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Histoarchitecture of albino rat's liver

Bioremediation of Abattoir Effluent: Implication for Bioproduct Synthesis

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ABSTRACT

Globally, Abattoirs produce a considerable amount of byproducts from animals. Although these byproducts are a valuable source of industrial proteins which could be used for a variety of value-added applications, they are currently either underutilized in high-value applications or used in the production of relatively low-value products such as pet food and animal feed . In addition, some byproducts of animal slaughter do not fit in the food and feed chains, thus making their disposal in the environmental a major concern. Waste processing is revolutionized, thus, use of Abattoir waste can be incorporated into the industrial processes with the aim of producing value-added bio-based products such as biogas, biofertilizers, biosurfactants, bioethanol, enzymes and single cell proteins, to name a few. Energy transition through waste to energy pathways leading to biogas production and electricity will help mitigate greenhouse gas emissions. Furthermore, byproducts from abattoir effluents could be used to make high-value items such as animal feed, glue, and fertilizers. The current study evaluated biodegradation of abattoir waste for value added product production under related critical topics such as abattoir waste composition, abattoir waste treatment, and strategies involved with an emphasis on bioremediation/biodegradation and biodegradation's implications for bioproduct formation. The study infers that a sustainable transition of energy and a cleaner environment lies in conversion of Abattoirs waste to wealth.

INTRODUCTION

The impact of indiscriminate abattoir effluent discharge has been a source of pollution around the world due to its severe impact on people and environmental health. The lack of waste treatment plants and standards for adequate disposal in many developing countries causes a slew of other environmental issues in the afflicted countries. Much research has emphasized the role of abattoir wastewater as a nutritional source for pathogenic bacteria. Our environment is confronted with major issues due to large waste volumes and insufficient garbage disposal systems, particularly in developing countries [1]. Abattoirs are facilities where animals such as cows, sheep, goats, and the like are butchered for human consumption. Livestock production at abattoirs is regarded as a possible food source mostly for the poor, and massive amounts of Abattoirs waste are generated during meat processing [2].

The hazard of Abattoirs waste emanating from poor abattoir waste management can thus put the demand for oxygen on the receiving environment thus producing a large population of microorganisms (decomposers), of which some may be pathogenic [3]. Rapid urbanization in low-income countries is putting enormous strain on massive amounts of abattoir waste in cities. From farm to fork, the production of meat comprises not only for human consumption but also for useful byproducts such as leather and skin, but also garbage. Relatively high quantities of liquid, fats and suspended solid of distinct nature are generated from Abattoirs [4]

The undeveloped and developing countries have the weakest waste management programs. A good number of them are deficient in strategies used for the disposal of liquid and solid waste generated from abattoirs. According to FAO [2], these wastes are dumped indiscriminately or washed away without any further processing. The quantity and nature of the wastes varies although it includes animal parts that are inedible, animal carcasses, bones, blood and hides [5].

Furthermore, abattoir effluent has a high volume of organic load which consists of a significant number of suspended particles in the waste. This generates contamination and has the capacity to damage the water, soil and air thus posing health risks [6]. Abattoir wastes have impact on aquatic life, quality of air, agriculture, and potable water supplies, as well as posing health hazards and causing methemoglobin anemia [7]. Despite this, a massive volume of waste generated by abattoirs is simply discarded and released into the open environment with no management system or treatment, The treatment of abattoir effluent remains the most reliable and efficient method of reducing the environmental pollution that it may cause. Environmental pollutants released through effluent by abattoirs may be complicated due to changes brought about by additional substances used during animal processing [8].

Abattoir waste has been treated using a variety of methods, including bioremediation or biodegradation, physical and chemical treatments, trickling filters, landfills, activated sludge, wastewater lagoons, and so on. However, bioremediation provides the dual benefits of providing a sustainable, cost-effective treatment and a safer environment, and it can be used to produce value-added bioproducts. Thus, this study focused on bioremediation of abattoir waste for value-added product production under related critical topics such as abattoir waste composition, abattoir waste treatment, and strategies involved, with an emphasis on bioremediation and the implications of bioremediation for bioproduct formation

Abattoir Effluent Composition

Proper techniques for assessing the characteristics of waste disposed by the meat processing sector are challenging to develop. Monitoring a specific plant and its waste is tough due to many processes as well as several components of techniques utilized in carcass processing. Furthermore, a large proportion of pollutant load in the form of effluents emitted by abattoirs are believed to fluctuate on a regular basis [9]. Because of its unique properties, changing composition at the time of release, and considerable amount of mineral, biogenic, and organic debris, liquid effluent emitted from abattoirs is incredibly challenging in terms of treatment or purification.

Pollution's main indices, such as effluent composition, can serve as the primary indication of pollution. The indicator components include suspended particles, COD, organic nitrogen, BOD, and lipids, which are typically many times greater than ordinary home sewage released. Because of the difference between industrial and domestic effluents, abattoir effluent cannot be discharged directly into natural water bodies or a township sewage discharge system. Chemical and biological contaminants are present in abattoir effluents as colloids, suspended particles, and dissolved chemicals [10]. Figure 1 below shows a flow of processes involved in meat processing and associated waste generation.

Effects of Untreated Abattoir Wastewater on Environment, Plants and Animals

Effects of Untreated Abattoir Effluent on the Environment

The slaughter of animals is viewed by the global population as a potential source of protein as well as a contaminant [11]. Abattoir activities have effects on the people who live nearby either directly or indirectly.

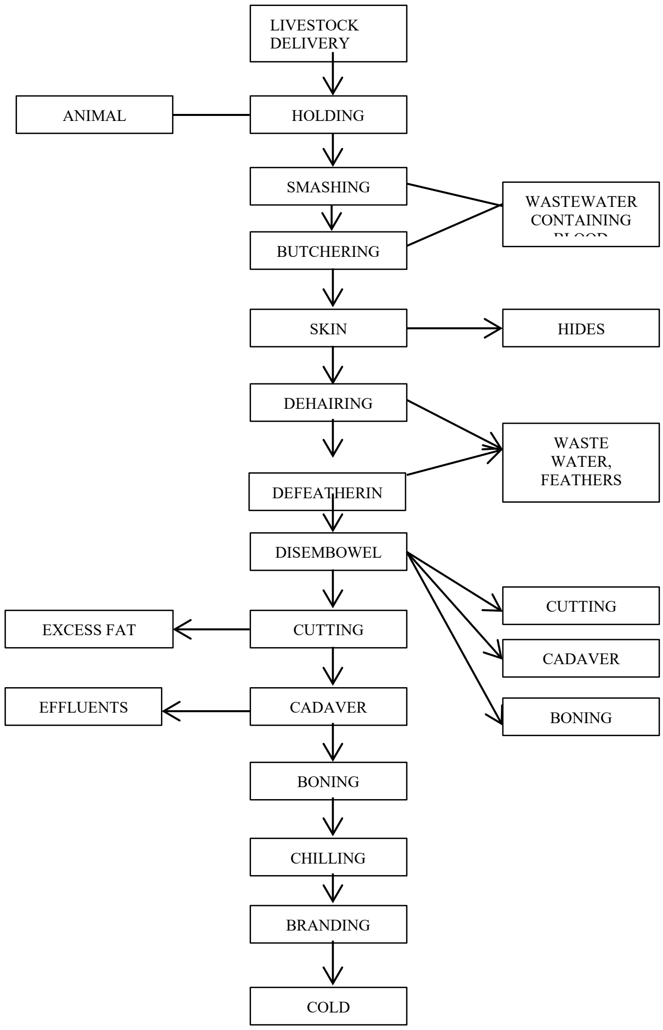

Fig. 1. A Flow chart of major processes in abattoir and associated waste generation.

Improper abattoir waste management has an impact on the air, land, and water. According to researchers, the pollutant load from abattoir wastewater is quite enormous, and the negative effects are huge. Microorganisms isolated from slaughterhouse wastewater could lead to infection in humans and cause food poisoning [12]. In developing nations, hardly any attention has been paid to the impacts of abattoir waste on the environment. The environment is unsafe due to improper dumping of trash generated by the abattoir industry's activities. Microorganisms have been isolated from mounds of solid and liquid waste created by this sector, according to research. These microbes cause sickness in both humans and animals. Above all, this circumstance lowers the quality of life for the animals and humans who live in such an environment [13].

Methemoglobinemia is induced by an increase in nitrites and nitrates in ground water generated by abattoir wastewater. According to reports, the accumulation of abattoir waste in the environment produces methane gas, which contributes to the greenhouse effect [14]. The efficacies of primary producers are reduced by the pollution of water bodies and this in turn affects the primary producers. Man is affected indirectly as fish which happens to be her primary source of protein are affected by the contaminated water. Anaerobic conditions caused by these contaminants has a significant impact on aquatic life survival [15]. Light penetration is reduced automatically due to the presence of suspended solids, and this affects the survival of photosynthetic organisms as well as changes in feeding habitats and benthic spawning grounds [16]. The lack of these species changes the features of the river bottom, making it hospitable for a wide range of organisms. The cleaning of the paunch content in water bodies reduces oxygen availability in water bodies, impacting aerobic species. The discharge of slaughterhouse effluent into water bodies degrades water quality and may have quite an impact on human recreation in such water bodies [17].

Blood, a key part of abattoir waste, has a significant negative impact on aquatic bodies. The chemical oxygen demand (COD) is around 375,000 mg / L. The availability of oxygen is decreased and this results in fierce competition among the aerobic microorganisms within the ecosystem thus also increasing the levels of biochemical oxygen demand (BOD) and decreasing the dissolved oxygen hence putting the aquatic life at risk [18]. Enrichment of nitrogen and phosphorus in receiving sensitive bodies of water can lead to eutrophication by increasing the algal growth, a condition known as an algal bloom. This reduces the growth and survival of fish as well as other aquatic organisms' flora [19]. According to Rajpal *et al.* [20], when the quantity of organic waste exceeds the capacity of microorganisms to break and recycle it down, eutrophication occurs. Because of the reduction in aquatic dissolved oxygen, blooming and eventual collapse, hypoxia/anoxia occurs thus leading to widespread mortality of fishes and benthic invertebrates across large areas [21].

The discharge of untreated abattoir effluents alters and threatens the natural habitat of species in the environment. Because of pollution in the environment, there is geographical and temporal variation in the benthic population. The presence of oligochaetes and diptera has an impact on human health [22]. The discharge of untreated abattoir effluents has a significant impact on river species richness. The presence of a high biochemical oxygen demand will have an effect on the geographical and temporal heterogeneity of macroinvertebrates [22] Contaminant bioaccumulation in fish from abattoir wastewater dumped into aquatic ecosystems can disrupt the food chain or web and endanger native flora and animals [23]

Effects of untreated Abattoir effluent on the Plants

Untreated abattoir wastewater can have serious consequences for plants. When abattoir effluent, which contains a combination of organic and inorganic contaminants, is not properly treated, it can damage land and water supplies [24]. According to Liu and Haynes [25], here are some of the effects of untreated abattoir effluent on plants:

1. **Soil contamination:** Organic materials, nutrients, and pathogens are abundant in untreated abattoir effluent. This wastewater can pollute the soil if it is applied to agricultural fields or used for irrigation. Excess nutrients can cause nutritional imbalances, impairing plant growth and development.
2. **Reduced plant productivity:** Pollutants in untreated abattoir wastewater might hinder plant growth and decrease yield. Organic debris and suspended particles in large concentrations can clog soil pores, inhibiting water infiltration and root development. This can limit nutrient intake and impede plant growth.
3. **Toxicity**: Toxic chemicals like heavy metals, antibiotics, and hormones may be present in untreated abattoir effluent.
4. These compounds can build up in plants and produce toxicity, resulting in slowed development, chlorosis (leaf yellowing), and even plant death.
5. **Spread of pathogens:** Pathogens found in abattoir effluent include bacteria, viruses, and parasites. These viruses can be conveyed to plants when untreated wastewater is used for irrigation, posing a risk to human health if the contaminated plants are consumed.
6. **Environmental impact:** Untreated abattoir effluent discharge into bodies of water can induce eutrophication, a process in which excess nutrients create algae blooms and oxygen depletion in aquatic environments. This can harm aquatic plants and animals, upsetting the ecosystem's balance. To mitigate these harmful consequences, abattoir effluent must be appropriately treated before it is released into the environment or utilized for irrigation. Primary, secondary, and tertiary treatment procedures can remove pollutants, nutrients, and pathogens from wastewater, assuring its safe disposal or reuse [26].

Effects of untreated Abattoir effluent on the Animals

Untreated abattoir wastewater can have serious consequences for animals. Abattoir effluent, often called as abattoirss, comprises a variety of pollutants and toxins that can harm both aquatic and terrestrial creatures [27]. According to Mittal [12], some of the effects of untreated abattoir effluent on animals are

1. **Water Pollution**: When untreated abattoir effluent is dumped into bodies of water such as rivers or streams, it can pollute the water. The effluent contains significant levels of organic matter, nutrients, and disease-causing organisms harmful to aquatic life and capable of degrading the quality of water.
2. **Eutrophication:** The nutrients in abattoir effluent are high, especially nitrogen and phosphorus. When fertilizers are introduced into bodies of water, they can promote eutrophication, which is the excessive development of algal and aquatic plants. This can use up available oxygen in the water, leading to the death of fish and other aquatic species.
3. **Contamination of Food Chain:** Pollutants can build in the tissues of animals if they ingest plants or drink water polluted with untreated abattoir effluent. This can result in bioconcentration, where pollutants become more concentrated as they migrate up the food chain. Humans who consume these tainted animals may eventually be exposed to hazardous toxins.
4. **Soil Contamination:** Untreated abattoir effluent can contaminate the soil if it is used for irrigation or applied to agricultural land. Organic materials, pathogens, and heavy metals can collect in the soil as a result of the effluent. This can have an impact on soil fertility as well as the health of plants and animals that rely on the soil environment.
5. **Health Risks:** Animals that come into contact with untreated abattoir effluent may develop health problems. Pathogens such as bacteria, viruses, and parasites can be found in effluent and cause diseases in animals. Furthermore, exposure to excessive amounts of contaminants in wastewater can cause a variety of health concerns [28].

To mitigate these negative effects, it is crucial to treat abattoir effluent before it is discharged or reused. Proper treatment methods can remove pollutants, nutrients, and pathogens, ensuring that the effluent meets acceptable standards and does not harm the environment or animals [29].

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Treatment of Abattoir Effluent

Physicochemical Treatment Methods

Floatation, screening, and dissolved air are the key techniques used in the meat and poultry industries to clean abattoir effluent [30]. These methods are designed to remove lipids, grease, colloidal and suspended particles from wastewater. However, to improve abattoir effluent treatment, chemicals are added [31]. Blood, a key constituent of slaughterhouse wastewater, has the ability to inhibit floc formation. To improve protein flocculation and precipitation of the effluent, blood coagulants are added. Aluminium sulfate and ferric chloride are examples of coagulants and flocculants that can reduce Chemical Oxygen Demand to a very large extent while also providing a significant amount of nutrients [31].

Physicochemical methods of abattoir effluent treatment are effective in removing nutrients from effluent. Ammonia stripping and breaking point has been used to remove ammonia from abattoir effluent. Aerated ponds with lime have also eliminated ammonia from effluent. Although, due to the huge volume of slaughterhouse effluent, these technologies emit a disagreeable odor and are uneconomical [18, 32].

Biological Treatment Methods

The aim of biological treatment methods is to minimize the organic and inorganic substances concentration, as well as pathogens, in slaughterhouse effluent. This approach has the potential to eliminate up to 90% of pollutants from abattoir wastewater [33]. Aerobic and anaerobic approaches can minimize biological oxygen demand as well as total suspended solids in abattoir effluents. The contact time between the microorganisms and the slaughterhouse effluent is critical in these procedures. The biological treatment technologies utilized in abattoirs include lagoons (aerobic, anaerobic and facultative) activated sludge processes and trickling filters [34].

Trickling filter (TF)

This is a popular technology adopted by slaughterhouses to treat abattoir effluent generated during their operations [35]. The microorganisms cling to the support media, generating a biological layer. The film metabolizes the organic stuff in the abattoir effluent. The bacteria need oxygen for growth; it is obtained naturally from the atmosphere. The amount delivered is proportional to the temperature of the abattoir effluent. The organisms' growth is proportional to the amount of biofilm produced [36]. A part of the clarified liquid from the secondary abattoir effluent is sometimes recycled to the biofilter to optimize hydraulic distribution of the slaughterhouse effluent over the filter. The main advantage of this treatment procedure over others is its low space and energy requirements [35].

Activated Sludge

The system is used by the majority of abattoirs that use biological waste treatment. It has the highest effectiveness in the world for removing soluble biodegradable chemicals and harmful bacteria from wastewater. The activated sludge treatment method is entirely aerobic[37]. After primary settling, clarified effluent is sent into a basin which is aerated and mixed with a mass of microorganisms actively, bacteria and protozoa, breakdown these organic waste into carbon dioxide, water, to produce new cells, and other end products. It stands out because of the flexibility of these operations and low cost. The negative effects of activated sludge treatment include sludge thickening, excess sludge formation, and the laborious nature of the system [38].

Sequencing Batch Reactor

The is also known as a fill and draw reactor system, comparable to activated sludge [35]. This system has four basic phases: fill (the receipt of raw abattoir effluent), react (the time required to perform the desired reaction), settle (the time required to separate the microorganisms from treated abattoir wastewater), and idle (the period between discharging and refilling the tank). However, depending on the effluent standards, these times may be changed or deleted [36]. This method is effective at removing suspended particles and biochemical oxygen demand, as well as nitrification and nitrogen and phosphorus removal [39]. This treatment process has been used to handle slaughterhouse effluent from abattoirs, piggeries, wineries, and landfill leachate [40].

Effluent Lagoons

Abattoir effluent lagoons are man-made facilities built to store and treat abattoir effluent discharged by industries, residences, and abattoirs [41]. When land is available, this treatment approach is advised. However, because it is not capital demanding and has minimal operational and maintenance requirements, it is commonly employed for the treatment of abattoir effluent [42]. The use of lagoons to treat abattoir wastewater does not interfere with the physical and biochemical interactions of organisms in the aquatic ecosystem. As a result, it is suggested for removing biochemical oxygen demand, suspended particles, and nutrients [35]. The principal methods for removing organic and inorganic chemicals from abattoir effluent in lagoons are biological degradation and sedimentation [3]. Regardless of the lagoon's type (aerobic or anaerobic), bacteria are the major participants in waste breakdown in close or beneficial contact with algae [43].

Bioremediation

Microorganisms are primarily utilized in the bioremediation cleaning procedure. This procedure is dependent on the microorganisms' proliferation and survival in the polluted environment during the cleanup phase. Bioremediation is basically a method that specializes in removing pollutants from the environment and restoring it to its original, contaminant-free state. It is a method used to remove pollutants from soils, groundwater, slaughterhouse effluent, sludge, industrial effluent, and gasses [44].

Bioremediation is the technique of stimulating microorganisms to rapidly degrade dangerous organic contaminants into environmentally benign conditions in soils, sediments, chemicals, materials, and ground water. In addition, it is a method of cleaning up contaminated environments by utilizing microbes' various metabolic skills to convert contaminants to harmless products via mineralization, carbon dioxide and water production, or conversion into microbial biomass [3, 45]. Microorganisms use three fundamental methods to achieve bioremediation: biotransformation, biodegradation, and mineralization. Biotransformation is the process by which bacteria change the molecules or structure of chemicals (pollutants) into less or non-hazardous molecules. The breakdown of organic substances into tiny organic or inorganic chemicals that are environmentally benign is known as biodegradation. Mineralization is the breakdown of organic molecules completely into inorganic substances such as water and harmless carbon dioxide [46]. The goal of bioremediation is to transform hazardous substances into non-toxic or less toxic substances. Furthermore, it is designed to degrade organic contaminants to undetectable levels or, if detectable, to levels within regulatory bodies' allowed ranges [47].

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Thus, bioremediation is a subfield of biotechnology that deals with toxins that harm the environment and its inhabitants. It is critical in cleansing contaminants utilizing microorganisms. Bacteria are critical in this process because they convert dead materials into organic stuff and nutrients [48]. Indeed, bioremediation is regarded as an environmentally acceptable method of decontaminating polluted settings [47, 49].

Nature's initial recyclers are microorganisms (mainly bacteria and fungi). Their ability to convert natural and manmade contaminants into energy and raw materials for their own growth suggests that costly chemical or physical cleanup techniques could be replaced by biological processes. Microorganisms in the proper quantities, combinations, and environmental conditions generate effective bioremediation [50]. At the presence of existing contaminants and other physical circumstances, microorganisms at contaminated places will continue to adapt and survive. As long as there is water present, these indigenous species can consume the available nutrients and electron acceptors. Water aids in the transit of organisms, the dissolution of contaminants, and the production of end goods [51].

As a result, bioremediation becomes a more effective natural method of rapidly degrading contaminants in the environment. Because of the benefits it provides, this technology is attractive and favored. Bioremediation is not only utilized to degrade contaminants; it can also be used to detoxify polluted abattoir wastewater, air, and soil. During environmental cleanups, organisms involved in the degradation process gradually adapt to the polluted environment and use the pollutants as a source of food and energy to help the ecosystem [5, 50].Microorganisms frequently metabolize contaminants to create carbon dioxide or methane, water, and biomass that are minimally or non-toxic [16, 43]

Advantages of Bioremediation of Abattoir Effluent

Hazardous compounds are rendered innocuous or less poisonous as a result of these processes. Microbial remediation often produces water, carbon dioxide, and biomass as end products [38, 44]. Bioremediation can be carried out in the presence or absence of oxygen. Jeyasingh and Philip [52] claims bioremediation carried out in the presence of oxygen yields faster results compared to other techniques of abattoir effluent treatment, bioremediation is regarded to be the cheapest method of cleaning up polluted land and water. Microorganisms use pollutants as a nutrient or source of energy during the cleanup of contaminated soil and water [53]. Bioremediation of abattoir wastewater can be done *in situ* or *ex situ*. The *ex-situ* ensures that the site's usual operations are neither hampered or hindered [52]. Any type of pollution can be treated with bioremediation. Organisms can be genetically modified to handle a specific pollutant. Bioremediation technology is a versatile technology since it can be combined with physical and chemical methods of getting rid of toxins [54].

Bioaugmentation for Abattoir Waste Treatment

One of the most extensively utilized bioremediation procedures is bioaugmentation of abattoir wastewater. It is the introduction of microbial life with specialized catabolic capacities into a polluted environment in order to stimulate or agitate the indigenous population to quickly decompose the toxins [55]. According to Alexander [56], bioaugmentation involves inoculating contaminated soil or water with specific strains or microorganisms in a consortium in order to boost the system's biodegradation capability for a specific pollutant organic molecule. When the pace of disintegration is extremely slow, the introduction of microbes becomes unavoidable. This approach is frequently used in both in situ and ex situ bioremediation [54].

Biostimulation of Abattoir Effluent

Biostimulation of abattoir effluent is a technology that boosts the ability of indigenous microorganisms to degrade contaminants. This is accomplished through the addition of electron acceptors such as oxygen, carbon, and nitrogen [55]. The addition of critical nutrients and other substances alters the environment in order to support and benefit the microorganisms throughout the degradation process [57]. The combination of inorganic nutrients has a greater effect than single nutrients. A study found that increasing the micronutrients and decreasing the macronutrients required by indigenous microorganisms can boost their activity. The highest amount of stimulation of indigenous microorganisms was observed when 75% sulphur, 3% nitrogen, and 11% phosphorus were used. Composting bioremediation technologies are a biostimulation medium [58].

Composting Bioremediation

The composting bioremediation technique is based on mixing the primary composting components with the contaminated soil, and as the compost matures, the pollutants are destroyed by the active micro-flora inside the combination [49]. Composting bioremediation has made use of organic additives. Many are based on the use of cow, pig, or poultry bird dung [59]. Cadavers, guts, bones, feathers, fats, veggies, leftover mushroom compost, and garden debris are also acceptable materials. They aid in the biodegradation of aromatic compounds, adding a new dimension to composting bioremediation. Composting is limited to in situ bioremediation [55].

Land Treatment

Land treatment is a system that is governed by the same principles as agriculture methods, which control the bio-cycling of intrinsic substances in the soil. Tilling the soil and mixing pollutants with clean soil decreases toxicity prior to final breakdown by natural microorganisms [60, 61].Aerobic microorganisms degrade pollutants in the presence of oxygen. This approach is suitable for soil remediation at depths ranging from 10 to 35 cm. Furthermore, the microorganism utilized to carry out the procedure determines the technology used in bioremediation of abattoir wastewater. The microbial cells are just as crucial as the procedures. Organisms capable of cleaning up the contaminated environment are either indigenous to the area or brought there [62].

Organisms involved in Bioremediation of Abattoir Effluent

Microorganisms are capable of surviving in any environment. Abattoir effluent polluted environments are not excluded because adaptability to such environments allows for survival [43, 63]. They have the ability to use both natural and manufactured substances. Microbes have the greatest bioremediation potential since they are decomposers naturally in various ecosystems around the world and can quickly proliferate. Because of their fast and complicated nature, microorganisms are difficult to replace as principal bioremediation agents with chemical or physical remediation agents [49]. Microorganisms commonly used in bioremediation are *Pseudomonas, Bacillus, Rhodococcus, Achromobacter, Alcaligenes, Sphingomonas, Corynebacterium, Micrococcus, Mycobacterium, Arthrobacter, Vibrio, Acinetobacter, Flavobacterium, Nocardia.*, and species [64]. Experiments shows that bacterial and fungal isolates were isolated from abattoir effluents in Akunlemu and Bondija abattoir located in Oyo [65, 66].

The bacteria *Staphylococcus aureus, Proteus* sp, *Escherichia coli* and *Pseudomonas* sp were isolated obtained while *Aspergillus niger, Aspergillus flavus,Penicillium, Fusarium* were the fungi isolated. These organisms isolated from abattoir effluents could damage the effluent since they can thrive in it. A consortium of microbes, on the other hand, can achieve complete mineralization. Microorganisms' breakdown contaminants in a chronological order, therefore various organisms play unique roles in mineralization [67].

Implication of Bioremediation of Abattoir waste for Bioproduct Formation

The breakdown of organic molecules by microorganisms such as bacteria and fungi into simpler and less toxic chemicals is referred to as bioremediation. The significance of bioremediation for bioproduct generation from abattoir wastewater lies in the possibility of converting waste into valuable resources [68]. To eliminate organic contaminants from abattoir wastewater, the methods can be used in effluent treatment systems. Aerobic and anaerobic biological processes activated sludge systems, and artificial wetlands can all be used as treatment options. Microorganisms are used in these processes to break down organic matter, transforming it into carbon dioxide, water, and biomass.

Value-added Bio-products of Bioremediation of Abattoir Effluent

Biogas Production

Anaerobic digestion, which involves the breaking down of organic substances by microbes in the absence of oxygen, is a typical treatment procedure for abattoir effluent. This process generates biogas, which is largely constituted of methane and carbon dioxide and can be used as a renewable energy source [68]. Biogas can be utilized for heating, power generation, and even transportation. Sina and Fekade [69] did research on bioenergy abattoirs. The experiment found that four selected abattoirs generated about 1,509.406 tons of abattoir wastes per year, and that anaerobic digestion can yield 86,158m3/year of biogas and 121.25 tons of biofertilizer.

Biofertilizer Production

A nutrient-rich biofertilizer can be produced as a byproduct of biodegradation processes such as aerobic composting also known as anaerobic digestion. The treated wastewater can be converted into a useful agricultural resource, supplying necessary nutrients to improve soil quality and crop productivity. With its benefit and soil efficiency, the present estimated biofertilizer (121.25 ton/year) from four abattoir sites can cover approximately 3,235 hectares/year. When converted into dollars, the cost of biogas and biofertilizer is estimated to be $55,645 per year. The study concluded that anaerobic digestion might produce a large quantity of biogas and biofertilizer from abattoir waste [69].

Organic Acids

Abattoir effluent can be used as a feedstock for microbial fermentation to produce organic acids. Acetic acid, propionic acid, lactic acid, butyric acids are among the organic acids that can be created. These organic acids are used in various industries, such as food, pharmaceutical, and chemical. Lactic acid, for example, is employed as a food preservative, pH regulator, and flavor enhancer. Acetic acid is extensively used in the production of vinegar as well as as a chemical intermediary [70].

Proteins and Amino Acids

Proteins in abattoir effluent can be digested and transformed into important biochemicals. Proteins can be hydrolyzed or digested enzymatically to yield peptides and amino acids that have applications in the food, pharmaceutical, and cosmetic sectors. Amino acids can be utilized as nutritional supplements or as building blocks for medicinal medication production. Peptides generated from abattoir effluent can have bioactive qualities including antibacterial or antioxidant activity and can be used in functional foods or pharmaceutical formulations [71].

Bio-based Chemicals

Microbial fermentation techniques can be used to transform organic compounds found in abattoir wastewater into bio-based chemicals. Organic acids (acetic acid, lactic acid), amino acids, enzymes, and bioactive substances can all be created by the metabolic activities of microorganisms. These bio-based compounds have uses in industries such as food and beverage, medicines, and bioplastics [72]. According to Limeneh et al. [73], industries processing meat generates large volume of solid and liquid waste, a large percentage of the live weight of the animals is not consumed by humans probably due to cultural beliefs, religious, and health issues, and their disposal is either by landfill or incineration. These byproducts contain enormous amounts of protein, fat, keratin, collagen, and mineral matter, which could be exploited to create high-value biomaterials, biochemicals, and byproducts [20, 72].

Bioplastics

Effluent from slaughterhouses can be used to make bioplastics. Bioplastics are made from renewable resources and are a more environmentally friendly alternative to traditional petroleum-based plastics. Organic matter in wastewater can be transformed into building blocks for bio-plastics manufacture, such as polyhydroxyalkanoates (PHA), using techniques such as microbial fermentation. PHA can be used to make a variety of plastic products with a lower environmental impact [74].

Animal Feed

Certain abattoir effluent components, such as proteins and lipids, can be processed and turned into animal feed. These nutrients can be extracted, processed, and made into feed products for livestock or aquaculture by using proper treatment processes. This contributes to the use of waste as a valuable resource for animal nutrition, minimizing the demand for additional feed ingredients [74]. Because they include mineral content, most slaughter by-products are ideal for the aforementioned application. However, the byproducts must be broken down into small particles so that animals may digest them. Organic residues are preferentially used to make animal fodder. The meat processing industry's animal feedstock plays a significant role in guaranteeing ample organic sources and affordable animal protein [24].

Enzymes

Abattoir effluent contains a variety of enzymes that can be isolated and used in a variety of businesses. Enzymes are biocatalysts that speed up chemical reactions and have numerous applications [75]. Proteases generated from abattoir effluent, for example, can be used in the food business to tenderize meat or in the detergent sector to remove stains. Lipases can be used to make biodiesel or in the manufacture of cleaning goods. These enzymes can be exploited as important biocatalysts in various industrial processes by isolating and purifying them. Many bacterial species including *Bacillus licheniformis, Bacillus brevis* and Aspergillus spp have been isolated from abattoir wastes and used them to produce enzymes such as proteases. In comparison to OMO detergent, these produced very good results. Proteases are employed in the soaking, dehairing, and bating stages of skin and hide preparation. The enzymatic treatment removes

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unwanted pigments, enhances skin area, and results in clean hide. Traditionally, bating is an enzymatic process involving pancreatic proteases [76, 77].

Bioenergy Production

Aside from biogas, the biodegradation of abattoir wastewater can provide various bioenergy products. For example, solid leftovers formed during the treatment process, such as sludge or biomass, can be used to generate biomass energy. As one of the waste to energy pathways for energy transition, the production of biogas and electricity will help to reduce emissions of greenhouse gases. According to the study, only 2,800 kg of the total solid and liquid waste generated by abattoirs is used in biogas production, leaving 55,300 kg of trash unprocessed by the biogas digestor. This increases the possibility for energy recovery from abattoir waste and minimizes reliance on fossil fuels [78, 79].

Bioactive Compounds

Bioactive chemicals found in abattoir effluent, such as peptides, antibacterial agents, or antioxidants, can be extracted and used in the pharmaceutical, nutraceutical, and cosmetic sectors. Various procedures, such as chromatography, filtration, or precipitation, can be used to extract these bioactive chemicals from effluent. They can be refined and made into products that provide specific health or functional benefits. [9]. The biodegradation of abattoir wastewater can produce bioactive chemicals having medicinal potential. These bioactive byproducts are extractable and can be used in the pharmaceutical and nutraceutical sectors. Antimicrobial peptides generated from effluent, for example, can be employed in the creation of new medicines or as additives in personal care products. The presence of bioactive chemicals in abattoir wastewater provides prospects for value generation and product diversification [80].

Microbial Biomass

Microorganisms are essential in the biodegradation of abattoir wastewater. The production of biomass during the treatment procedure can be gathered and used to manufacture microbial protein or single-cell protein (SCP). Microbial biomass has the potential to be a protein-rich feed element for animal nutrition or a sustainable source of protein for human use. The use of microbial biomass improves resource efficiency and lowers reliance on traditional protein sources [8, 47, 80]. Table 1 below give some specific instances where abattoir wastes were used for value added product production via bioremediation while figure 2 illustrates some bioproducts that can be synthesized from abattoir waste

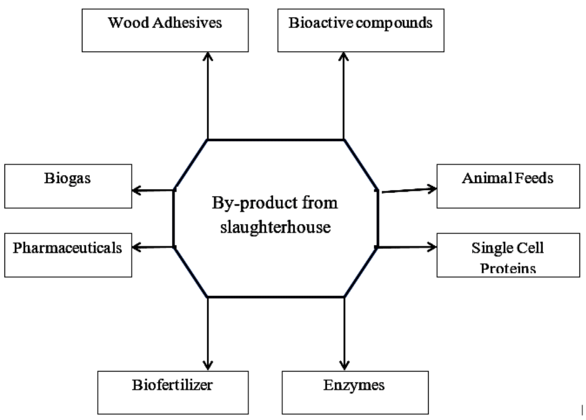

Fig 2. Flowchart illustrating value added products from Abattoir.

Table 1. Bioproducts synthesized from abattoir waste via bioremediation and quality / quantity of the products.

Bioproduct	Strategy involved	Microorganism involved	Quality of product produced	Ref
Proteases	Submerged fermentation	*Bacillus subtilis*	Maximum protease activity to be 20.74 U/ml	[81]
amylase and protease	Submerged fermentation	*Aspergillus niger* *Penicillium frequestans*	4.48×10^4 mg mL-1 sec-1 3.28×10^4 mg mL-1 sec-1	[82]
keratinolytic protease	fermentation	*Bacillus sp*	899.30U/ml	[83]
Biogas Biofertilizer	anaerobic digestion	Consortium	206.63×10^3 m^3 /year 43,184.9 kg per year	[84]
Bioelectricity	Anaerobic digestion	Consortium	1664.6 MWh	[85]
Blood meal	vegetable carriers milling	Consortium c	Gross energy - 17–20 MJ/kg dry matter Crude protein - 132–530 g/kg DM	[86]
Biogas Biofertilizer	anaerobic digestion	Consortium	85,139 m^3/year biogas 111.25 ton/year biofertilizer	[87]
Biogas Biofertilizer	anaerobic digestion	Consortium	46,951.72m^3/year of biogas 65,112.3 Kg/year biofertilizer	[88]
Polyhydroxy-yalkanoates	Anaerobic fermentation	*P. resinovorans* *P. putida* GPo1 *P. putida* KT2440	5.9–12.8 g L−1, mcl-PHA	[89]
Polyhydroxy-yalkanoate	Shaking flask	*Pseudomonas citronellolis* DSM 50332	1.35 g l-1 mcl-PHA	[90]

Conclusion and Future Perspective

Our environment is suffering major issues due to increasing waste volumes and insufficient garbage disposal systems. In developing countries around the world. There is also a dearth of literature on the quantification of slaughterhouse waste and a lack of worker awareness on abattoir waste. This study mainly highlights the multiple potentials of abattoir effluent for synthesis of value-added products such as biogas, biofuel, biofertilizers, enzymes, and single cell proteins, to name a few.

The use of abattoir waste for the generation of biogas and bio-fertilizer, as well as other value-added products, was discussed. This research demonstrated how abattoir waste (effluents) might be used for various purposes. Installing an anaerobic digester, for example, may offer a big volume of biogas, a high biofertilizer yield, and electricity generation while simultaneously cutting greenhouse gas (GHG) emissions. Anaerobic digestion provides an effective waste recycling process, helps to minimize greenhouse gas emissions and inorganic fertilizer usage.

As a long-term strategy for management, it can ensure the safety of public and environmental health. As a result, biogas technology would be the long-term solution to ensuring environmental and public health, while proper disposal would be a short-term option. This suggests that abattoir waste has the potential to create cash, act as a source of employment, and provide a variety of other benefits. Finally, wastes could be changed via biotechnological processes to assure public and environmental health safety and, so serving as a means of long-term solution. If by-product characterization is properly managed every by-product would be utilized into high-value biomaterial.

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Traditional butchering process found in Nigeria gradually are heading in the direction of posing serious public health threats. The Food and Agriculture Organization of the United States, predicts that meat production in developing countries in 2030 has to be 260 million tons, of which nearly 130-170 million tons would be taken as by-products. These by-products provide us with a potential for the production of high valued by-products through a biorefinery approach. The utilization of the by-products is important as it creates better returns to the producer, reduces environmental impact, and further increases producer's return. Currently, byproducts from the meat processing industries are used in applications such as compositing, rendering, and glue. Some examples of ways to incorporate byproducts into high-value products are discussed in this study.

Microbiologically, biogases are created from byproducts by anaerobic digestion. Cattle, sheep and poultry waste are utilized to generate energy in biomass because they are high in organic matter, and fresh waste is usually more suited for its production. The intestinal content is one of the by-products used in the generation of biogases; stomach and blood are the preferred sources of production. Biogas is mostly derived from organic leftovers and contains 45-85 vol% methane (CH_4) and 25-50 vol% carbon dioxide (CO_2).

Biomass is the world's only renewable energy source, supplying power, heating, liquids and gases, cooling, and solid fuel. The meat processing industry accounts for over 12% of primary nutrition and 82% of worldwide energy consumption. Biogases, on the other hand, are formed through anaerobic fermentation of byproducts. By 2027, the biogas production capacity will be 30,000MW. The potential for researching biomass from abattoir effluent/wastes for its multiple development advantages is enormous. Beyond attaining sustainable energy, cleaner energy equates to a cleaner environment and better health. The biomass conversion technique is inexpensive, and the fuel is widely available for communal or individual exploitation, making it an appealing option for achieving energy self-sufficiency.

As a result, rural-to-urban migration would be reduced because individual communities/households may employ frequently available biomaterial to manufacture power and other value-added bio products from abattoir wastes, making life more comfortable and having a favorable impact on companies. The adoption of abattoir waste treatment technology by the municipality should create a long-term strategy to protect the health of the public and environment, while ensuring adequate abattoir effluent waste disposal as a short-term plan.

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