, and providing excellent customer service can help mitigate the risk of market competition.
4. Pricing Volatility: Pricing volatility in the chicken feed market can pose a risk to the project's profitability. Factors such as fluctuations in raw material costs, changes in market demand, and pricing strategies of competitors can impact the pricing dynamics. To mitigate this risk, the project should closely monitor market trends, assess cost structures, and adopt flexible pricing strategies that allow for adjustments as needed. Maintaining a competitive

yet sustainable pricing approach and conducting regular pricing reviews will help manage pricing volatility effectively.

5. Supply Chain Disruptions: The project's supply chain is susceptible to various disruptions, such as transportation delays, supplier issues, and natural disasters. To mitigate this risk, the project should establish strong relationships with suppliers, maintain alternative supplier options, and develop contingency plans to address potential disruptions. Regular monitoring of the supply chain, effective communication with suppliers, and implementing robust logistics management systems are key steps in managing supply chain risks.

Table 9 The anticipated risk is analyzed in the table below.

Risk	Severity	Likelyhood	Risk impact	Recommended action(s)/Mitigation mechanism
Raw Material supply and Availability	Acceptable	Probable	Low	The project should establish long-term agreements with tanneries and explore alternative sources of raw materials, such as partnerships with other waste management entities or suppliers.
product not complying with Regulatory standards	Generally unacceptable	probable	High	It is crucial to stay updated with the evolving regulatory landscape and implement necessary measures to comply with the applicable laws and standards. Engaging with regulatory authorities, conducting regular audits, and investing in quality control systems can help mitigate this risk.
Market Competition	Acceptable	Possible	Medium	It is important to conduct a thorough market analysis, identify unique selling points, and develop a strong value proposition that differentiates the product. Building strong relationships with customers, offering superior product quality, and providing excellent customer service can help mitigate the risk of market competition
raw material Pricing flactuation	Tolerable	Not likely	Low	The project should closely monitor market trends, assess cost structures, and adopt flexible pricing strategies that allow for adjustments as needed. Maintaining a competitive yet sustainable pricing approach and conducting regular pricing reviews will help manage pricing volatility effectively

Supply Chain Disruptions	Acceptable	Probable	Medium	Regular monitoring of the supply chain, effective communication with suppliers, and implementing robust logistics management systems are key steps in managing supply chain risks
product Quality inconsistency	Generally unacceptable	Probable	High	Establishing product quality specification and regular process quality control and assurance is critical to maintain the quality consistency. If the product has quality problem the company will be pulled out of the market

SEVERITY	LIKELIHOOD	IMPACT
Acceptable	Not likely	Low
Tolerable	Possible	Medium
Generally unacceptable	Probable	High

Regarding the risk on the above parameters the severity, likelihood and risk impact has analyzed for each parameter to be considered as potential risks on the above table. For example, for supply of raw material, it is clear that the supply of raw material will be scares during fasting time because the supply of raw hide and skins is very less during that time so the of raw material supply is acceptable one who process chicken feed knows and can plan the production volume accordingly. If someone knows the problem to be occurred to some extent, it is less risky that is why the risk impact for raw material supply is represented as 'Low".

Major risks to be anticipated are

1. The risk of the product not fulfilling the regulatory requirement
2. The quality inconsistency

Both parameters have high risk if not properly managed and mitigation mechanism not well established. Therefore, to fulfill the legal requirement the company has to ensure raw material that is raw hide and skin trimmings free from any contaminations especially chrome containing wastes by must be completely isolated from all the wastes to be utilized for chicken feed production. Secondly, the quality issue is critical to handle customers if not the product will be pulled from the market so there must be quality control and assurance system to be established and implemented.

6.2. Project 2 Production of Gelatin from Leather Solid Waste (Raw Hide Trimming Waste)

Gelatin is a protein product derived from the partial hydrolysis of collagen found in natural sources such as animal skin, connective tissue, and bones. It is a highly digestible protein that contains all essential amino acids, except tryptophan. Gelatin is not a chemically modified substance, but rather a natural protein obtained through specific production processes.

In this technical feasibility study, the aim is to explore the production of gelatin from animal bovine bones, which will serve as the primary raw material for the proposed facility. Gelatin is a protein

substance present in the tissues of mammals, specifically in the connective tissues binding muscles to bones, bones to each other and other organs, as well as in the skin. It is extracted from collagen, another protein found in these tissues. When animal skin, bones, and connective tissues (typically from cattle and pigs) are boiled with water, the collagen transforms into a water-soluble protein known as gelatin. Upon cooling, the solution solidifies into a gel rather than reverting to collagen. Gelatin exhibits various properties, such as strong shaping ability, transparent gel formation, flexible film formation, easy digestibility, solubility in hot water, and ease of molding, making it widely used in numerous sectors, especially in food production.

Gelatin is commonly available in powdered or granulated form, appearing slightly yellow to light tan in color. It is a relatively tasteless and odorless substance. Being an amphoteric substance, gelatin can act as both an acid and a base, allowing it to be titrated with acids and alkalis. Gelatin contains relatively few ionizable groups, primarily contributed by the carboxyl groups of aspartic and glutamic acids, the imidazolium group of histidine, and the guanidinium group of arginine. Additionally, there are terminal amino and carboxyl groups present.

The gelatin molecules, like those of other proteins, are large and complex. The average molecular weight of gelatin ranges from 15,000 to 250,000. Gelatin consists of approximately 18 different amino acid radicals that are interconnected in an ordered manner. These amino acids, obtained through complete hydrolysis of gelatin, are listed in the table below. In terms of elemental composition, gelatin contains 50.5% carbon, 6.8% hydrogen, 17% nitrogen, and 25.2% oxygen.

By conducting a thorough technical feasibility study, we can evaluate the viability of establishing a gelatin production facility using raw hide trimming waste from the leather industry. This study will encompass various aspects, including raw material sourcing, production processes, quality control measures, market analysis, and financial considerations.

6.2.1. Application of Gelatin

Gelatin finds numerous applications across various industries, including medicine, cosmetics, tissue engineering, nutritional supplements, surgical tools, food production, and agriculture (Lee et al., 2001; Stenzel et al., 1974). In certain countries, raw hide trimming, lime trimming, chrome shaving, wet blue trimming, and fleshing waste materials are utilized as raw materials for producing products like glue, industrial gelatin, feed, and fertilizers (Li et al., 2008).

The applications of gelatin can be broadly categorized into three major areas: food, pharmaceutical, and photographic industries. In the food industry, gelatin is commonly recognized for its use in gelatin desserts and confectionery products. It also serves as a binding and glazing agent in meat products. In the pharmaceutical and health industry, gelatin is extensively used for manufacturing the shells of hard and soft capsules used for medications, dietary and health supplements, syrups, and more. Its high digestibility and natural protective coating properties make it an ideal choice for medication encapsulation. Moreover, gelatin's unique chemical and physical properties make it a crucial component in the photographic industry. It is employed in the preparation of silver halide emulsions for the production of photographic film.

Overall, gelatin's versatility and wide range of properties make it a valuable ingredient in various industries, contributing to the development of innovative products and applications.

6.2.2. Project Location

The proposed project will be strategically located in the vicinity of Modjo city due to its favourable conditions for raw material collection and distribution of the final gelatine products to end users. This location offers several advantages that are crucial for the success of the venture.

One significant advantage is the abundant availability of raw materials, such as fleshing waste, raw trimming waste, and sheep hair, in the surrounding areas. Modjo city's proximity to various regional states ensures a steady supply of these raw materials, reducing transportation costs and logistical challenges.

In terms of infrastructure, the site benefits from existing facilities and utilities. The availability of electric power, water supply, telephone networks, and other essential infrastructure components simplifies the establishment and operation of the gelatine production plant. This infrastructure support minimizes the need for extensive investments in creating new infrastructure, thus optimizing overall project costs.

Another key advantage is the accessibility to a skilled and unskilled workforce. Modjo city and its surrounding regions offer a pool of potential employees with diverse skill sets. This availability of manpower simplifies the recruitment process and ensures access to the required expertise for efficient production operations.

Additionally, the central location of Modjo city facilitates the distribution of the final gelatine products to various end users across different regional states. This centralized position reduces the overall distribution costs and enhances the project's market reach.

The choice of Modjo city as the project location combines favourable factors such as the availability of raw materials, existing infrastructure, access to a skilled workforce, and convenient distribution capabilities. These factors contribute to the feasibility and success of the gelatine production facility, enabling efficient production processes and market penetration.

6.2.3. Land Requirements and Building Construction

In Modjo City, the estimated average price of land is approximately 260 ETB per square meter for an 80-year lease with a payment plan spread over 40 years. Considering the proposed gelatine production facility, the total land requirement comprises areas for product plants as well as warehouses for both raw materials and finished products awaiting distribution.

For the integrated products, the estimated land cost is 5.0, amounting to approximately 1.3 million ETB. This cost encompasses the necessary land for setting up the production plants and warehouses, ensuring efficient operations and storage capabilities.

It is essential to consider various factors while assessing the land requirements for the project. These factors may include the size of the production facility, the layout and design of the buildings, the specific needs for storage and handling of raw materials and finished products, as well as potential future expansion plans.

In addition to land requirements, the construction of the buildings should be planned and executed according to industry standards and regulations. This includes considerations for structural integrity, compliance with safety and environmental guidelines, and the incorporation of necessary amenities and utilities required for the production process.

Building construction should be carried out in a manner that optimizes the workflow and functionality of the gelatine production facility. Proper segregation of different sections within the

buildings, such as production areas, storage areas, quality control laboratories, and administrative offices, should be implemented to ensure efficient operations and ease of monitoring.

Furthermore, attention should be given to the selection of appropriate building materials, ensuring durability and suitability for the specific requirements of the gelatine production process. Compliance with relevant building codes and regulations is essential to guarantee a safe and sustainable working environment.

Overall, the land requirements and building construction for the gelatine production facility should be carefully planned, considering factors such as land costs, functional layout, compliance with regulations, and the long-term expansion potential of the project.

6.2.4. Machinery Requirement and Cost

The selection of appropriate machinery is crucial for the successful operation of the gelatin production project. In order to ensure the efficient and reliable production of gelatin, thorough research and evaluation have been conducted to identify the most suitable machinery for each specific production process. It is recommended to source these machines from reliable suppliers, both locally and internationally.

Several factors have been taken into consideration during the machinery selection process. Firstly, durability is a key factor, as the machinery should be able to withstand the rigorous production demands and operate consistently over an extended period of time. Additionally, the fitness of the machinery for the intended purpose is essential, ensuring that it meets the specific requirements of gelatin production.

Price is another important consideration, as the machinery should be cost-effective without compromising quality and performance. The availability of spare parts is also crucial, as it ensures timely maintenance and repairs to minimize downtime. Furthermore, guarantee provisions from the machinery supplier provide added assurance of product quality and after-sales support.

Energy efficiency is a significant consideration, as machinery with lower energy consumption contributes to cost savings and environmental sustainability. Advanced technology and automation features should also be considered to enhance production efficiency and product quality.

In selecting machinery suppliers, their experience and success in the industry play a vital role. Suppliers with a proven track record and expertise in gelatin production machinery ensure the delivery of reliable and high-quality equipment.

The costs associated with machinery procurement will vary depending on the specific requirements of the gelatin production facility. It is recommended to obtain detailed quotations from multiple suppliers to compare prices and evaluate the best options available. Additionally, installation costs, training expenses, and ongoing maintenance and service agreements should be factored into the overall machinery investment.

By carefully considering these factors and conducting thorough evaluations, the gelatin production project can ensure the acquisition of suitable machinery that meets quality standards, enhances production efficiency, and contributes to the overall success of the venture

The estimated total cost of machinery and equipment for the gelatin production project is 5,742,000.00 ETB.

Table 10 Estimated total cost of machinery and equipment for the gelatin production

S/N	Equipment	Capacity	Quantity	Single Price (USD)	Total Price (USD)	Total Price (ETB)
1	Soaking and liming drum	5000ltr	2	20,000	40,000.00	2,320,000.00
2	Washing machine	5000lt	3	10,000	30,000.00	1,740,000.00
3	Extraction unit or reactors	5000 ltr	2	12,000	24,000.00	1,392,000.00
4	Seaports	Set	1	5,000	5,000.00	290,000.00
	Total			**99,000.00**		**5,742,000.00**

6.2.5. Equipment and Tools Requirement

The cost of equipment and tools necessary for gelatin production has been obtained from local markets and quotations from alibaba.com. The total cost of equipment and tools amounts to 1,957,400.00 ETB.

Table 11 Total cost of equipment and tools

S/N	Name of Equipment or Tools	Quantity	Unit Cost (USD)	Total Cost (USD)	Total Cost (ETB)
1	Hand Cart	1	50.00	50.00	2,700.00
2	Hydraulic Trolley	1	500.00	500.00	27,000.00
3	Knives	5	10.00	50.00	2,700.00
4	Weighing Machine	1	2,000.00	2,000.00	110,000.00
5	Digital Balance Weighing	1	1,000.00	1,000.00	55,000.00
6	Isuzu Car	1	32,000.00	32,000.00	1,760,000.00

	Total		**35,560.00**	**35,600.00**	**1,957,400.00**

6.2.6. Raw Material and Input Requirements for Production and Cost

The main raw material used in gelatin production is rawhide trimming waste. In addition to raw trimming waste, hide pelt trimming and limed splits can also be utilized, but these wastes are already proposed for glue production. The chemicals required for the gelatin production process include lime, sulfide, wetting agent, acid, sodium hydro sulfite, charcoal, and others.

The annual raw material requirement for gelatin production at the selected plant capacity and production program is estimated as follows:

- Rawhide trimming waste: 420,000 kg/year
- Sulfide: 7,000 kg/year
- Acid: 7,000 kg/year
- Sodium hydro sulfite: 3,500 kg/year
- Charcoal: 2,800 kg/year

Table 12 Unit prices and total costs for these raw materials

Type of Raw Material	Unit Price (ETB/kg)	Quantity (kg/day)	Quantity (kg/year)	Total Cost (ETB/day)	Total Cost (ETB/year)
Rawhide trimming waste	2.5	1,500	420,000	3,750.00	1,050,000.00
Sulfide	120	25	7,000	3,000.00	840,000.00
Acid	80	25	7,000	2,000.00	560,000.00
Sodium hydro sulfite	60	12.5	3,500	750.00	210,000.00
Charcoal	5	10	2,800	50.00	14,000.00
Total				**9,550.00**	**2,674,000.00**

The total annual cost of raw materials is estimated to be 2,674,000.00 ETB, taking into account the net gelatin production capacity of 300 kg per day.

By considering the machinery, equipment, and raw material requirements, the gelatin production project can be well-equipped to meet production targets and ensure efficient operations

6.2.7. Production Capacity

The proposed plant capacity for the gelatin production line is designed to operate with 8 working hours per shift, one shift per day, and 280 working days per year. The production program is based on these parameters.

The total raw hide trimming waste generated from the tanneries in the Modjo area amounts to 1,195,767 kg per year. Among these, the Xiang Zing tannery utilizes 459,415 kg per year for their gelatin production. This leaves a balance of 736,352 kg per year of raw hide trimming waste available for our study.

Considering that there may be challenges in collecting 50% of the total waste generated and that other competitors may utilize some of the remaining waste, an estimated 440,000 kg of raw hide trimming waste is available per year for our gelatin production.

It is important to note that these production figures are based on the assumption that the gelatin plant is operating at full capacity and utilizing the available raw materials efficiently.

By optimizing production processes and ensuring proper utilization of raw materials, the gelatin production facility can achieve its designed capacity and meet the projected production volumes. Regular monitoring and adjustments may be necessary to ensure consistent output and maximize the efficiency of the gelatin production process.

6.2.8. Production Program

In the first year of production, it is anticipated that the gelatin production plant may not obtain the full required amount of raw materials (rawhide trimming waste) due to competition from another market player. Therefore, the plant will start operating at 50% of its full production capacity in the initial year.

However, as the plant establishes itself and strengthens its position in the market, it is expected to gradually increase its production capacity. The production program for the gelatin production plant is outlined as follows:

First Year: The plant will operate at 50% of its full production capacity due to limited availability of raw materials. This allows the plant to establish itself in the market and ensure a steady supply of raw materials.

Second Year: The production capacity will increase to 60% as the plant gains more traction and secures a higher share of the raw material supply. This increase in production capacity reflects the growing stability and market presence of the gelatin production plant.

Third Year: The production capacity will further increase to 75% as the plant continues to establish itself and build stronger relationships with raw material suppliers. The plant will be able to secure a larger portion of the rawhide trimming waste required for gelatin production.

Fourth Year: The production capacity will reach 85% as the plant expands its operations and strengthens its position in the market. This growth in production capacity demonstrates the plant's ability to meet the increasing demand for gelatin.

Fifth Year: The production capacity will reach 90% of the full capacity as the plant operates at its highest level of efficiency and effectiveness. By this stage, the gelatin production plant will have established itself as a key player in the market, ensuring a stable supply of raw materials and meeting the growing demand for gelatin.

It is important to note that this production program takes into consideration the plant's ability to obtain an adequate supply of raw materials and gradually scale up its operations. As the plant progresses through the years, it will strive to maximize its production capacity and meet the market demand for gelatin. Regular assessments and adjustments will be made to optimize production processes and ensure the smooth operation of the gelatin production plant.

Table 13 Production Program and Capacity Utilization Rate in the table below

Item	**Year**				
	1	2	3	4	5
Capacity Utilization Rate, (%)	50	60	75	85	90
Production, of gelatin kg/annum	52,500.00	63,000.00	78,750.00	89,250.00	94,500.00

6.2.9. Human Requirement

The project will create employment opportunities for the local community, particularly for creative youth and females. The labor force will be managed through a modern management approach, incorporating a well-defined organizational structure and management practices. This structure will facilitate task allocation, coordination, supervision, and ultimately contribute to the achievement of the organization's goals.

To meet the projected market demands over the next five years, the gelatin production plant will initially require 40 employees. These employees will be distributed across various departments, including direct production areas and supporting staff functions. The manpower requirements are outlined in the following table:

The exact number of employees required in each department will depend on the specific needs of the gelatin production plant. This includes the production process, ensuring quality control,

equipment maintenance, managing the warehouse, handling administrative tasks, sales and marketing efforts, finance management, and human resources responsibilities.

As the gelatin production plant grows and expands its operations, additional employment opportunities may arise. This could include hiring more staff members in existing departments or creating new positions to support the increasing production capacity and market demands.

The employment opportunities provided by the project will not only contribute to the local economy but also promote inclusivity by actively involving creative youth and females in the workforce. The gelatin production plant will strive to create a positive work environment that fosters growth, skill development, and equal opportunities for all employees.

The organization's management will be responsible for overseeing the workforce, ensuring efficient operations, promoting a culture of teamwork and collaboration, and providing necessary support and training for the employees. The human resources department will play a key role in recruitment, training, performance management, and fostering a positive work environment.

Overall, the gelatin production plant aims to create sustainable employment opportunities and contribute to the development and empowerment of the local community through its workforce.

6.2.10. Financial Analysis

To conduct a financial analysis for the gelatin production unit, we will consider the unit price of gelatin, the average availability of raw materials, and the expenses incurred in personnel costs, material costs, tools, and equipment.

Unit Price of Gelatin: The unit price of gelatin is 220 ETB per kilogram.

Average Availability of Raw Materials: The average availability of raw materials is calculated at 1,500 kg per day.

Percentage Yield of Gelatin: The percentage yield of gelatin from raw trimmings is estimated to be between 20-30% of the salted weight. Therefore, at full capacity operation, the gelatin plant can produce an average of 0.25 * 1,500 kg = 375 kg of gelatin per day.

Now, let's analyze the expenses:

Personnel Costs: The total personnel cost is estimated to be 1,914,000.00 ETB. This includes salaries and benefits for the employees working in various departments of the production operation.

Material Costs: The total material cost is estimated to be 2,674,000.00 ETB. This includes the cost of raw materials required for gelatin production, such as raw hide trimming waste, sulfide, acid, sodium hydro sulfite, and charcoal.

Tools: The total cost of tools required for gelatin production is estimated to be 1,957,400.00 ETB. This includes equipment and tools such as hand carts, hydraulic trolleys, knives, weighing machines, digital balance weighing, and an Isuzu car.

Equipment: The total cost of machinery and equipment required for gelatin production is estimated to be 5,742,000.00 ETB. This includes equipment such as soaking and liming drums, washing machines, extraction units or reactors, and seaports.

Based on the financial analysis, we can calculate the total expenses incurred for the gelatin production unit:

Total Expenses = Personnel Costs + Material Costs + Tools + Equipment

Total Expenses = 1,914,000.00 + 2,674,000.00 + 1,957,400.00 + 5,742,000.00

Total Expenses = 12,287,400.00 ETB

The financial analysis provides an overview of the estimated expenses for setting up and operating the gelatin production unit. It is important to consider additional costs such as overhead expenses, utilities, maintenance, marketing, and other miscellaneous expenses to have a comprehensive understanding of the financial implications of the project. Furthermore, revenue projections, profit margins, and return on investment should be considered to assess the profitability and financial viability of the gelatin production unit

Profit Margin

To calculate the profit for the gelatin production unit, we need to consider the revenue generated from the sale of gelatin and deduct the total expenses incurred.

Revenue:

The revenue can be calculated by multiplying the unit price of gelatin by the production capacity:

Revenue = Unit Price * Production Capacity

Revenue = 220 ETB/kg * 375 kg/day * 280 days/year

Revenue = 22,050,000.00 ETB/year

Total Expenses:

The total expenses for the gelatin production unit were calculated to be 12,287,400.00 ETB.

Profit:

Profit = Revenue - Total Expenses

Profit = 22,050,000.00 ETB - 12,287,400.00 ETB

Profit = 9,762,600.00 ETB

Therefore, the estimated profit for the gelatin production unit is 9,762,600.00 ETB per year.

It is important to note that this calculation is based on the given unit price of gelatin and production capacity. Actual profit may vary depending on various factors such as market demand, competition, operating efficiency, and cost fluctuations. Additionally, other financial considerations such as taxes, depreciation, interest, and overhead costs should be taken into account for a comprehensive profit analysis.

Projected income

To calculate the projected revenue and production capacity with a 10% annual revenue growth, we will use the given Production Program and Capacity Utilization Rate for years 1 to 5. We will assume that the revenue growth is consistent with the increase in production capacity.

Year Production Program and Capacity Utilization Rate (%) Production of Gelatin (kg/annum) Revenue (ETB)

1 50% 52,500.00 52,500.00 * 220 = 11,550,000.00

2 60% 63,000.00 63,000.00 * 220 = 13,860,000.00

3 75% 78,750.00 78,750.00 * 220 = 17,325,000.00

4 85% 89,250.00 89,250.00 * 220 = 19,635,000.00

5 90% 94,500.00 94,500.00 * 220 = 20,790,000.00

To calculate the projected revenue for each year, we multiply the production of gelatin by the unit price of 220 ETB/kg.

Next, to calculate the projected revenue growth, we will apply a 10% increase to the previous year's revenue.

Year Projected Revenue (ETB)

Year 1. 11,550,000.00

Year 2. 11,550,000.00 * 1.10 = 12,705,000.00

Year 3. 12,705,000.00 * 1.10 = 13,975,500.00

Year 4. 13,975,500.00 * 1.10 = 15,373,050.00

Year 5. 15,373,050.00 * 1.10 = 16,910,355.00

The projected revenue takes into account the 10% annual growth rate.

Please note that this projection assumes a consistent annual revenue growth rate and does not consider other factors that may impact revenue, such as market conditions, competition, and changes in pricing. It is important to conduct a comprehensive analysis and consider various factors to make accurate revenue projections.

Calculate ROI and payback period

To calculate the ROI (Return on Investment) and payback period, we need to consider the revenue and expenses for each year.

To calculate the annual profit, we subtract the expenses from the revenue for each year.

Table 14 Production capacity rate, revenue, expense, and profit for each year

Year	Capacity Utilization Rate	Revenue	Expense	Profit
1	50%	11,550,000.00 ETB	12,287,400.00 ETB	-737,400.00 ETB
2	60%	13,860,000.00 ETB	7,527,210.00 ETB	6,332,790.00 ETB
3	75%	17,325,300.00 ETB	8,656,292.00 ETB	8,668,708.00 ETB

4	85%	19,635,000.00 ETB	9,954,735.00 ETB	9,680,265.00 ETB
5	90%	20,790,000.00 ETB	11,447,946.00 ETB	9,342,054.00 ETB

To calculate the cumulative cash flow, we sum up the annual profits over the years.

Year 1: -737,400.00 ETB

Year 2: 6,332,790.00 ETB

Year 3: 15,001,498.00 ETB

Year 4: 24,681,763.00 ETB

Year 5: 34,023,817.00 ETB

The payback period is the time it takes to recover the initial investment. In this case, the initial investment is the total expenses of 12,287,400.00 ETB, and 5,742,000.00 ETB is one investment spent during establishment of project and will not continue in subsequent years

By analyzing the cumulative cash flow, we can see that the payback period is reached in Year 3. This means that it takes approximately 3 years to recover the initial investment.

To calculate the ROI, we divide the cumulative cash flow by the initial investment and multiply by 100 to get the percentage.

ROI = (Cumulative Cash Flow / Initial Investment) * 100

ROI = (34,023,817.00 / 12,287,400.00) * 100

ROI = 276.82%

The ROI for the gelatin production unit is approximately 276.82%.

Please note that this analysis is based on the provided revenue and expense figures and does not take into account other financial factors such as taxes, depreciation, interest, and overhead costs. Additionally, future revenue and expense projections may vary based on various factors, so it's important to conduct a comprehensive financial analysis considering all relevant factors and assumptions.

6.2.11. Market Feasibility Report

Gelatin is a versatile substance with various applications in the food, cosmetics, and pharmaceutical industries. Assesses the market demand, supply, pricing, competition, and trends is crucial to determine the viability of the gelatin market in Ethiopia.

Gelatin is derived from collagen, a protein found in animal tissues, and is widely used for its gelling, binding, and thickening properties. It is an essential ingredient in a range of products, including confectionery, desserts, cosmetics, and pharmaceutical capsules. As the demand for

processed foods, cosmetics, and pharmaceuticals continues to grow in Ethiopia, the market potential for gelatin usage is expected to expand.

By understanding the market feasibility of gelatin for industrial purposes, stakeholders can make informed decisions regarding investment, production capacity, pricing strategies, and marketing efforts. The report will serve as a valuable resource for entrepreneurs, investors, and industry participants seeking to tap into the growing market opportunities presented by gelatin in Ethiopia

The gelatin market in Ethiopia has been experiencing steady growth due to several factors. The increasing consumption of processed foods, the rising popularity of gelatin-based cosmetics, and the expanding use of gelatin in pharmaceutical products are driving the demand in the industrial sector. Gelatin serves as a crucial ingredient in these industries, providing functionalities such as gelling, binding, and texture improvement.

Factors Driving Gelatin Demand:

1. **Processed Food Industry**: The processed food industry in Ethiopia is witnessing significant growth, driven by changing consumer preferences and an increasing urban population. Gelatin finds extensive use in various food products, including desserts, confectionery, dairy products, and meat products, due to its gelling and stabilizing properties. The demand for gelatin as a food ingredient is expected to grow in parallel with the processed food industry.
2. **Cosmetics Industry:** The cosmetics industry in Ethiopia is experiencing remarkable growth, with a rising demand for personal care and beauty products. Gelatin is widely used in cosmetics for its film-forming, emulsifying, and moisturizing properties. It is employed in the formulation of creams, lotions, masks, and hair care products. The growing focus on natural and sustainable ingredients in cosmetics further contributes to the demand for gelatin-based formulations.
3. **Pharmaceutical Industry:** The pharmaceutical industry in Ethiopia is evolving and expanding to meet the healthcare needs of the population. Gelatin plays a crucial role in pharmaceutical applications, particularly in the production of capsules, coatings for tablets, and drug delivery systems. Gelatin capsules are preferred for their ease of swallowing and efficient drug release properties. As the pharmaceutical industry grows, the demand for gelatin in this sector is expected to increase.

Market Challenges: Despite the positive market outlook, there are certain challenges that need to be addressed for the sustained growth of the gelatin market in Ethiopia:

1. **Supply Constraints**: The local supply of gelatin in Ethiopia is limited, primarily consisting of small-scale producers. The production capacity and quality of gelatin need to be improved to meet the growing demand. Additionally, the availability of high-quality raw materials for gelatin extraction poses a challenge for local producers.
2. **Pricing Pressures**: The pricing of gelatin is influenced by various factors such as production costs, transportation expenses, and import duties. The high production costs and limited economies of scale for local producers contribute to relatively higher gelatin prices. This can affect the affordability and competitiveness of gelatin-based products in the market.
3. **Competitor Landscape:** The gelatin market in Ethiopia is competitive, with both small-

scale and large-scale producers vying for market share. Local producers face competition from imported gelatin products that often have established brand recognition and quality standards. Local producers need to focus on product quality, innovation, and cost-effectiveness to compete effectively in the market.

In general, the demand for gelatin for industrial purposes in Ethiopia is driven by the growth of the processed food, cosmetics, and pharmaceutical industries. As consumers become more conscious about product ingredients and quality, the demand for gelatin-based formulations is expected to increase. However, addressing supply constraints, managing pricing pressures, and enhancing competitiveness are crucial for the sustainable growth of the gelatin market in Ethiopia. Businesses and investors should consider these factors and capitalize on the growing market opportunities by offering high-quality gelatin products tailored to the specific needs of the Ethiopian market.

Supply Feasibility Report: Gelatin for Industrial Purposes in Ethiopia

Assessing the supply dynamics is crucial for stakeholders interested in entering or expanding their presence in the Ethiopian gelatin market. The gelatin market in Ethiopia faces certain supply-related challenges, including limited production capacity, access to high-quality raw materials, and technological constraints. Understanding the supply feasibility is essential for ensuring a consistent and reliable supply chain to meet the growing demand for gelatin in industrial applications.

1. **Production Capacity:**

The production capacity of gelatin in Ethiopia is currently limited, with small-scale producers being the main suppliers. These producers face challenges such as high production costs, limited access to modern technology, and a scarcity of high-quality raw materials. To enhance the supply capacity, investments in production infrastructure, advanced technology, and quality control measures are necessary.

2. **Raw Material Availability:**

The availability of high-quality raw materials is crucial for gelatin production. In Ethiopia, the primary source of raw materials for gelatin is rawhide trimming waste from the leather industry. However, the consistent supply of rawhide trimming waste can be affected by factors such as the fluctuation in the leather industry, waste management practices, and collection and transportation logistics. Developing efficient systems for raw material collection and ensuring a stable supply are essential for a sustainable gelatin supply chain.

3. **Technology and Processing:**

The gelatin production process requires specialized equipment and expertise. Small-scale producers in Ethiopia often face challenges in accessing modern technology and adopting efficient processing techniques. Upgrading production facilities, investing in advanced machinery, and providing training and technical support to producers can improve the processing capabilities and overall supply chain efficiency.

4. **Quality Control**

Gelatin manufacturers must adhere to stringent national and international food processing requirements. These regulations include but are not limited to the cleanliness of the plant, equipment, and employees; and allowable percentages of additives, flavorings, and colorings.

Automated and computerized technologies allow the processors to preset and monitor ingredient amounts, time and temperature, acidity and alkalinity, and flow levels. Valves are installed along pipelines to allow for continuous sampling of the product.

Gelatin is processed to varying "bloom" values that measure the gel strength or firmness. The desired strength corresponds to the manner in which the gelatin will be used. The bloom value is technically measured and monitored throughout the production process.

5. **Logistics and Distribution:**

Efficient logistics and distribution networks are essential for timely delivery of gelatin to customers. Challenges such as transportation infrastructure, storage facilities, and coordination between suppliers and buyers need to be addressed. Developing robust logistics systems and establishing partnerships with reliable transport and distribution providers can streamline the supply chain and reduce delivery lead times.

Price feasibility

This price feasibility report examines the pricing dynamics and factors influencing the affordability and competitiveness of gelatin for industrial purposes in Ethiopia. Assessing the price feasibility is crucial for stakeholders interested in entering or operating in the Ethiopian gelatin market and ensuring a sustainable and profitable business model.

Market Pricing Overview:

The price of gelatin in Ethiopia is influenced by various factors, including production costs, raw material availability, transportation expenses, import duties, and market competition. Understanding the pricing dynamics is essential for setting competitive prices that reflect the value of gelatin and meet the affordability expectations of customers.

1. **Production Costs:**

The production costs associated with gelatin manufacturing play a significant role in determining its price. Factors such as labor costs, raw material expenses, energy costs, machinery maintenance, and quality control measures contribute to the overall production costs. Efficient production processes, economies of scale, and technological advancements can help in minimizing production costs and ensuring price competitiveness.

2. **Raw Material Availability and Costs:**

The availability and cost of raw materials, primarily rawhide trimming waste, are key factors affecting the pricing of gelatin. Fluctuations in the supply and demand of raw materials can influence the market price. Factors such as the stability of the leather industry, waste management practices, and transportation costs impact the availability and affordability of raw materials. Ensuring a stable supply chain and exploring alternative sources of raw materials can help in managing price fluctuations.

3. **Import Duties and Taxes:**

Import duties and taxes imposed on gelatin can significantly impact its pricing in the Ethiopian market. Importing gelatin from international suppliers may incur additional costs such as customs duties, value-added tax (VAT), and other levies. Understanding the import regulations and tax

structure is crucial for determining the final pricing of gelatin products and assessing the competitiveness of imported versus domestically produced gelatin.

4. **Competition and Market Positioning:**

The gelatin market in Ethiopia is competitive, with both small-scale and large-scale producers vying for market share. Price positioning plays a critical role in attracting customers and establishing a competitive edge. Small-scale producers may have cost advantages due to lower production expenses, while large-scale producers benefit from economies of scale. Analyzing market trends, customer preferences, and competitor pricing strategies can help in setting appropriate price points.

5. **Market Demand and Affordability:**

Understanding the demand patterns and affordability of gelatin in the Ethiopian market is essential for pricing decisions. Market research and customer surveys can provide insights into customers' willingness to pay, price sensitivity, and value perceptions. Balancing affordability with profitability is crucial for achieving a sustainable pricing strategy.

Pricing gelatin for industrial purposes in Ethiopia requires careful consideration of production costs, raw material availability, import duties, competition, market demand, and customer affordability. Striking the right balance between competitive pricing and profitability is crucial for long-term success in the gelatin market. Regular monitoring of pricing dynamics, cost optimization measures, and responsiveness to market trends will help Ethiopian gelatin producers maintain competitiveness and capture market opportunities.

6.2.12. Risk Analysis Report

The risk analysis section of this report assesses the potential risks and challenges associated with the gelatin production project. Potential risks are identified, evaluated and mitigation strategies are recommended for each anticipated risk as follows

Risk	Severity	Likelyhood	Risk impact	Recommended action(s)/Mitigation mechanism
Raw Material supply and Availability	Acceptable	Not likely	Low	The project should establish long-term agreements with tanneries and explore alternative sources of raw materials, such as partnerships with other waste management entities or suppliers.

Environmental Compliance Risk	Generally unacceptable	Probable	High	The gelatin production plant consumes more water to clean the tannery wastes to utilized so there is huge load of waste water discharged from the process so there must be standards effluent treatment plant to treat the waste so that the wastes need to fulfill the discharge limits set by national authority. if the environmental management is below the standard the plant will be forced to be closed by regulatory bodies so there must be sufficient system to handle the issue of environment
Health and Safety Risk	Generally unacceptable	Not likely	Medium	There shall be health and safety implementation system with clear working procedure in order to proactively prevent the occurrence of any health and safety damages. Workers need to have adequate awareness and knowhow on how to protect their safety and health during the working time so continuous awareness creation training is mandatory to tackle this issue
Natural Disaster Risk	Generally unacceptable	Not likely	Medium	since natural disasters occur suddenly and might damage all the gelatin production plant, products and manpower, therefore the company need to be insured by any insurance company to mitigate the impact.
product Quality inconsistency	Generally unacceptable	Probable	High	Establishing product quality specification and regular process quality control and assurance is critical to maintain the quality consistency. If the product has quality problem the company will be pulled out of the market

SEVERITY	LIKELIHOOD	IMPACT
Acceptable	Not likely	Low
Tolerable	Possible	Medium
Generally unacceptable	Probable	High

From the above risk matrix one can see that there are risks associated with the implementation of the gelatin project, risks that have a potential to directly affect the production process with high risk impact as well as the market of the product needs to be critically handled proactively so as to maximize the production volume as well as deliverability of the final product. Since risk is calculated by multiplying the severity of the event with likelihood/ probability of the occurrence, the above risk impact is calculated similarly in all cases. Therefore, the risk of environment compliance issues and quality inconsistency will be the major factors that can highly expected to affect the performance of the Gelatin production plant.

6.2.13.Business Model

Business Model Canvas for a gelatin production business:

1. Key Partnerships:
   - Raw material suppliers (tanneries, slaughterhouses)
   - Equipment suppliers
   - Distribution partners
   - Research institutions
2. Key Activities:
   - Gelatin production from rawhide trimming waste
   - Quality control and assurance
   - Research and development for product improvement
   - Marketing and sales
3. Key Resources:
   - Manufacturing facility
   - Raw materials (rawhide trimming waste)
   - Machinery and equipment for gelatin production
   - Skilled labor and workforce
   - Research and development capabilities
   - Distribution network
   - Brand and reputation
4. Value Proposition:
   - High-quality gelatin products
   - Competitive pricing
   - Sustainable and eco-friendly production
   - Customized solutions for specific customer needs
   - Strong market reputation and reliability
5. Customer Segments:
   - Food manufacturers
   - Pharmaceutical companies
   - Cosmetic producers
   - Industrial applications (adhesives, coatings, etc.)
6. Channels:
   - Direct sales to customers
   - Distribution through wholesalers and retailers
   - Online sales platforms
7. Customer Relationships:
   - Personalized customer service
   - Technical support
   - Continuous communication for feedback and improvement
8. Revenue Streams:
   - Sales of gelatin products (per kilogram, bulk orders)
   - Long-term contracts with customers
   - Potential licensing or partnership opportunities
9. Cost Structure:
   - Raw material costs
   - Equipment and machinery maintenance

- Labor costs
- Research and development expenses
- Marketing and advertising costs
- Administrative and overhead expenses

10. Key Metrics:
    - Total revenue and profit margin
    - Customer satisfaction and retention rates
    - Market share and growth
    - Production efficiency and yield
    - Return on investment (ROI)
    - Sustainability metrics (e.g., waste reduction, energy efficiency)

Note: The Business Model Canvas is a framework to outline key aspects of a business. The above example is a general template and can be customized to fit the specific requirements and characteristics of a gelatin production business.

7. Policy and Legal Framework for Environmental Management

7.1. Environmental Policy of Ethiopia

The Environmental Policy of Ethiopia was approved in 1997 becoming the first key document that collected environmental sustainable development principles. The aim of the Environmental Policy of Ethiopia is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable economic and social development through the suitable management and use of resources and the environment as a whole in order to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (EPA, 1997). In order to guarantee its effective implementation, the Environmental Policy of Ethiopia strengthens the creation of an organizational and institutional framework from federal to community levels. Furthermore, it provides a number of guiding principles associated with principles of sustainable development to ensure Environmental Impact Assessment (EPA, 1997). Establishment of Environmental Protection Organs Proclamation 295/2002 establishes the organizational requirements and identifies the need to establish a system that enables coordinated but different responsibilities of environmental protection agencies at federal and regional levels. The Proclamation indicates the duties of different administrative levels responsible for applying the law.

Environmental Pollution Control Proclamation No. 300/2002 on Environmental Pollution Control principally attempts to ensure the rights of citizens to a healthy environment by the imposition of obligations that will protect the environment of the country. The proclamation has its base on the principle that each citizen has the right to live in a healthy environment and, also, has the obligation of protecting the environment of the country. The law attends to the establishment of environmental quality standards for water, soil and air, the management of both, municipal and hazardous waste, and monitoring of pollution. The Proclamation serves as a guide to enable the development of the main environmental standards applicable in Ethiopia. Not accomplishing these standards can lead to criminally punishable offences. Additionally, it supports the Regional Environmental Authority and/or the EPA to select environmental inspectors in order to control

environmental pollution. In accordance with this fact, inspectors from the relevant regional environmental agency or from EPA are allowed to visit, without previous announcement, any land or premises at any time, at their judgment.

Solid Waste Management Proclamation N0 513/2007 aims to promote community participation in order to prevent adverse effects and enhance benefits resulting from solid waste. It guides urban local governments in order to define how to prepare solid waste management action plans. Assessment of tannery solid waste management A case of Sheba Leather Industry in Wukro (Ethiopia) Consequently, solid Waste Management Proclamation No. 513/2007 states (Article 5.1) that Urban Administrations shall guarantee the participation of the lowest administrative levels and their respective local communities in designing and implementing their solid waste management practices. Article 5.1 establishes that each urban administration or Region should determine its own schedule in order to prepare its solid waste management plan and report of implementation. Any additional information required will be conceded from the Regional Environmental Protection Authorities and federal EPA.

Prevention of Industrial Pollution Regulation Proclamation 300/2002 was developed by the Federal Environmental Protection Authority and confirmed by the Council of Ministers in order to prevent industrial pollution while assuring compatibility of industrial development with environmental conservation. This Regulation stipulates significant obligations to industrial operators. A factory below these regulations is committed to prevent or minimize the generation and release of pollutants in order to satisfy the environmental standards. Additionally, industrial operators are supposed to implement internal environmental monitoring systems, control the rate of pollutants generated, and describe the disposal mechanisms applied. As a consequence, following Regulation 159/2008, industries are enforced to present annual reports declaring the previous statements.

Environmental Guidelines and Standards Between 2008-2010 EPA had established preliminary environmental standards and guidelines for several industrial sector activities and ambient environmental qualities. They include the draft Guideline on Sustainable Industrial Zone/Estate Development. Few years later, the Environment Council selectively accepted some of the industrial environmental standards for twelve specific industrial sub-sectors. The leather sector is included and, therefore, should respect the industrial emission standards. Although Ethiopia has incorporated useful environmental laws, additional policy mechanisms and instruments are needed to compel the above law. It is noticeable the existence of serious weaknesses in the integration of environmental policies in the tanning sector as a tool for the promotion of sustainable development (Framis, 2018).

7.2. Environmental Impacts of Tannery Solid Waste

Solid wastes generated from tanning industries contain different chemicals which are used during leather manufacturing process. These tannery solid wastes have different characteristics as different chemical and mechanical processes are applied to the raw hides/skins. If these solid waste generated during various tanning operations are not properly utilized or disposed they are likely to cause a number of problems on the environment. Salt dust or de-dusted salt if stored in heaps outside the tanneries or dumped in open dumping area is likely to be washed away during rains and cause groundwater pollution. Hair waste and lime sludge if discharged along with the effluents are likely to choke the drains. Raw and green fleshings, limed fleshings, splits (splitting waste) and trimmings putrefy easily and give rise to noxious smells. In many tanneries, it is the foul odour

which emanate from some of these putrescible solid wastes which accounts for much of the smell traditionally associated with tannery wastes. Some of the bio-degradable tannery solid wastes are sources of pathogenic bacteria and volatile organic compounds emission. Vegetable and chrome tanned shavings and splits do not easily decompose. If they are not utilized, problems of disposal are encountered. Primary and secondary sludge obtained during the treatment of tannery wastes are also putrescible. Excess heavy metal accumulation in soil is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible. Some of tannery solid waste contains chromium metal which is the most widely used in tanning industries as chromium salt and it causes carcinogenic effect when it enters human body through food chain. The standard safe limit for chromium metal in the soil is 150ppm. In general where tanning industries have long been established there has been usually a simultaneous growth in industries which can use tannery solid wastes to produce some valuable products. This pattern is especially helpful to the tanning industry in the case of obnoxious rag and limed fleshings, trimmings and splits which are lifted by chicken feed and gelatin production units.

7.3. Opportunity, Challenges and Recommendation Regarding Ethiopia law and regulation

Opportunity and Strength	Gaps and Challenge	Recommendations
❖ Existence of Law and regulations ❖ Roles and responsibilities are assigned even if some are overlapped ❖ Policies and strategies are articulated ❖ At all level of administration levels there is EPA ❖ Controlling, monitoring and enforcement are undertaken	❖ Lack of effective environmental management system ❖ Weak framework to create social sustainability ❖ Weak institutional linkages ❖ Poor implementation capacity ❖ Weak capacity to adapt to the global dynamics	❖ Implementing effective environmental management system ❖ Building internal capacity to gain leverage in the emerging global dynamics ❖ Develop strong institutional linkages ❖ Strengthen the implementation capacity ❖ Weak capacity to adapt to the global dynamics

7.4. Integrated Waste Management

Integrated waste management (IWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. To be responsive to public attitudes, the disciplines that must be considered in integrated solid waste management include administrative, financial, legal, architectural, planning, environmental, and engineering functions. For a successful integrated solid waste management plan, it is necessary that all these disciplines communicate and interact with each other in a positive interdisciplinary relationship. The four basic waste management options (strategies) for IWM are: (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills. Figure 2.3 below shows waste management hierarchy.

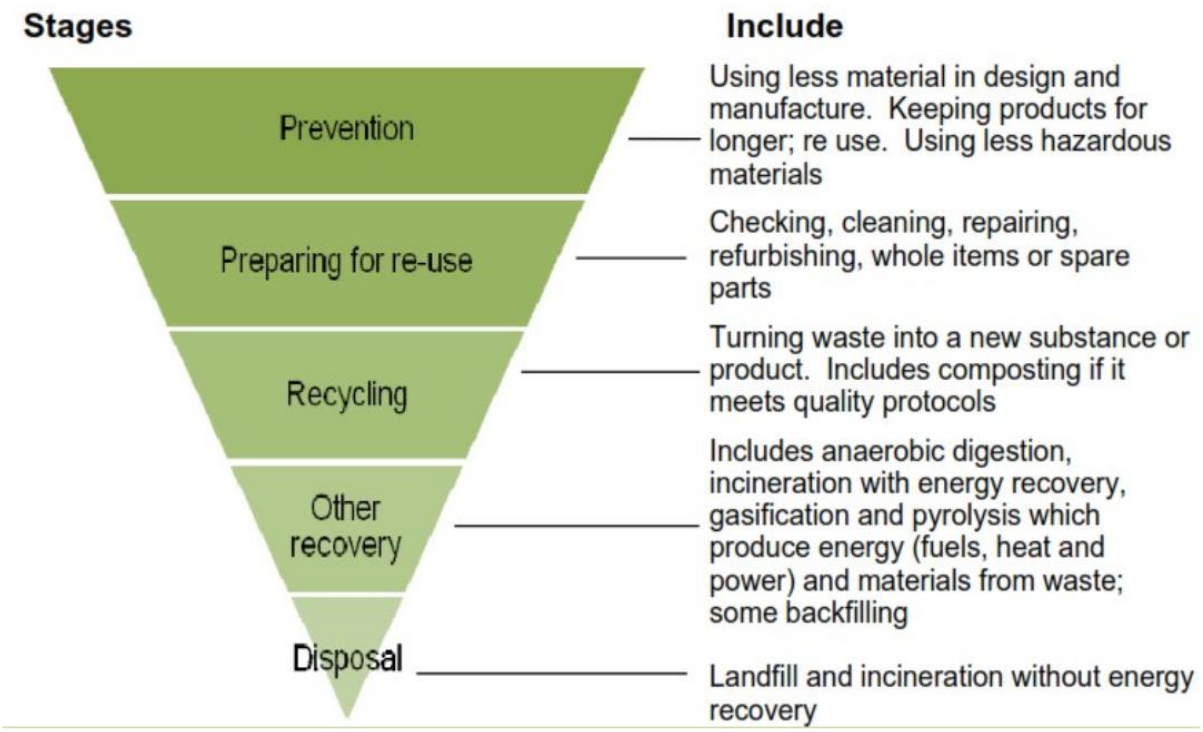

Figure 8 Waste Management Hierarchy

Production of chicken feed and gelatin from tannery solid waste is a part of integrated waste management as recycling is one component of waste hierarchy. Additionally, there production process has to be in a way that follows the integrated waste management hierarchy for achieving sustainable development.

7.5. Environmental and Social Impact of Gelatin Production from Leather Solid Waste

Gelatin is the most abundant type of collagen, which is obtained from animal biomass. Extraction of collagen/gelatin can be done by alkaline or acid treatment of leather biomass. However, the biomass like splitting waste or vegetable tanned leather waste that does not contain chromium is recommended for applications of collagen/gelatin in cosmetics, food industries, and medical sectors. Therefore, collagen/gelatin can be extracted from leather biomass, which has several industrial applications such as adhesive, dye and plaster, textile, paper, cosmetics, foodstuff, pharmaceuticals, biogas production, edible packaging, and biofuel production (Ayele et al., 2021).

Acid hydrolysis also has the disadvantages of severe hydrolysis of collagen and time consuming. The amino acid containing hydroxyl and amide group can be destroyed by using alkali hydrolysis, which also need long treatment time. Enzymatic hydrolysis needed specific species of enzyme and high cost, meaning that it is difficult to industrialize. In order to improve the dechromisation efficiency, ultrasonic technique can be simultaneously used during the procedure of this dechromisation treatment. Combination of acid hydrolysis, alkali hydrolysis and enzymatic hydrolysis might be significant increasing the yield of collagen and decreasing the cost (Li et al., 2019).

Gelatin production requires a significant amount of water for processing and cleaning purposes. This may result in increased water usage and potential strain on local water resources. Implementing water recycling systems and efficient water management practices can help reduce water consumption and minimize the impact on water resources. The production process generates solid waste, such as trimming waste and by-products, as well as liquid waste in the form of effluents. Proper waste management systems should be in place to handle and treat these wastes effectively. Promoting recycling, reusing, or converting waste into valuable by-products can minimize the environmental impact associated with waste generation. The other one is gelatin production typically requires energy-intensive processes, such as boiling, drying, and extraction. The use of fossil fuels for energy generation can contribute to greenhouse gas emissions and climate change. Adopting energy-efficient technologies and renewable energy sources, such as solar or biomass, can reduce the carbon footprint and promote sustainable energy practices. The sourcing of raw materials for gelatin production, such as rawhide trimming waste, may have implications for biodiversity. It is important to ensure responsible sourcing practices, including adherence to animal welfare standards and sustainable procurement policies. Engaging in collaborations and certifications with organizations focused on biodiversity conservation can help mitigate any negative impacts.

7.5.1. Laws and Regulation related with Gelatin Production

- **Environmental Pollution Control Proclamation No. 300/2002** on Environmental Pollution Control principally attempts to ensure the rights of citizens to a healthy environment by the imposition of obligations that will protect the environment of the country.

- **Solid Waste Management Proclamation N0 513/2007** aims to promote community participation in order to prevent adverse effects and enhance benefits resulting from solid waste.

- **Prevention of Industrial Pollution Regulation Proclamation 300/2002** was developed by the Federal Environmental Protection Authority and confirmed by the Council of Ministers in order to prevent industrial pollution while assuring compatibility of industrial development with environmental conservation.

- **"The Pharmacists and Druggists Proclamation No 43/1942"** was used to regulate both the professions and the facilities where they were practiced, comprehensive regulation of the pharmaceutical market was introduced in 1964 by a regulation called "Pharmacy Regulation No. 288/ 1964". This legislation formed the legal basis for official establishment of drug regulation in the history of Ethiopia, enabling the regulation of the practice of pharmacists, druggists and pharmacy technicians; manufacturing, distribution, and sale of medicines. In June 1999, a new regulation called the "Drug Administration and Control Proclamation No. 176/1999" repealed most parts of the regulation 288/1964. The law established an independent Drug Administration and Control Authority (DACA) with further mandate of setting standards of competence for licensing institutions/facilities. DACA was re-structured as Food, Medicine and Health Care Administration and Control Authority (EFMHACA) of Ethiopia by the "Proclamation No. 661/2009" in 2010 bearing additional responsibilities like regulation of food, health care personnel and settings.

Lastly, proclamation to provide for food and medicine administration *No. 1112/2019*

- This proclamation shall be applicable in respect of food, medicine, medical device, cosmetics, and tobacco product intended to be placed on the market or offered, in any other way, for use by the public, and other products and raw materials regulated under this proclamation.

  Different parts of the proclamation state that
  - **Part 2** regulates the executives organs, this includes power and duties.
  - **Part three**, food safety and administration, requires that every food establishment who provides food for use by the public shall ensure its safety; the rigor of safety shall be based on the type and potential risk to human health. Food trade establishments shall be registered and food manufacturing, preparation, storage and transport in every food establishment shall complies with safety requirements. Food manufacturing must pass through quality control systems in every food establishment.
  - **Part four** concerns medical devices and cosmetics administration, this includes use of drugs, illegal manufacturing, public health pesticides.
  - **Part six** concerns packaging, labelling, advertisement and promotion.

Gelatin specifications as GMIA (Gelatin Manufactures Institute of America) for different application stated as follows

Table 15 Typical specifications for edible gelatins

Parameters	Gelatin Type A	Gelatin Type B
pH	3.8-5.5	5.0-7.5
Gel Strength(Bloom)	50-300	50-300
Viscosity (cP)	15-75	20-75
Ash(%)	0.3-0.2	0.5-2.0
Moisture(%)	10.5±1.5	10.5±1.5

Table 16 Typical tablet gelatin specification

Parameters	Gelatin Type A	Gelatin Type B
pH	3.8-5.5	5.0-7.5
Gel Strength(Bloom)	50-300	50-300
Viscosity (cP)	15-75	20-75
Ash(%)	0.3-0.2	0.5-2.0

Table 17 Typical specification for type B bone photographic gelatin

Parameters	Gelatin Type B
Ph	5.65-5.85
Gel Strength(Bloom)	250-310
Viscosity (cP)	74.0-95.0
Moisture (%)	10.5-13.0
Absorbance, 420nm	0.0-0.158
Absorbance, 650nm	0.0-0.032

Finally, as shown from the above table's adherence to environmental regulations and standards is crucial for sustainable gelatin production. Regular monitoring, reporting, and compliance with environmental laws and regulations ensure that the production process aligns with best practices and minimizes negative environmental impacts. Training on policy, laws and regulation of as a country and international based as well as taking benchmark of countries such as German, Switzerland etc. on solid waste management is also valuable in order to transfer knowledge and skill for effective environmental management.

7.6. Environmental and Social Impact of Chicken Feed Production from Leather Waste

In a country like Ethiopia, the huge amount of solid tannery waste has been traditionally disposed on landfills. Most of these landfills were not constructed properly and therefore toxic metals, especially chromium, have leached out into the adjacent soil making it unfit for cultivation and other uses. Chicken feed manufacturers have discovered the potential of these wastes to be the principal component of animal feed because of their protein content. Solid tannery waste contains untanned components like raw trimmings and fleshings, which are mostly protein contaminated with some salts. Using this protein concentrate as Chicken feed is a perfect example of industrial symbiosis, an association between companies in which the wastes or byproducts of one become the raw materials for another. The tannery owners could now earn money by selling their wastes instead of spending money on land filling. Additionally, this practice can have social implications by creating opportunities for waste management and recycling industries, supporting local economies, and reducing the reliance on traditional protein sources in chicken feed production.

7.6.1. Laws and Regulation related with chicken Feed Production

- **Environmental Pollution Control Proclamation No. 300/2002** on Environmental Pollution Control principally attempts to ensure the rights of citizens to a healthy environment by the imposition of obligations that will protect the environment of the country.
- **Solid Waste Management Proclamation N0 513/2007** aims to promote community participation in order to prevent adverse effects and enhance benefits resulting from solid waste.
- **Prevention of Industrial Pollution Regulation Proclamation 300/2002** was developed by the Federal Environmental Protection Authority and confirmed by the Council of Ministers in order to prevent industrial pollution while assuring compatibility of industrial development with environmental conservation.

In Ethiopia, Proclamation No. 728/2011 Veterinary Drug and Feed Administration and Control Proclamation says

On Feed Quality Standards

- No feed or feed additive may be put into use unless it is ascertained by the appropriate organ that it complies with the quality standards issued or adopted by the competent organ.

On Feed Safety Control

3. Any feed, feed raw material or additive shall be produced, stored and transported in a manner which prevents contamination and deterioration.
4. Without limiting the generality of sub-article (1) of this Article:
    a) feed and feed raw materials and additives processing plants and storage and transportation facilities shall be kept clean and effective pest control programs shall be implemented;

    b) containers and equipments used for processing, storage, transport, handling and weighing feed and feed raw materials and additives shall be kept clean;

    c) cleaning programs may be effective and minimize residues of detergents and disinfectants;

    d) any feed processing facility may not be close to feedlot or fattening or slaughter house;

    e) any feed shall be free from minerals, ingredients and pathogens which are danger

Chromium (Cr) has been considered an essential nutrient for humans and animals. It has been shown to have antioxidative properties in vivo and it is integral in activating enzymes and maintaining the stability of proteins and nucleic acid. Its primary metabolic role, however, is to potentiate the action of insulin through its presence in an organometallic molecule called the glucose tolerance factor (GTF). Almost all of the sources of chromium in the earth's crust are in the trivalent state (Cr^{3+}), and naturally occurring chromium compounds in the hexavalent oxidation state are rare. Hexavalent chromium (Cr^{6+}) compounds are thus man-made products. Chromium is absorbed primarily in the small intestine. Chromium toxicity is primarily associated with exposure to hexavalent chromium compounds. Trivalent and hexavalent chromium compounds behave differently in the body. However most of the Cr^{6+} is believed to be reduced to Cr^{3+} by extracellular fluids before reaching sites of absorption in the small intestine. Information is meagre on chromium toxicity for poultry. Dietary concentrations of chromium ranging from 3 to 1,000 $CrCl_3$ mg/kg caused effects on growing chicks.

Table 18 Maximum permissible limits for chicken feed

Elements	Toxic Level	
	Broiler Diets	**Layer Diets**
Essential trace elements, ppm		
Iron	4500	4500
Copper	50–806	50–806
Zinc	500–4000	500–4000
Manganese	4000–4800	4000–4800
Selenium	5–20	5–20
Chromium	10–300	10–300
Cobalt	100–200	100–200
Heavy metals, ppm		
Lead	10–1000	10–1000
Cadmium	12–40	12–40
Arsenic	100	100
Nickel	300–500	300–500
Boron	200–5000	200–5000
Aluminum	500–3000	500–3000

Source: Food and Agriculture Organization (FAO)/ World Health organization (WHO).

The toxicity of leather waste by heavy metals and possible transfer to common food items like chicken, eggs and fish arose quite strongly. So a careful follow up and measurement of concentration has to be done in continuous manner.

Good extension approach and tailor-based training are the two most valuable inputs to improve chicken feed production in Ethiopia. To bring improvements to the system, these activities must be given by professionals and continuous assessment and improvement has to be in place. This result sustainable development and help to compile with rules and regulation Ethiopia.

8. Conclusion

In this study we concluded that remarkable amount of solid waste is generated from the tanning industry and the same is sent to the land fill without due consideration to the environmental and society health issues. The output of the feasibility study shows that out ten products, seven products are not feasible (biogas, tallow oil, biopolymer, keratin, adsorbent, bio-stimulant and wool fat). Whereas chicken feed, gelatin and binder sot match making are feasible.

Since Binder sot match making is addressed by LLPIRDC and Solidaridad, conducting the feasibility study for binder is just duplication of effort.

The market feasibility report concludes that establishing a chicken feed production plant utilizing leather solid waste as a raw material presents a viable and lucrative investment opportunity. The analysis conducted indicates a strong market potential, rising demand, and favorable market conditions for such a venture. By implementing effective marketing strategies, competitive pricing, and efficient operations, the project has the potential for success and profitability.

Through the proposed marketing and distribution channels, the project can effectively reach the target customers, including large-scale poultry organizations, small-scale farmers, and other potential customers in the poultry industry. By highlighting the unique selling points of the chicken feed produced from leather solid waste, such as its sustainability and nutritional value, the project can differentiate itself in the market and attract customers.

Although the gelatin market in Ethiopia faces certain supply-related challenges, the overall supply feasibility can be enhanced through strategic investments, improved infrastructure, technological advancements, and quality control measures. Strengthening the supply chain will not only meet the growing demand for gelatin in industrial applications but also contribute to the growth and competitiveness of the Ethiopian gelatin industry. Collaboration among stakeholders, government support, and industry-wide initiatives will be crucial in realizing the full supply potential of gelatin in Ethiopia.

As a recommendation attention should be given to change the significant amount of leather solid waste from threat to an opportunity that can serve as resource and converted in to value added consumer product and this sustainably can reduce environmental pollution in addition to its economic benefit.

9. References

Ahmed, S., Fatema-Tuj-Zohra, Khan, M.S.H., Hashem, M.A., 2017. Chromium from tannery waste in poultry feed: A potential cradle to transport human food chain. Cogent Environ. Sci. 3. https://doi.org/10.1080/23311843.2017.1312767

Ayele, M., Limeneh, D.Y., Tesfaye, T., Mengie, W., Abuhay, A., Haile, A., Gebino, G., 2021. A Review on Utilization Routes of the Leather Industry Biomass. Adv. Mater. Sci. Eng. 2021. https://doi.org/10.1155/2021/1503524

Chaudhary, R., Pati, A., 2016. Poultry feed based on protein hydrolysate derived from chrome-tanned leather solid waste: creating value from waste. Environ. Sci. Pollut. Res. 23, 8120–8124. https://doi.org/10.1007/s11356-016-6302-4

Chojnacka, K., Skrzypczak, D., Mikula, K., Witek-Krowiak, A., Izydorczyk, G., Kuligowski, K., Bandrów, P., Kułażyński, M., 2021. Progress in sustainable technologies of leather wastes valorization as solutions for the circular economy. J. Clean. Prod. 313. https://doi.org/10.1016/j.jclepro.2021.127902

Elsayed, N.H., Taha, G.M., Mohamed, O.A., 2021. Industrial Gelatin from Leather Chrome Shavings Wastes. J. Biomed. Res. Environ. Sci. 2, 1035–1043. https://doi.org/10.37871/jbres1346

Framis, C.P., 2018. "Assessment of tannery solid waste management, A case of Sheba Leather Industry in Wukro (Ethiopia)" 1–92.

Hussain, F.S., Memon, N., Khatri, Z., Memon, S., 2020. Solid waste-derived biodegradable keratin sponges for removal of chromium: A circular approach for waste management in leather industry. Environ. Technol. Innov. 20, 101120. https://doi.org/10.1016/j.eti.2020.101120

Jambulingam, R., Srinivasan, G.R., Palani, S., Munir, M., Saeed, M., Mohanam, A., 2020. Process optimization of biodiesel production from waste beef tallow using ethanol as co-solvent. SN Appl. Sci. 2, 1–18. https://doi.org/10.1007/s42452-020-03243-7

Li, Y., Guo, R., Lu, W., Zhu, D., 2019. Research progress on resource utilization of leather solid waste. J. Leather Sci. Eng. 1, 1–17. https://doi.org/10.1186/s42825-019-0008-6

Mottalib, M.A., Sultana, A., Somoal, S.H., Abser, M.N., 2016. Assessment of Heavy Metals in Tannery Waste-Contaminated Poultry Feed and Their Accumulation in Different Edible Parts of Chicken. IOSR J. Environ. Sci. 10, 72–78. https://doi.org/10.9790/2402-1011017278

Onenc, S., Kilincli, O., Ismail, C.K., Yilmaz, O., Yanik, J., 2011. Use of solid wastes from the leather industry as an adsorbent. J. Residuals Sci. Technol. 8, 131–139.

Pahlawan, I.F., Sutyasmi, S., Griyanitasari, G., 2019. Hydrolysis of leather shavings waste for protein binder. IOP Conf. Ser. Earth Environ. Sci. 230. https://doi.org/10.1088/1755-1315/230/1/012083

Priebe, G.P.S., Kipper, E., Gusmão, A.L., Marcilio, N.R., Gutterres, M., 2016. Anaerobic digestion of chrome-tanned leather waste for biogas production. J. Clean. Prod. 129, 410–416. https://doi.org/10.1016/j.jclepro.2016.04.038

Rahman, M.A., Kamal, S., Salam, A., Salam, M.A., 2014. Assessment of the Quality of The Poultry Feed and its Effect in Poultry Products in Bangladesh. J. Bangladesh Chem. Soc. 27.

Rigueto, C.V.T., Rosseto, M., Krein, D.D.C., Ostwald, B.E.P., Massuda, L.A., Zanella, B.B., Dettmer, A., 2020. Alternative uses for tannery wastes: a review of environmental, sustainability, and science. J. Leather Sci. Eng. 2. https://doi.org/10.1186/s42825-020-00034-z

Shaibur, M.R., 2023. Heavy metals in chrome-tanned shaving of the tannery industry are a potential hazard to the environment of Bangladesh. Case Stud. Chem. Environ. Eng. 7, 100281. https://doi.org/10.1016/j.cscee.2022.100281

Sinkiewicz, I., Śliwińska, A., Staroszczyk, H., Kołodziejska, I., 2017. Alternative Methods of Preparation of Soluble Keratin from Chicken Feathers. Waste and Biomass Valorization 8, 1043–1048. https://doi.org/10.1007/s12649-016-9678-y

Stefan, D.S., Bosomoiu, M., Constantinescu, R.R., Ignat, M., 2021. Composite polymers from leather waste to produce smart fertilizers. Polymers (Basel). 13, 1–21. https://doi.org/10.3390/polym13244351

Sundar, J., 2023. The study of plant growth promoter production from leather industrial solid waste. Int. J. Recycl. Org. Waste Agric. 12, 47–57. https://doi.org/10.30486/ijrowa.2022.1945254.1375

Xu, L., Geelen, D., 2018. Developing biostimulants from agro-food and industrial by-products. Front. Plant Sci. 871, 1–13. https://doi.org/10.3389/fpls.2018.01567

10. Annex

Annex I Different Data

Table 19 Framework for the feasibility study

S.N	Criteria	Indicators
1.	Waste supply and availability	○ Waste supply and Availability ○ Reliability of resource supply ○ Competitors' index for waste resource
2.	Institutions, regulations and investment climate	○ Structure and capacity of institutions ○ Policy and legal Framework support ○ Level of budgetary and other issues ○ Community support
3.	Market assessment	○ Product Quality ○ Price competitiveness
4.	Technical and logistical assessment	○ Availability/suitability of the processes/ technologies ○ Technology (resource) requirements index (spare parts, other production factors) ○ Performance and efficiency of process/technology ○ Operation and maintenance (O&M) requirements
5.	Financial analysis	○ Net Present Value (NPV) & Internal Rate of Return (IRR) ○ Income Statement & Balance Sheet ○ Response to sensitivity changes

6.	Health and environmental risk and impact assessment	○ Work-related risks Environment and OHS ○ Risk reduction strategies in place ○ Estimated emissions (solids fluids and gas) to waterbodies soil and air
7.	Socio-economic impact assessment	○ Socio-economic benefit/cost ○ Environmental and health benefit /cost

Table 20 data collection methodologies and stakeholders to be communicated/consulted

Data collection methods/tools	Potential stakeholders concerned
Review of literature and national and international laws/regulations, case studies, etc **Use of questionnaires** **On-site factory visit** **Observation/interview (existing businesses,** **tannery factories)**	**Oromia Environmental Protection Authority** **Federal Environmental Protection Authority** **Tanneries** **Ethiopian leather industry association(ELIA)** **Leather and leather products industry research and development center(LLPIRDC)** **Manufacturing industry development institute(MIDI)** **Ministry of Industry (MoI)** **Tannery bi product manufacturers relevant to the assignment, if any** **Federal and Regional Enterprise development bodies**

- Interview of relevant institutions
- Review of secondary data
- Analyzing process flow diagram
- Consultative meeting/discussion with
- Expert judgment

- Leather and leather products industry research and development center(LLPIRDC)
- Manufacturing industry development institute(MIDI)
- Ministry of Industry (MoI)
- Tannery bi product
- Modjo town Municipality
- Banks
- Central Statistics Agency

Table 21 Total hide lime pelt trimming waste generated in the last five years in each tannery around the study area

Year	**Installed capacity**	**2010**	**2011**	**2012**	**2013**	**2014**	total pcs	**total pelt trimming in kg**	**average pelt trimming in kg**
Tannery Name	Hide	Hide	Hide	Hide	Hide	Hide			
Modjo	140,000	53,000	39,583	70,399	25,566	89,017	277,565	499,617.00	99,923
Colba	168,000	168,000	119,618	57,057	106,720	102,200	553,595	996,471.00	199,294
Xiang Zing	206,930	140,000	127,395	607,938	166,757	154,303	1,196,393	2,153,507.40	430,701
Ethiopia Tannery	336,000	158,000	258,712	105,739	61,209	60,929	644,589	1,160,260.20	232,052
Dx			0		19,200		19,200	34,560.00	6,912
Friendship	280,000	33,614	0		0	129,779	163,393	294,107.40	58,821

Hodaochen	0		0		0	76	76	136.80	27
George Shoe	0		86,450	47,489	52,413	72,815	259,167	466,500.60	93,300
TOTAL	1,130,930	552,614	631,758	888,622	431,865	609,119	3,113,978	5,605,160.40	1,121,032

Table 22 Total hide lime split waste generated the last five year in each tannery around the study area

Year	**Installed capacity**	**2010**	**2011**	**2012**	**2013**	**2014**	total pcs	**total lime split in kg**	**average lime split in kg**
Tannery Name	Hide	Hide	Hide	Hide	Hide	Hide			
Modjo	140,000	53,000	39,583	70,399	25,566	89,017	277,565	471,861	94,372
Colba	168,000	168,000	119,618	57,057	106,720	102,200	553,595	941,112	188,222
Xiang Zing	206,930	140,000	127,395	607,938	166,757	154,303	1,196,393	2,033,868	406,774
Ethiopia Tannery	336,000	158,000	258,712	105,739	61,209	60,929	644,589	1,095,801	219,160
Dx			0		19,200		19,200	32,640	6,528
Friendship	280,000	33,614	0		0	129,779	163,393	277,768	55,554
Hodaochen	0		0		0	76	76	129	26

George Shoe	0		86,450	47,489	52,413	72,815	259,167	440,584	88,117
TOTAL	1,130,930	552,614	631,758	888,622	431,865	609,119	3,113,978	5,293,763	1,058,753

Source: LLPIRDC- Leather and Leather Products Industry Research and Development center

Table 23 Required man power for chicken feed production

Production operation Department	**Quantity**	**Monthly salary**	**Total monthly expenditure**	**Annual expenditure**
General manager	1	10,000.00	10,000.00	120,000.00
Secretary	1	4,000.00	4,000.00	48,000.00
Foreman	1	4,500.00	4,500.00	54,000.00
Product Developer/researcher	1	5,000.00	5,000.00	60,000.00
machine operator	2	4,000.00	8,000.00	96,000.00
Quality controller	1	5,000.00	5,000.00	60,000.00
Electrician	1	4,500.00	4,500.00	54,000.00
Mechanic	1	4,500.00	4,500.00	54,000.00
temporary workers	4	3,000.00	12,000.00	144,000.00
Sales persons	1	4,500.00	4,500.00	54,000.00
Marketing expert	1	4,500.00	4,500.00	54,000.00
Purchasing expert	1	4,500.00	4,500.00	54,000.00

Accountant	1	4,500.00	4,500.00	54,000.00
Cashier	1	3,500.00	3,500.00	42,000.00
Personnel	1	4,000.00	4,000.00	48,000.00
Driver	1	3,500.00	3,500.00	42,000.00
Security guard	2	2,500.00	5,000.00	60,000.00
Total	**22**		**91,500.00**	**1,098,000.00**

Table 24 Human Requirement for gelatin production

Production operation Department	Quantity	Monthly salary	Total monthly expenditure	Annual expenditure
General manager	1	10,000.00	10,000.00	120,000.00
Secretary	1	4,000.00	4,000.00	48,000.00
Foreman	2	4,500.00	9,000.00	108,000.00
Product Developer/researcher	2	5,000.00	10,000.00	120,000.00
machine operator	4	4,000.00	16,000.00	192,000.00
Quality controller	2	5,000.00	10,000.00	120,000.00
Electrician	2	4,500.00	9,000.00	108,000.00
Mechanic	2	4,500.00	9,000.00	108,000.00
temporary workers	10	3,000.00	30,000.00	360,000.00
Sales persons	2	4,500.00	9,000.00	108,000.00
Marketing expert	2	4,500.00	9,000.00	108,000.00
Purchasing expert	2	4,500.00	9,000.00	108,000.00

Accountant	1	4,500.00	4,500.00	54,000.00
Cashier	1	3,500.00	3,500.00	42,000.00
Personnel	1	4,000.00	4,000.00	48,000.00
Driver	1	3,500.00	3,500.00	42,000.00
Security guard	4	2,500.00	10,000.00	120,000.00
Total	**40**		**159,500.00**	**1,914,000.00**

Annex II Production Process

1. Production Process of chicken feed

Process:

1. Collect lime pelt and lime split waste from tanneries, ensuring that it does not contain heavy metals or toxic chemicals.
2. Grind the waste materials into fine particles.
3. Mix the ground waste materials with oil cakes, agro-residues, flour, cereals, and minerals/vitamins in the specified ratios.
4. Thoroughly blend the ingredients to achieve a uniform mixture.
5. The resulting feed is suitable for day-old chicks up to 22 days of age.
6. Above 22 Days and Egg-Laying Chickens: For chickens older than 22 days and egg-laying chickens, a separate formula is required. This formula takes into account the nutritional needs specific to these stages:

   Ingredients:

   - Lime pelt and lime split waste from tanneries (pre-tanning waste only)
   - Oil cakes
   - Agro-residues
   - Flour
   - Cereals
   - Molasses
   - Minerals and vitamins

Mixing Ratio:

- Lime pelt and lime split waste (pre-tanning waste): 40%
- Oil cakes: 15%
- Agro-residues: 10%
- Flour: 10%
- Cereals: 10%
- Molasses: 10%
- Minerals and vitamins: 5%

Process:

1. Select pre-tanning waste materials such as raw trimming, lime trimmings, and lime splitting waste from tanneries. Avoid using chrome-containing wastes.
2. Grind the pre-tanning waste materials into fine particles.
3. Mix the ground waste materials with oil cakes, agro-residues, flour, cereals, molasses, and minerals/vitamins in the specified ratios.
4. Thoroughly blend the ingredients to achieve a uniform mixture.
5. The resulting feed is suitable for chickens older than 22 days and egg-laying chickens.

It is important to ensure that the feed is of high quality, free from contaminants, and meets the nutritional requirements of the specific age group or type of chicken. Regular testing and monitoring should be conducted to maintain the nutritional balance and safety of the feed.

2. Production Process of Gelatin

The gelatin production process involves the controlled hydrolysis of collagen, the main component found in rawhide, to extract gelatin. To prepare the rawhide for gelatin extraction, the hair is first removed through a dehairing process. A pre-treatment step is then performed on the raw material using either acid or alkali.

The pre-treatment process serves two purposes. Firstly, it helps remove non-collagenous substances present in the rawhide, ensuring a purer gelatin extraction. Secondly, the dehairing process ensures that the rawhide is free from hair, which could negatively impact the quality of the extracted gelatin.

The pre-treatment process is crucial in maximizing the gelatin yield without compromising the desired properties of the extracted gelatin. By carefully controlling the pre-treatment conditions, such as the duration and concentration of the acid or alkali used, the collagen in the rawhide can be effectively hydrolyzed to obtain high-quality gelatin.

Once the pre-treatment is complete, the rawhide is ready for the gelatin extraction process. The hydrolysis of collagen is carried out under controlled conditions, typically involving the use of heat and enzymes. This controlled hydrolysis breaks down the collagen molecules into smaller peptides, resulting in the formation of gelatin.

During the hydrolysis process, it is important to carefully monitor and control factors such as temperature, time, and pH to ensure optimal gelatin formation. This ensures that the extracted gelatin possesses the desired properties, such as gel strength, viscosity, and clarity.

After the hydrolysis process, the gelatin solution is typically subjected to filtration and purification steps to remove any impurities and unwanted substances. This further enhances the quality and purity of the gelatin.

The final step in the gelatin production process involves drying the gelatin to remove excess moisture, resulting in a powdered or granulated form that is suitable for various applications.

Overall, the gelatin production process entails careful pre-treatment of the rawhide, controlled hydrolysis of collagen, filtration and purification, and drying to obtain high-quality gelatin with desired properties. The process ensures maximum yield while preserving the desirable characteristics of the extracted gelatin for its various applications.

Inspection and Cutting

Upon arrival at the food processing plant, the animal parts undergo a thorough inspection to ensure quality. Any decayed parts are discarded. The bones, tissues, hide, and skins are then loaded into chopping machines, which cut them into small pieces approximately 12.7 cm in diameter. This size reduction process facilitates further processing.

De-hairing: The collected rawhide trimming waste from tanneries is loaded into a drum for washing, removal of dirty substances, and de-haring. This is achieved by treating the rawhide with sulfide and lime. The process helps to effectively remove hair and impurities from the rawhide, preparing it for subsequent processing steps.

Degreasing and Roasting: After the cutting process, the animal parts undergo a high-pressure water spray to wash away debris. They are then subjected to a degreasing step, where they are soaked in hot water to reduce the fat content to approximately 2%. The degreased bones and skins are moved to an industrial dryer via a conveyor belt, where they are roasted at around 200°F (100°C) for approximately 30 minutes. This roasting step helps to further remove any remaining fats and impurities.

Acid and Alkaline Treatment: The animal parts are soaked in vats containing lime or other acid/alkali solutions for approximately five days. This treatment serves multiple purposes. It removes minerals and bacteria, facilitating the release of collagen. In the acid wash, typically a 4% hydrochloric acid with a pH below 1.5 is used. In the alkaline wash, potassium or sodium carbonate with a pH above 7 is employed. The acid and alkaline treatments play a crucial role in the gelatin extraction process.

Boiling: The chopped bone, tissue, and skin pieces are loaded into large aluminum extractors and boiled in distilled water. A tube connected to the extractor allows workers to draw off the liquid,

which now contains gelatin. To ensure sterility, the liquid undergoes flash-heating at around 375°F (140°C) for approximately four seconds.

Evaporating and Grinding: The liquid from the extractor passes through filters to remove any remaining bits of bone, tissue, or skin. It is then piped into evaporators, where the liquid is separated from the solid gelatin. The liquid portion is discarded, and the gelatin is pressed into sheets. Depending on the intended application, the gelatin sheets may be further processed through a grinder to achieve a fine powder consistency.

Flavoring and Coloring: If the gelatin is destined for use in the food industry, sweeteners, flavorings, and colorings may be added at this stage. These additives are carefully mixed into the powdered gelatin in pre-set amounts to achieve the desired taste and appearance.

Packaging: The packaging process is automated, with predetermined quantities of gelatin poured into overhead funnels. From there, the gelatin flows down into bags made of either polypropylene or multi-ply paper. The bags are then vacuumed to remove excess air and sealed, ensuring the freshness and integrity of the gelatin during storage and transportation.

Annex III Interview Questions

Part I Interview Guidelines

1. Please fill the following your bio.

2. Age ☐

3. Sex Male ☐ Female ☐

4. Marital status. Single ☐ Married ☐

5. Educational background

6-12 ☐ Certificates ☐ Diploma ☐

Degree, ☐ MA or LLM ☐ PhD ☐ Specialist ☐

6 Employment Background

Civil servant ☐

Government Officials ☐

Private business owner or other ☐

1. Did you know that there are legislations to protect and control the environment, prevention of industrial pollution control? If yes what are they? If no why? Reason out your cause under here.

2. How do you see the implementation of environmental protection Legislation?

3. Do you think that there is an environmental pollution? If yes tell me the sources of pollution in your town

4. Is there any administrational, civil and criminal measure taken by organization? If yes on which organization?

5. Is there any registered damage on human health by leather industries hazardous waste substances?

6. Do the leather manufacturing industries treat the sludge released from them?

7. What are the identified problems based on the assessment and evaluation takes by internal and external examiner?

8. Do you think there is a lacuna between the environmental protection laws? If yes, define it.

9. What about the organizational structure of environmental protection authority and leather industry?

10. Do you think that leather manufacturing industries have proper EIA?

11. Does the society have complains on the leather manufacturing industries hazardous and toxic substances like bad smell and other causes? If yes, how do you treat complains?

12. What are the identified societies complains regarding leather industries?

13. What is the measure you took to redress the damages?

14. Do you have ISO certification?

15. Do you think that a wastes from the leather industry polluting the soil, water and human and animal health?

16. What are the critical and fundamental challenges you faced from the leather processing industries?

17. How do you explain the level of water quality in the Modjo town?

18. Do you think that societies are deserved to drink the water edge to the leather industry? If

so how?

19. Is there problem with the soil and water due to the leather industry? If so, how?

Part: II. Interviewee questions for a communities living around the leather industries

1. Do you the leather industry impact your socio-economic activities? How?

2. Did you get a chance to bring your question for concerned organ of the government? If so what was the response?

3. Is there any variation of lose productivity of the soil and water quality while, the leather

Industries expanded?

4. Have you benefited from the leather industries?

Part III: Interviewee question for the government organs and other stakeholders

1. Is there any problem or challenge in controlling environmental pollution due to the hazardous waste sewerage substances and toxic chemical waste compounds?

2. Do you think that those environmental protection legislations are efficient in controlling and curbing environmental pollution problem of the leather industries?

3. Do you think that there are the leather processing industries that have no EIA and not certified?

4. Do you conduct the EIA early?

5. Do you think these are implemented properly?

6. Do you think that the environmental protection laws have lacunas? If so what are the gaps you have identifies?

7. What are the measures your regulatory authority could take regarding environmental pollution by the leather industries?

8. How do you explain the measure taken by relevant authority?

9. Do you believe all leather manufacturing industries are environment friendly or conducive for all human and nonhuman or animals‟ health?

10. Do you have comment on the organizational framework of environmental protection regulatory authority?

Part IV, Interviewee guide line question designed to investigate the legal related subjects.

1. Do you think that the leather industry has impact your socio-economic activities? If so how?

2. Did you get a chance to bring or claim your question for concerned organ of the government? If so what was the response?

3. Is there any variation of lose productivity of the soil and water quality while, the leather industries expanded?

4. Have you benefited from the leather industries?

Annex IV Best Practices to be implemented for Better Management of Tannery Solid Wastes

Best Practices to be Implemented for Better Management of Tannery Solid Wastes

In Ethiopian tanneries the conventional way of production is just linear way (take-make-use-dispose) of production. Due to this the tanneries are generating huge quantities of solid wastes at various stages and the wastes collected, mixed together and dumped at open land fill. But for better utilization of tannery solid wastes, it is critical to improve the environmental performance of tanneries. The conventional way of waste handling is not recommended to develop high value products from the solid wastes generated in all leather processing unit operation. Therefore, the best practices to be implemented to maximize the utilization of solid wastes are described in the table below.

s/no	Tannery unit operations	Existing waste management practice	Recommended practices
1.	Raw hide and skin trimming wastes	-Dumped at open land fill together with other wastes	• Proper segregation of raw hide and skin trimming is recommended for better utilization. • Since raw trimming waste is relatively free of chemical contaminations it can be safe for recovery of chicken/ dog feed and other valuable products.
2	Management of preservation/de-dusted salt	-Dumped with other wastes and repeatedly used for preservation of hides and skins in some tanneries	• Disposal of salt in open land is not recommended since it increases salinity therefore proper segregation and collection is critical in order to re-use it. • Preservation salt recovery and re-use technologies are developed and implemented in some tanneries in Ethiopia. • De dusted salt can be utilized in tannery production at pickling stage that will have positive impact in minimizing the TDS and chloride loads in effluent treatment plant
3	Management of hair wastes	-Hair wastes are dumped together with other wastes. -Most tanneries use hair destruction method in liming operation	• Hair wastes need to be segregated and measured in order to produce value added products such as keratin and wool fat. • Tanneries need to implement hair saving unhairing method in order to improve the management of hair wastes. • There should be hair filtration system to be fitted on liming drums so as to improve hair collection.

4	Fleshing wastes	-In most tanneries fleshing wastes are mixed with chrome containing wastes and dumped in open land fill	• There should be proper segregation of fleshing wastes • Green fleshing need to be practiced. • Fleshing wastes need to measured and need to be treated properly to avoid bad smell. • Should not be mixed with any other wastes that contain heavy metals such as chrome shavings
5	Lime trimming wastes	-Not properly segregated -Utilized for production of gelatin and glue but during high production dumped with other wastes causing bad smell	• Lime wastes need to be properly segregated and measured • Lime trimming wastes can also be utilized for production of protein filler to be used in leather re-tanning operation. •
6	Lime splitting	-Not properly segregated -Utilized for production of gelatin and glue to some extent. -sometimes mixed with other wastes and dumped in open land fill	• Proper waste segregation practice need to be implemented • Lime splitting machine need to be adjusted properly for uniform splitting of the pelt for suede leather production from splits. • Should not be mixed with chrome containing wastes. •
7	Chrome containing solid wastes(shaving, buffing, wet blue splitting and trimmings)	-Not properly segregated and in most cases the chrome containing wastes are mixed with other wastes and dumped in open land fill	• There should be chrome management system in the tannery • Chrome containing wastes should not be mixed with any other wastes since it has the probability for chrome oxidation. • Chrome containing wastes need to be recycled and re-used • Chrome containing wastes need to be utilized in tannery itself as an example of circular economy •

8	Crust and finished leather trimming	-There is no proper segregation of wastes and all wastes are mixed and dumped at open land fill causing serious environmental pollution.	• There should be proper segregation practice • Since the waste contain dyestuffs, pigments and other chemicals, it has to be managed separately • Crust and finished trimming wastes can be utilized for production of regenerated leather

Annex V Guidelines for Chicken Feed Preparation Using Leather Tannery Waste

Guidelines for Chicken Feed Preparation Using Leather Tannery Waste

Summary

Producing top-quality chicken feed demands a careful balance of precision and care, from the selection of raw materials to continuous improvement efforts. Prioritizing safety in every step, we start with meticulous raw material selection, ensuring they meet stringent safety and quality standards. By processing waste materials efficiently, we minimize environmental impact and develop a balanced feed formulation that caters to the unique nutritional needs of poultry.

Our specialized mixing equipment ensures uniform nutrient distribution, guaranteeing every bird receives the necessary nourishment. Rigorous quality control processes maintain feed safety, while proper storage and handling keep it fresh and pest-free. Extensive documentation and regulatory compliance are non-negotiable, underscoring our commitment to excellence. In harmony with the environment, we explore recycling opportunities, striving for sustainable feed production.

Our dedication to continuous improvement drives us to stay at the forefront of research, invite customer feedback, and consult poultry experts. It's a journey toward feed perfection, where every step matters, ensuring healthy and productive poultry.

II. Introduction

Welcome to the world of chicken feed production, where precision meets nutrition and safety is paramount. In this journey, we'll explore the essential guidelines and practices that drive the creation of high-quality chicken feed.

From sourcing the finest raw materials to the intricate art of formulation, meticulous mixing, rigorous quality control, and environmental responsibility, this narrative unfolds the secrets behind producing top-notch chicken feed. Join us as we delve into the world of feed production, where every measure is taken to ensure the health and well-being of our poultry, while upholding the highest standards of safety and sustainability

3. Guidelines for Chicken Feed Preparation Using Leather Tannery Waste

Preparing chicken feed using leather tannery waste is an innovative and sustainable approach. However, it's important to follow certain guidelines to ensure the safety, quality, and nutritional value of the feed. Here's a draft of guidelines for preparing chicken feed at leather tanneries (Ahmed et al., 2017; Mottalib et al., 2016; Hossain et al., 2014; Mazumder et al., 2013; Adeel et al., 2012; Rahman et al., 2014; Shaibur, 2023):

3.1 Safety First: Ensuring a Secure Feed Preparation Process

When it comes to preparing chicken feed using leather tannery waste, prioritizing safety is not just a good practice; it's an absolute necessity. Here's an exploration of the safety measures you should rigorously implement:

- Prioritizing Safety:
    - Safety should always be the foremost consideration in your feed production process. It's a commitment that starts at the very top of your organization and should permeate every level.

- Instill a culture of safety consciousness among your workforce. Make sure that everyone understands that their well-being is paramount. This not only protects your employees but also ensures the consistent quality of the feed.

- Personnel Training:
  - Well-trained personnel are the foundation of a safe operation. Provide comprehensive training to all employees involved in the feed production process. This training should encompass various aspects:

  - Chemical Awareness: Train your staff to recognize potential hazards associated with tannery waste. Ensure they understand the chemicals used in the tanning process and their possible risks.

  - Equipment Operation: Familiarize employees with the safe operation of machinery and equipment used in feed production. This includes understanding emergency shutdown procedures.

  - Emergency Response: Conduct regular drills for emergency scenarios such as chemical spills, fires, or accidents. Ensure all employees know how to respond swiftly and appropriately.

  - Hygiene Practices: Emphasize the importance of personal hygiene to prevent contamination of the feed. Employees should follow strict handwashing procedures, especially after handling raw materials.

  - Consider certification or accreditation programs for your personnel, which can be beneficial in demonstrating their competence in safety and quality control.

- Personal Protective Equipment (PPE):
  - Handling raw materials, especially tannery waste, requires the use of appropriate PPE to safeguard employees' health. This includes:

  - Gloves: Provide sturdy gloves designed for chemical resistance. Ensure that employees wear them at all times when handling materials.

  - Masks: Respiratory protection is essential if there's any potential for inhalation of harmful particles or fumes. Provide masks or respirators based on risk assessments.

  - Goggles: Protect the eyes from splashes, dust, or fumes by providing goggles or face shields. Proper eye protection is non-negotiable.

  - Aprons and Coveralls: Depending on the nature of the waste, full-body protection may be necessary. Supply appropriate coveralls and aprons for added safety.

- Regularly inspect and maintain PPE to ensure it's in good condition. Replace damaged or worn equipment promptly.

These safety measures are not only ethical but also legally mandated in many jurisdictions. Neglecting safety can lead to accidents, health issues for your workforce, and regulatory penalties. On the flip side, a safe and healthy work environment boosts employee morale, productivity, and the reputation of your feed production facility.

In summary, by placing safety at the core of your operations, providing extensive training, and ensuring the use of proper protective gear, you create a secure foundation for your chicken feed production facility. Safety isn't just a checkbox; it's a continuous commitment that safeguards your employees, your product, and your reputation.

By adhering to these guidelines, tanneries can responsibly repurpose leather waste into high-quality chicken feed, contributing to sustainability and minimizing environmental impact while ensuring the health and productivity of poultry.

3.2. Raw Material Selection: The Heart of Safe and Quality Feed Production

Selecting the right raw materials is a pivotal step in ensuring the safety, quality, and nutritional value of chicken feed when utilizing leather tannery waste. Here, we delve deeper into the importance of this process:

- Careful Selection Process:

    - Quality Assurance: Your primary concern is the well-being of the poultry that will consume this feed. Therefore, the tannery waste you select must be of high quality and free from contaminants. This waste should come from a trusted source with a reputation for producing safe and clean materials.

    - Contaminant-Free: Leather tannery waste can vary widely in composition. It's essential to ensure that the waste you choose doesn't contain harmful substances. This includes avoiding materials treated with chemicals especially heavy metals that might be toxic to poultry or could negatively impact the quality of the final product. In this particular case, chrome containing wastes shall be avoided due to hazardous nature of chromium so chrome shavings, wet blue trimmings, buffing and dye containing wastes need to be avoided during selection of raw materials. In addition to that the chrome containing liquid wastes shall be avoided since it can contaminate other pre-tanning solid wastes if there is any leakage.

    - Consistency: Maintain consistency in the source of tannery waste to ensure that your feed formulation remains stable and predictable. Inconsistent waste can lead to variations in feed quality and may harm poultry health.

- Regular Testing Protocols:

- Safety Assurance: Regular testing of tannery waste is an absolute necessity. This process involves thorough analysis to identify and quantify any potential contaminants, such as heavy metals, chemical residues, or pathogens.

- Quality Standards: Establish clear quality standards for tannery waste. This should include maximum allowable levels for specific contaminants, ensuring they are well below levels that could harm poultry or violate regulatory guidelines.

- Testing Frequency: Implement a regular testing schedule based on the risk assessment of your supply chain. Higher-risk sources might require more frequent testing. Ensure that testing is conducted by qualified personnel using accredited laboratories.

- Record Keeping: Maintain detailed records of all testing results. These records serve as crucial documentation for ensuring compliance with safety and quality standards and can be valuable in case of audits or recalls.

- Collaboration with Suppliers:

    - Transparent Communication: Foster open communication with your tannery waste suppliers. They should be aware of your safety and quality standards and be committed to meeting them.

    - Audits and Inspections: Periodically audit or inspect your suppliers' facilities to ensure they are adhering to best practices in waste management and safety. This can provide valuable insights into the source of your raw materials.

- Continuous Improvement:

    - Research and Innovation: Stay informed about advancements in waste treatment and tannery processes that can lead to cleaner, safer waste products. Investing in research and development can help optimize your selection process.

    - Feedback Loops: Establish feedback mechanisms with your poultry farm customers. Their observations and feedback can help you refine your raw material selection and processing techniques, ensuring that the feed consistently meets the needs of the poultry.

In conclusion, raw material selection is the foundation of safe and high-quality chicken feed production using leather tannery waste. By being meticulous in your selection process, implementing regular testing procedures, and fostering collaboration with trusted suppliers, you not only protect the health of the poultry but also maintain the reputation and trust of your feed production facility. Continuous improvement ensures that you stay at the forefront of safety and quality standards in the industry.

3.3. Waste Processing: Enhancing Efficiency and Sustainability

The process of transforming leather tannery waste into chicken feed is not solely about ingredient selection; it also involves efficient waste processing. Let's delve deeper into why this step is crucial and how to manage it effectively:

- Particle Size Reduction:
    - Grinding and Shredding**: Leather tannery waste, in its raw form, can be unwieldy and challenging to incorporate into feed formulations. Grind or shred the waste into smaller, more manageable pieces. This increases the surface area and aids in even mixing with other feed ingredients.
    - Facilitating Mixing: Smaller particles ensure that tannery waste disperses uniformly throughout the feed. This is essential for consistency in nutrient distribution, ensuring that each batch of feed provides the necessary nutrition to poultry.
- Waste Management Practices:

    - Odor Control: Tannery waste can be notorious for its strong and unpleasant odor. Implement measures to control and minimize these odors. This not only improves working conditions for your staff but also ensures a more pleasant environment for your facility's neighbors.

    - Environmental Impact: Leather tannery waste can have a significant environmental impact if not managed properly. To mitigate this, consider the following practices:

    - Waste Segregation: Separate tannery waste from other types of waste in your facility. This prevents cross-contamination and allows for more efficient recycling or disposal.

    - Composting: Explore the possibility of composting organic portions of the waste. Composting can help reduce the environmental footprint and even create a valuable byproduct that can be used in agriculture.

    - Regulatory Compliance: Stay informed about local and national regulations governing waste management. Ensure your practices align with these regulations to avoid legal and environmental issues.

    - Efficient Resource Utilization: Evaluate whether there are any useful byproducts that can be extracted from the waste, such as bioenergy or other materials that can be sold or repurposed.
- Continuous Improvement:

    - Research and Development: Keep an eye on emerging technologies and practices in waste management. There may be innovative solutions that can help you process tannery waste more efficiently and sustainably.

    - Employee Training: Train your employees in proper waste handling procedures. This includes safe methods for grinding or shredding waste and best practices for waste management to prevent accidents and ensure compliance with regulations.

- Environmental Responsibility:

    - Community Engagement: Engage with your local community and neighbors to address any concerns they may have regarding waste processing. Being a responsible and transparent member of the community can go a long way in maintaining positive relationships.

    - Environmental Impact Assessment: Periodically assess the environmental impact of your waste processing operations. This can help you identify areas for improvement and demonstrate your commitment to sustainability.

3.4. Formulation: Crafting Optimal Nutrition for Poultry Well-being

The formulation of chicken feed is a precise science that demands careful consideration of various factors to meet the nutritional requirements of poultry. It's a process that impacts the health, growth, and productivity of your birds. Let's delve into the intricacies of feed formulation:

- Balancing Nutritional Requirements:

    - Diverse Needs: Poultry at different stages of life and with different purposes (meat production, egg laying, breeding) have varying nutritional needs. Young chicks need more protein for growth, while layers require nutrients for egg production. Therefore, your feed formulation must account for these differences.

    - Age and Breed: Consider the age and breed of your poultry flock. Different breeds may have distinct dietary requirements. For example, broilers and layers have different nutritional needs due to their distinct roles in poultry farming.

    - Ingredient Selection: Choose feed ingredients that provide the necessary nutrients, including proteins, carbohydrates, fats, vitamins, and minerals, in the right proportions. Leather tannery waste should complement other ingredients to create a well-balanced diet.

- Expert Consultation:

    - Poultry Nutritionists: Collaboration with poultry nutritionists or experts is invaluable. These professionals have a deep understanding of avian nutritional requirements and can help fine-tune your feed formulation.

    - Nutritional Analysis: Conduct comprehensive nutritional analysis of your feed ingredients, including the tannery waste. This analysis can reveal the precise nutrient content of each ingredient and guide your formulation.

- Optimizing Costs: Nutritionists can help you create formulations that meet poultry dietary needs while optimizing costs. They can identify cost-effective ingredient combinations without compromising on nutrition.

- Feed Testing and Quality Assurance:

  - **Batch Testing**: After formulating the feed, perform batch testing to ensure that the actual feed matches the intended formulation. This helps identify any discrepancies and ensures that the birds receive the expected nutrition.

  - Quality Control: Implement strict quality control measures at every stage of feed production. This includes ingredient testing, in-process checks, and final product analysis to maintain consistency and quality.

- Flexibility and Adaptability:

  - Changing Needs: Poultry nutritional needs can change based on factors such as season, health status, and production goals. Your feed formulation should be flexible enough to adapt to these changes while maintaining nutritional integrity.

  -Monitoring and Adjusting: Regularly monitor the performance of your birds. If you observe any issues such as slow growth or declining egg production, consult with a poultry nutritionist to adjust the feed formulation accordingly.

- Compliance and Regulations:

  - Regulatory Compliance: Ensure that your feed formulation adheres to local and national regulations governing animal feed. Compliance is not only a legal requirement but also essential for the health of your birds and the safety of consumers.

- Record Keeping:

  - Detailed Records: Maintain comprehensive records of your feed formulations, including the specific ingredients used, their quantities, and any adjustments made. These records are crucial for quality control, compliance, and future reference.

3.5. Mixing and Blending: The Art of Uniformity in Chicken Feed Production

The mixing and blending phase of chicken feed production is where individual ingredients unite to create a homogeneous, nutritionally balanced product. It's a critical step that requires precision and specialized

equipment to ensure uniformity and maximize the nutritional benefits of your feed. Let's delve into this crucial process:

- Specialized Mixing Equipment:
    - Ribbon Mixers or Paddle Mixers: These are commonly used in feed production. They have horizontal agitators that move ingredients in both directions, providing efficient and thorough mixing.
    - Vertical Mixers: These mixers lift ingredients upward and then drop them through a rotating drum, facilitating an even blend.
    - Batch vs. Continuous Mixers: Consider the scale of your operation. Batch mixers are suitable for smaller operations, while continuous mixers are more efficient for larger-scale production.
    - Cleanliness and Maintenance: Regularly clean and maintain your mixing equipment to prevent contamination and ensure consistent performance.
- Uniform Nutrient Distribution:
    - Balanced Nutrition: The goal of feed mixing is to ensure that every batch of feed contains a consistent distribution of nutrients. This guarantees that every bird receives the essential nutrients it needs for growth, health, and productivity.
    - Micro-Ingredients: Pay particular attention to micro-ingredients like vitamins and minerals, as these are required in small quantities but are critical for poultry health. Uniform distribution is essential to prevent nutrient imbalances.
- Consistency in Mixing Ratios:
    - Precision: Accurate measurement of ingredients is paramount. Even small deviations in mixing ratios can have a significant impact on the nutritional quality of the feed.
    - Monitoring Systems: Consider implementing monitoring systems that track the input and output of ingredients during the mixing process. This allows for real-time adjustments to maintain the desired ratios.
- Hygiene and Safety:
    - Cleanliness: Ensure that all equipment, containers, and tools used in the mixing process are clean and free from contaminants. Any contamination at this stage can affect the entire batch of feed.

- Safety Measures: Continue to prioritize safety. Operators should use appropriate personal protective equipment (PPE) and follow safe operating procedures while handling ingredients and operating mixing equipment.

- Test Batches:

    - Quality Assurance: Before full-scale production, consider running test batches to verify that the mixing process results in the desired uniformity and nutritional content. This can help you fine-tune your process and ensure consistency.

- Regular Maintenance and Calibration:

    - Equipment Maintenance: Routine maintenance and calibration of mixing equipment are critical. Over time, wear and tear can affect the performance of mixers. Regular checks and maintenance prevent production issues.

- Documentation:

    - Batch Records: Maintain detailed batch records that document the mixing process for each production run. These records are essential for quality control, troubleshooting, and traceability.

3.6. Quality Control: Safeguarding Poultry Nutrition and Safety

Quality control is the cornerstone of any successful chicken feed production operation. It's the process that ensures that every batch of feed meets not only the required nutritional standards but also the stringent safety and quality standards necessary for the well-being of your poultry flock. Let's dive into the nuances of this crucial aspect:

- Quality Control Process:

    - **Design a Comprehensive Plan**: Establish a systematic quality control process that spans the entire production cycle, from raw material intake to finished feed packaging. This plan should detail procedures, responsibilities, and key performance indicators.

    - **Real-Time Monitoring**: Implement real-time monitoring systems that allow you to track ingredient inputs, mixing ratios, and other critical parameters. This helps catch deviations immediately and prevent issues from escalating.

    - **Documentation**: Maintain detailed records of all quality control checks and results. These records provide a traceable history of each batch and are invaluable for audits and regulatory compliance.

- Nutritional Content Assessment:

- **Regular Testing**: Regularly test samples from each batch of feed for their nutritional content. This includes analyzing protein, fat, fiber, vitamins, minerals, and other nutrients. Any deviations from the formulation should trigger corrective actions.

- **Ingredient Variability**: Understand that ingredient quality can vary over time due to factors like seasonality and supplier changes. Adjust feed formulations as needed to account for these variations.

- **Micro-Ingredients**: Pay special attention to micro-ingredients, like vitamins and minerals, which are required in small quantities but are vital for poultry health. Deviations in these components can have significant impacts.

- Contaminant Testing:

    - **Pathogen Monitoring**: Implement regular testing for pathogens such as Salmonella and E. coli. Contaminated feed can lead to disease outbreaks among poultry.

    - **Heavy Metals and Toxins**: Test for the presence of heavy metals, mycotoxins, and other contaminants that can enter the feed through raw materials or processing equipment. Establish maximum allowable limits and take corrective actions if these are exceeded.

- Corrective Actions:

    - Immediate Response: When variations or issues are detected through quality control checks, take immediate corrective actions. This might include adjusting the feed formulation, recalibrating equipment, or addressing the root cause of the problem.

    - Traceability: Maintain strict traceability of all batches to identify the source of any issues. This is essential for recall procedures, should they ever be necessary.

    - **Root Cause Analysis**: Investigate the underlying causes of any quality control issues. This analysis helps prevent future occurrences and continuously improves your production process.

- Continuous Improvement:

    - Feedback Loops: Foster a culture of continuous improvement. Encourage feedback from your quality control team, production staff, and even customers. Use this feedback to refine your processes and enhance product quality.

- Stay Informed: Keep up-to-date with advancements in feed production technology and nutritional science. Implement innovations that can further enhance quality control and nutritional precision.

- Regulatory Compliance:

  - Know the Regulations: Stay well-informed about the regulations governing chicken feed production in your region. Ensure that your quality control procedures are aligned with these standards.

- Training and Education:

  - Team Training: Invest in training programs for your quality control personnel. Ensure that they are well-versed in the latest testing techniques and industry best practices.

- External Audits:

  - **Third-Party Audits**: Consider third-party audits to validate the effectiveness of your quality control processes. This can enhance trust among customers and regulatory agencies.

In summary, quality control in chicken feed production is a meticulous and multi-faceted process that safeguards both poultry nutrition and safety. By implementing a rigorous quality control plan, conducting regular testing, and responding swiftly to any deviations, you not only ensure that your feed consistently meets nutritional and safety standards but also demonstrate a commitment to the health and well-being of your poultry and the success of your operation.

3.7. Storage and Handling: Preserving the Quality and Safety of Chicken Feed

Storage and handling practices for chicken feed are critical to maintaining the quality, safety, and effectiveness of the feed. These practices ensure that the poultry receive nutritious and uncontaminated feed while also preventing waste. Here's a detailed exploration:

- Storage Conditions:

  - Clean and Dry Storage: Store prepared feed in a clean, dry, and well-ventilated area. Moisture is a major threat to feed quality, as it can lead to mold growth and spoilage. Ensure the storage facility is free from leaks and humidity.

  - Pest-Proof Containers: Use pest-proof containers to prevent infestations. Rodents, insects, and birds are common pests that can contaminate the feed. Invest in containers with secure lids and seals to keep these pests out.

  - Temperature Control: Maintain consistent storage temperatures. Extreme heat or cold can affect the nutritional content and stability of the feed. Ideally, the storage area should be cool and protected from direct sunlight.

- Air-Tight Containers: If possible, store feed in air-tight containers to prevent oxidation, which can degrade certain nutrients. Vacuum-sealed bags or containers with gaskets are effective for this purpose.

- Elevated Storage: Elevating feed off the ground helps prevent moisture seepage and pest access. Pallets or shelves can serve this purpose.

- Labeling and Documentation:

    - Production Dates: Clearly label feed containers with production dates. This allows for easy monitoring of feed freshness and helps with inventory management (first-in, first-out).

    - Ingredient Lists: Include a complete list of ingredients and their proportions on the label. This is crucial for traceability and for addressing potential allergens in the feed.

    - Usage Instructions: Provide clear usage instructions, including recommended feeding rates, especially if you have different formulations for various stages of poultry growth.

    - Lot Numbers: Assign lot numbers to each batch of feed. This helps in tracking specific batches in case of quality concerns or recalls.

    - Storage Recommendations: Include storage recommendations on the label, such as temperature guidelines and precautions against pests.

- Inventory Management:

    - First-In, First-Out (FIFO): Implement a FIFO system for managing inventory. This means using the oldest feed first to minimize spoilage and ensure that poultry receive fresh and nutritionally sound feed.

    - Regular Inventory Audits: Conduct regular audits of your feed inventory to identify expired or soon-to-expire feed. These can be isolated and used promptly or discarded if necessary.

- Hygiene and Sanitation:

    - Cleaning Procedures: Routinely clean storage containers and areas to prevent contamination. Use food-safe sanitizers if necessary.

    - Sanitizing Equipment: If you use scoops or utensils to handle feed, ensure they are regularly cleaned and sanitized.

    - Personal Hygiene: Promote good personal hygiene among those handling the feed. Employees should wash their hands thoroughly before and after handling feed to prevent contamination.

- Quality Checks:

    - Visual Inspections: Regularly inspect stored feed for signs of spoilage, such as mold, insects, or off-odors. Any compromised feed should be removed immediately.

    - Sampling and Testing: Periodically sample and test stored feed to ensure it still meets the intended nutritional specifications. Address any deficiencies or issues promptly.

- Emergency Measures:
    - Emergency Preparedness: Have a plan in place for emergencies such as power outages or equipment failures. This might include backup generators or alternative storage arrangements.

3.8. Documentation: The Backbone of Accountability and Quality Assurance

Maintaining comprehensive records in chicken feed production is more than just a matter of good practice; it's a critical element for ensuring accountability, traceability, and continuous improvement. Let's delve into the importance and components of effective documentation:

- Ingredient Quantities:

    - Accurate Recording: Precise measurements of all feed ingredients are crucial for consistency. Record the quantity of each ingredient used in each batch of feed. This helps in assessing ingredient costs and allows for troubleshooting if issues arise.

    - Supplier Details: Include details about the suppliers of ingredients. This information can be vital in case of recalls or quality concerns related to specific batches.

- Production Dates:

    - Date and Time Stamps: Document the date and time of each feed production batch. This is essential for ensuring feed freshness, adherence to shelf life, and efficient inventory management using the first-in, first-out (FIFO) system.

    - Shift Information: If your production runs span multiple shifts or teams, note the shift or team responsible for each batch. This can help pinpoint any variations that occur between shifts.

- Quality Control Checks:

    - Thorough Records: Maintain detailed records of all quality control checks conducted during feed production. Include information about the tests performed, the results obtained, and any actions taken in response to deviations.

    - Sampling Protocols: Specify how samples were collected and from which parts of each batch. Proper sampling procedures are essential for accurate quality assessment.

- Corrective Actions:

    - Documentation of Issues: Whenever variations or issues are detected through quality control checks or other means, document the nature of the problem, its potential causes, and the corrective actions taken. This information is invaluable for preventing recurrences.

    - Resolution Timeline: Include information about the timeline for resolving issues. This helps track how quickly corrective actions were implemented.

- Incidents and Deviations:

    - Detailed Incident Reports: For any significant incidents, deviations from standard procedures, or adverse events in the feed production process, create comprehensive incident reports. These should document the circumstances, actions taken, and resolutions.

    - Root Cause Analysis: For recurring incidents or deviations, conduct thorough root cause analyses. Document the findings and actions taken to prevent future occurrences.

- Regulatory Compliance:

    - Compliance Records: Maintain records demonstrating compliance with all relevant regulations governing feed production, safety, and labeling. These records are essential for audits and inspections.

    - Labeling Documentation: Keep records of labeling compliance, including ingredient lists, nutritional claims, and usage instructions on feed packaging.

- Communication Logs:

    - Supplier Communications: Record communications with ingredient suppliers, including orders, confirmations, and any issues raised.

    - Customer Feedback: Document customer feedback, both positive and negative. This information can guide improvements in feed quality and customer satisfaction.

- Archiving and Accessibility:

    - Safe Archiving: Store all documentation in a secure and organized manner. Consider digital record-keeping systems for ease of retrieval and backup.

    - Accessibility: Ensure that key personnel have access to necessary documentation. This facilitates quick responses to quality control issues and regulatory inquiries.

- Continuous Improvement:

    - Analysis and Review: Regularly review documentation to identify trends, recurring issues, or areas for improvement in your feed production process. Use this information to refine procedures and enhance quality.

- Training and Accountability:

    - Training Records: Keep records of employee training and certification in areas related to feed production and quality control. This demonstrates a commitment to staff competence.

- Emergency Response:

    - Emergency Plans: Document emergency response plans and procedures. This includes steps to be taken in case of equipment failures, contamination incidents, or natural disasters.

3.9. Environmental Considerations: Sustainable Practices in Chicken Feed Production

Environmental responsibility in chicken feed production is crucial not only for minimizing the ecological impact but also for ensuring long-term sustainability and regulatory compliance. Here's a comprehensive exploration of environmental considerations:

- Waste Disposal Mitigation:

    - Efficient Waste Management: Implement efficient waste management practices to minimize the environmental impact of waste disposal. This includes proper handling, storage, and disposal of waste materials generated during feed production.

    - Reduce, Reuse, Recycle: Prioritize the "3 Rs" – reduce, reuse, and recycle. Minimize waste generation wherever possible by optimizing processes. Consider reusing certain waste materials in other aspects of your operation.

    - Compliance with Regulations: Ensure compliance with local and national regulations governing waste disposal. Understand the requirements for different types of waste materials, including tannery waste, and dispose of them in accordance with applicable laws.

- Recycling and Repurposing:

    - Waste By-Products: Explore opportunities to recycle or repurpose waste by-products generated during feed production. For example, consider composting organic waste or extracting valuable components from waste materials.

- Resource Recovery: Investigate whether there are valuable resources, such as energy or nutrients, that can be recovered from waste streams. Technologies like anaerobic digestion can convert organic waste into biogas, which can be used as an energy source.

- Collaboration: Collaborate with other businesses or organizations that may have a use for your waste by-products. For instance, leather tannery waste might have applications in other industries, such as textiles or construction.

- Sustainable Sourcing:

    - Responsible Ingredient Procurement: Choose ingredient suppliers who follow environmentally responsible practices. This includes considerations like sustainable agriculture, responsible fishing, and ethical sourcing of raw materials.

    - Certifications: Look for suppliers and ingredients that have recognized certifications for sustainable and environmentally friendly practices, such as organic or Fair-Trade certifications.

- Energy Efficiency

    - Efficient Equipment: Invest in energy-efficient equipment for feed production. This reduces energy consumption and lowers greenhouse gas emissions associated with electricity or fuel use.

    - Renewable Energy: Consider transitioning to renewable energy sources, such as solar or wind power, to meet your energy needs. These sources are not only eco-friendly but can also result in long-term cost savings.

- Water Conservation:

    - Efficient Water Use: Implement water-efficient practices in your production process. This includes using water recycling systems and minimizing water wastage.

    - Monitoring and Reduction: Regularly monitor water consumption and look for opportunities to reduce usage. Implementing a water management plan can help identify and address areas of inefficiency.

- Biodiversity and Ecosystem Impact:

    - Assessment: Evaluate the impact of your feed production on local ecosystems and biodiversity. Implement measures to protect and preserve natural habitats.

    - Habitat Restoration: Consider participating in habitat restoration or conservation initiatives as part of your corporate social responsibility efforts.

- Public Awareness and Education:

- Engagement: Engage with your local community and stakeholders to raise awareness about your environmental efforts and share best practices for sustainable agriculture.

- Consumer Education: Educate consumers about the environmental benefits of choosing products that are produced using sustainable and environmentally responsible practices.

3.10. Regulatory Compliance in Feed Production: Navigating the Legal Landscape

Navigating the complex web of regulations governing feed production is essential to ensure not only the quality and safety of your chicken feed but also the legal and ethical operation of your business. Here's an in-depth exploration of regulatory compliance in feed production:

- Understanding the Regulatory Landscape:

    - Local, Regional, and National Levels: Regulations governing feed production can vary significantly from one locality, region, or nation to another. Familiarize yourself with regulations at all levels that apply to your operation.

    - Government Agencies: Identify the government agencies responsible for overseeing feed production regulations in your area. This might include departments of agriculture, health, or environmental agencies.

- Safety Standards:

    - Ingredient Safety: Ensure that all feed ingredients, including leather tannery waste, meet safety standards and are approved for use in animal feed. Some materials may have restrictions or require special permits.

    - Contaminant Levels: Understand limits on contaminants, such as mycotoxins, heavy metals, and pathogens, in feed ingredients and final products. Regularly test for these contaminants to maintain compliance.

    - Labeling Requirements: Comply with labeling regulations that dictate what information must be included on feed packaging. This often includes ingredient lists, nutritional information, and usage instructions.

- Environmental Compliance:
    - Waste Disposal: Adhere to environmental regulations regarding waste disposal, especially for materials like leather tannery waste. Understand how to properly handle, store, and dispose of waste in accordance with local laws.

    - Water and Air Quality: Be aware of regulations related to water and air quality, especially if your feed production facility is located near sensitive ecosystems or residential areas. Implement practices to minimize environmental impact.

- Permits and Reporting: Ensure that you have any required permits related to environmental compliance. Be prepared to report on your environmental impact as required by law.

- Safety and Health Regulations:

    - Employee Safety: Comply with workplace safety regulations to protect the health and well-being of your employees. This includes providing proper training, personal protective equipment (PPE), and safety protocols.

    - Record-Keeping: Maintain records related to workplace safety, such as incident reports, safety training logs, and equipment maintenance records.

- Compliance Audits and Inspections:

    - Regular Audits: Proactively conduct internal compliance audits to identify and address potential issues before external inspections occur.

    - External Inspections: Be prepared for external inspections by regulatory authorities. This includes having all necessary records and documentation readily available for review.

** Industry Associations and Standards:**

- **Participation**: Consider joining industry associations related to poultry or feed production. These organizations often provide guidance on regulatory compliance and industry best practices.

- **Voluntary Standards**: Familiarize yourself with any voluntary industry standards that are relevant to your feed production. Adhering to these standards can enhance the quality and safety of your products.

** Legal Counsel and Expert Consultation:**

- **Legal Advisors**: Seek legal counsel or consult with experts in feed production regulations. They can help you interpret complex regulations and ensure that your business operates within the law.

- **Continuous Education**: Stay informed about changes in regulations and attend relevant training or seminars to keep your knowledge up-to-date.

3.11. Continuous Improvement in Feed Production: The Path to Excellence

Continuous improvement is the engine that drives excellence in feed production. It involves a commitment to refining processes, embracing innovation, and actively seeking feedback from stakeholders to optimize feed quality and nutritional performance. Here's a comprehensive exploration of the principles and practices of continuous improvement in feed production:

- Research and Emerging Best Practices:

- Stay Informed: Keep abreast of the latest research findings, scientific advancements, and industry best practices related to feed production and poultry nutrition. Subscribe to academic journals, attend conferences, and engage with research institutions to access cutting-edge knowledge.

- Adopt Innovative Technologies: Embrace emerging technologies that can enhance the efficiency and precision of your feed production processes. For example, automated mixing systems and advanced quality control tools can improve consistency and safety.

- Nutritional Research: Pay particular attention to advancements in poultry nutritional science. Nutritional needs and preferences evolve, so your feed formulations should reflect the most current understanding of avian nutrition.

- Customer Feedback:

    - Feedback Mechanisms: Establish effective channels for receiving feedback from your customers, including poultry farmers and distributors. Encourage them to report any issues or provide suggestions for improvement.

    - Customer Surveys: Conduct periodic surveys to gather structured feedback on feed quality, effectiveness, and customer satisfaction. Use this information to identify areas for improvement.

- Expert Consultation:

    - Poultry Nutritionists: Collaborate with poultry nutritionists or experts who can evaluate your feed formulations and offer recommendations for optimization. They can help fine-tune the nutritional profiles to achieve better performance and health outcomes for poultry.

    - Quality Control Experts: Work with quality control experts who can help you implement more robust quality control processes and assess opportunities for streamlining production while maintaining safety and consistency.
- Performance Metrics and Benchmarking:

    - Establish Metrics: Define key performance indicators (KPIs) to measure various aspects of your feed production process, from ingredient sourcing to quality control. These metrics might include ingredient costs, batch consistency, and customer satisfaction.

    - Benchmarking: Compare your performance against industry benchmarks or competitors to identify areas where you can excel or areas that need improvement.

- Employee Training and Engagement:

- Continuous Learning: Invest in ongoing training and development for your employees. Informed and skilled employees are more likely to contribute to continuous improvement efforts.

- Engagement: Foster a culture of engagement and continuous improvement among your staff. Encourage them to identify and suggest improvements in their daily tasks.

- Root Cause Analysis:

    - Problem-Solving Approach: When issues or deviations occur, adopt a structured approach to identify and address the root causes. This prevents recurring problems and promotes long-term stability.

    - Data-Driven Analysis: Utilize data and analytics to understand the underlying factors contributing to issues or inefficiencies in your feed production.

- Iterative Process:

    - Plan-Do-Check-Act (PDCA): Embrace the PDCA cycle, a systematic approach to continuous improvement. It involves planning a change, implementing it, checking the results, and acting based on those results to refine the process further.

    - Iterate: Understand that continuous improvement is an iterative process. What works today may need adjustment tomorrow as circumstances evolve.

- Sustainability Initiatives:

    - Environmental Impact: Include sustainability initiatives in your continuous improvement efforts. Explore ways to reduce environmental impact, such as waste reduction, energy efficiency, and responsible sourcing.

    - Social Responsibility: Consider initiatives that promote social responsibility, including fair labor practices and community engagement. These can enhance your reputation and strengthen relationships with stakeholders.

Conclusion

In conclusion, the guidelines for chicken feed preparation using leather processing tannery waste offer a comprehensive blueprint for a sustainable, safe, and efficient production process. From the careful selection of raw materials to rigorous quality control and environmental responsibility, these guidelines reflect a commitment to excellence.

By prioritizing safety, embracing continuous improvement, and adhering to regulatory compliance, we not only ensure the well-being of our poultry but also contribute to the growth of a healthier, more sustainable poultry industry. Through these practices, we strive to make a positive impact, not only in the feed we produce but also in the world we share with our feathered friends.

Recommendations:

Based on the drafted guidelines for chicken feed preparation at Modjo Leathers Tanneries, the following recommendations are proposed to enhance the efficiency, safety, and sustainability of the feed production process:

1. Enhance Training Programs: Invest in comprehensive training programs for personnel involved in feed production. Ensure they are well-versed in safety protocols, quality control procedures, and environmental responsibility.

2. Regular Environmental Audits: Conduct regular environmental audits to assess the impact of waste disposal practices. Explore opportunities for further waste recycling or repurposing to minimize environmental harm.

3. Continuous Quality Monitoring: Implement real-time monitoring systems to track ingredient inputs, mixing ratios, and quality control checks. This helps in immediate issue detection and resolution.

4. Supplier Collaboration: Strengthen collaboration with ingredient suppliers to ensure consistent quality and safety of raw materials. Consider long-term partnerships with those who share a commitment to sustainability.

5. Customer Feedback Loop: Establish a structured customer feedback system to collect insights on feed quality, effectiveness, and satisfaction. Use this data for ongoing improvement.

6. Research and Development: Allocate resources for research and development initiatives. Stay at the forefront of nutritional science to fine-tune feed formulations for optimal poultry health and performance.

7. Sustainable Sourcing: Continuously evaluate ingredient sourcing practices to align with sustainable and ethical standards. Seek certifications and accreditations that reflect responsible sourcing.

8. Energy Efficiency: Explore energy-efficient technologies and renewable energy sources to minimize the environmental footprint of the production facility.

9. Water Conservation: Enhance water conservation efforts by implementing water recycling systems and efficient water usage practices.

10. Compliance Audits: Regularly conduct internal compliance audits to identify and rectify any deviations from regulatory requirements or best practices.

11. Employee Empowerment: Empower employees to actively participate in continuous improvement efforts. Encourage them to identify areas for enhancement and provide a platform for sharing ideas.

12. Community Engagement: Strengthen ties with the local community through outreach and social responsibility initiatives. Foster a positive image as a responsible corporate entity.

By implementing these recommendations, Mojo Leathers Tanneries can further elevate its chicken feed production, not only meeting industry standards but also exceeding them. This commitment to excellence will lead to healthier poultry, reduced environmental impact, and a positive contribution to the local community."

References

Ahmed, S., Fatema-Tuj-Zohra, Khan, M.S.H., Hashem, M.A., 2017. Chromium from tannery waste in poultry feed: A potential cradle to transport human food chain. Cogent Environ. Sci. 3. https://doi.org/10.1080/23311843.2017.1312767

Adeel S. S., A. Wajid, S. Hussain, F. Malik, Z. Sami, I. U. Haq, A. Hameed and R. Channa, Recovery of chromium from tannery wastewater by using bacillus subtilis in Guranwala. Pakistan Journal of Pharmacy and Biological Sciences, 2(2), 2012, 36-45.

Ayele, M., Limeneh, D.Y., Tesfaye, T., Mengie, W., Abuhay, A., Haile, A., Gebino, G., 2021. A Review on Utilization Routes of the Leather Industry Biomass. Adv. Mater. Sci. Eng. 2021. https://doi.org/10.1155/2021/1503524

Chaudhary, R., Pati, A., 2016. Poultry feed based on protein hydrolysate derived from chrome-tanned leather solid waste: creating value from waste. Environ. Sci. Pollut. Res. 23, 8120–8124. https://doi.org/10.1007/s11356-016-6302-4

Chojnacka, K., Skrzypczak, D., Mikula, K., Witek-Krowiak, A., Izydorczyk, G., Kuligowski, K., Bandrów, P., Kułażyński, M., 2021. Progress in sustainable technologies of leather wastes valorization as solutions for the circular economy. J. Clean. Prod. 313. https://doi.org/10.1016/j.jclepro.2021.127902

Elsayed, N.H., Taha, G.M., Mohamed, O.A., 2021. Industrial Gelatin from Leather Chrome Shavings Wastes. J. Biomed. Res. Environ. Sci. 2, 1035–1043. https://doi.org/10.37871/jbres1346

Framis, C.P., 2018. "Assessment of tannery solid waste management, A case of Sheba Leather Industry in Wukro (Ethiopia)" 1–92.

Hossain M. A., Z. Hasan, Excess amount of chromium transport from Tannery to human body through poultry Feed in Bangladesh and its carcinogenic effects. International Journal of Civil, Structural, 4(4), 2014, 1-10.

Hussain, F.S., Memon, N., Khatri, Z., Memon, S., 2020. Solid waste-derived biodegradable keratin sponges for removal of chromium: A circular approach for waste management in leather industry. Environ. Technol. Innov. 20, 101120. https://doi.org/10.1016/j.eti.2020.101120

Mazumder L. T., S. Hasan and M. L. Rahman, Hexavalent chromium in tannery solid waste based poultry feed in Bangladesh and its transfer to food chain. IOSR Journal of Environmental Science, Toxicology and Food Technology, 3(4), 2013, 44-51.

Jambulingam, R., Srinivasan, G.R., Palani, S., Munir, M., Saeed, M., Mohanam, A., 2020. Process optimization of biodiesel production from waste beef tallow using ethanol as co-solvent. SN Appl. Sci. 2, 1–18. https://doi.org/10.1007/s42452-020-03243-7

Li, Y., Guo, R., Lu, W., Zhu, D., 2019. Research progress on resource utilization of leather solid waste. J. Leather Sci. Eng. 1, 1–17. https://doi.org/10.1186/s42825-019-0008-6

Mottalib, M.A., Sultana, A., Somoal, S.H., Abser, M.N., 2016. Assessment of Heavy Metals in Tannery Waste-Contaminated Poultry Feed and Their Accumulation in Different Edible Parts of Chicken. IOSR J. Environ. Sci. 10, 72–78. https://doi.org/10.9790/2402-1011017278

Onenc, S., Kilincli, O., Ismail, C.K., Yilmaz, O., Yanik, J., 2011. Use of solid wastes from the leather industry as an adsorbent. J. Residuals Sci. Technol. 8, 131–139.
Pahlawan, I.F., Sutyasmi, S., Griyanitasari, G., 2019. Hydrolysis of leather shavings waste for protein binder. IOP Conf. Ser. Earth Environ. Sci. 230. https://doi.org/10.1088/1755-1315/230/1/012083
Priebe, G.P.S., Kipper, E., Gusmão, A.L., Marcilio, N.R., Gutterres, M., 2016. Anaerobic digestion of chrome-tanned leather waste for biogas production. J. Clean. Prod. 129, 410–416. https://doi.org/10.1016/j.jclepro.2016.04.038
Rahman, M.A., Kamal, S., Salam, A., Salam, M.A., 2014. Assessment of the Quality of The Poultry Feed and its Effect in Poultry Products in Bangladesh. J. Bangladesh Chem. Soc. 27.
Rigueto, C.V.T., Rosseto, M., Krein, D.D.C., Ostwald, B.E.P., Massuda, L.A., Zanella, B.B., Dettmer, A., 2020. Alternative uses for tannery wastes: a review of environmental, sustainability, and science. J. Leather Sci. Eng. 2. https://doi.org/10.1186/s42825-020-00034-z
Shaibur, M.R., 2023. Heavy metals in chrome-tanned shaving of the tannery industry are a potential hazard to the environment of Bangladesh. Case Stud. Chem. Environ. Eng. 7, 100281. https://doi.org/10.1016/j.cscee.2022.100281
Sinkiewicz, I., Śliwińska, A., Staroszczyk, H., Kołodziejska, I., 2017. Alternative Methods of Preparation of Soluble Keratin from Chicken Feathers. Waste and Biomass Valorization 8, 1043–1048. https://doi.org/10.1007/s12649-016-9678-y
Stefan, D.S., Bosomoiu, M., Constantinescu, R.R., Ignat, M., 2021. Composite polymers from leather waste to produce smart fertilizers. Polymers (Basel). 13, 1–21. https://doi.org/10.3390/polym13244351
Sundar, J., 2023. The study of plant growth promoter production from leather industrial solid waste. Int. J. Recycl. Org. Waste Agric. 12, 47–57. https://doi.org/10.30486/ijrowa.2022.1945254.1375
Xu, L., Geelen, D., 2018. Developing biostimulants from agro-food and industrial by-products. Front. Plant Sci. 871, 1–13. https://doi.org/10.3389/fpls.2018.01567