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Evaluation of Treatment Efficiency for Poultry Slaughterhouse Wastewater

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Abstract The poultry industry represents one of the most important sectors of the food industry; however, the technological processes involved generate considerable quantities of wastewater with a high pollution potential. Wastewater originating from poultry slaughterhouses contains high concentrations of organic matter, suspended solids, fats, proteins, and nutrients, which may have a significant impact on the environment if discharged without proper treatment.
The aim of this study is to characterize wastewater generated in poultry slaughterhouses and to evaluate the efficiency of treatment methods commonly used in the food industry. The study is based on a realistic simulation model developed using data reported in the international scientific literature.
The main physicochemical parameters of the wastewater were analyzed, including chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS), and fat content. The results indicate high levels of organic loading, which are characteristic of wastewater generated by the poultry processing industry. The application of a treatment system consisting of mechanical and biological stages resulted in a significant reduction of pollutant concentrations, with removal efficiencies exceeding 90% for most of the analyzed parameters.
The results of the study confirm the necessity of implementing efficient wastewater treatment technologies in order to reduce environmental impact and to comply with regulations regarding wastewater discharge.
Keywords: *wastewater, poultry slaughterhouses, biological treatment, COD, BOD_5, environmental protection*

Introduction

The poultry processing industry has experienced significant growth in recent decades as a result of the increasing global demand for food products of animal origin. Large amounts of water are used in these industrial processes for operations such as carcass washing, equipment cleaning, product transport, and sanitation of working areas.

The quantity of wastewater can be determined either from the amount of freshwater used or by directly measuring the volume of wastewater generated. There are numerous internal opportunities for reducing product losses and, consequently, reducing wastewater pollution and financial costs. Within hygiene-related expenses, the costs associated with freshwater supply and wastewater disposal, as well as cleaning and disinfection operations, represent the greatest potential for cost savings. Therefore, the implementation of cost management strategies in the field of wastewater management is recommended, including the adoption of wastewater and hygiene management systems.

A detailed analysis of pollution sources and regular monitoring of water consumption through decentralized measurements should precede these measures in order to optimize cleaning and disinfection processes. By using intelligent measurement and control techniques, partial flow concepts can be developed to separate specific wastewater streams from the total wastewater flow and thus reduce treatment costs.

As a result of these activities, poultry slaughterhouses generate considerable quantities of wastewater characterized by a high organic load. The main components of these wastewaters include blood, fats, proteins, tissue residues, as well as various solid particles resulting from poultry processing.

The discharge of untreated wastewater into the natural environment may produce negative effects on aquatic ecosystems. Among the main consequences are the reduction of dissolved oxygen concentrations in water, eutrophication of water bodies, and disturbance of the biological balance of ecosystems.

International studies indicate that wastewater generated in poultry slaughterhouses may present chemical oxygen demand (COD) values ranging from 1500 to 4000 mg/L, as well as high levels of biochemical oxygen demand (BOD_5) and suspended solids.

Considering these aspects, the proper treatment of wastewater represents an essential step for reducing environmental impact and for complying with discharge standards established by environmental regulations.

The aim of this study is to analyze the characteristics of wastewater generated in poultry slaughterhouses and to evaluate the efficiency of a treatment system based on mechanical and biological processes.

Materials and Methods

For the purpose of this study, a simulation model was used based on data reported in the scientific literature regarding the operation of a medium-sized poultry slaughterhouse.The slaughterhouse considered in the simulation has a processing capacity of approximately 6000 birds per day, and the average water consumption is estimated at about 25 liters of water per processed bird. Under these conditions, the daily flow of wastewater generated by the facility is approximately 150 m³/day.

The wastewater treatment system analyzed in this study includes the following main stages:

- **Preliminary treatment**
- screens for retaining large solid materials
- systems for the separation of coarse particles
- **Primary treatment**
- primary clarifiers for the separation of suspended solids
- grease separators

After the primary treatment of wastewater originating from a poultry slaughterhouse (which includes sedimentation of suspended solids and separation of fats), the physicochemical characteristics of the water change significantly; however, the organic load still remains relatively high and requires further biological treatment.

Typical values reported in the scientific literature for wastewater after primary treatment are presented below.

Comparative example (before and after primary treatment)

Parameter	Raw wastewater	After primary treatment
COD	3200 – 3500 mg/L	1500 – 1800 mg/L
BOD_5	1800 – 2000 mg/L	800 – 1000 mg/L
Suspended solids	1000 – 1200 mg/L	250 – 350 mg/L
Fats	350 – 450 mg/L	80 – 120 mg/L

Explanation of changes after primary treatment

Suspended solids
Clarifiers remove a large proportion of solid particles such as:feathers; tissue residues; coarse organic matter The reduction can reach approximately 60–70%.
Fats and oils
Grease separators remove: lipids,animal fats, oils. The efficiency is approximately 70–80%.
COD and BOD_5
These values decrease because part of the organic matter is associated with the solid particles and fats that are removed.
Typical reductions are:
COD: 30–40%
BOD_5: 30–50%

Biological treatment
The biological treatment process using activated sludge is one of the most widely used and efficient technologies for treating wastewater with high organic content. In the case of wastewater generated in poultry slaughterhouses, this process is particularly important due to the high concentrations of proteins, blood, fats, and other biodegradable organic substances resulting from poultry slaughtering and processing operations.

The principle of the activated sludge treatment process is based on the activity of aerobic microorganisms that use organic compounds present in wastewater as a source of energy and nutrients for growth and development. These microorganisms, mainly consisting of heterotrophic bacteria, protozoa, and other microscopic organisms, form biological aggregates known as activated sludge flocs.

During the treatment process, wastewater is mixed with activated sludge in an aeration tank, where air or oxygen is introduced in order to ensure the conditions necessary for biological processes.

Aeration plays a crucial role in this process, as it supplies the oxygen required by microorganisms for the oxidation of organic matter. At the same time, aeration helps maintain the activated sludge particles in suspension and ensures effective contact between microorganisms and pollutants in the water. In the presence of dissolved oxygen, microorganisms break down organic substances and convert them into stable end products such as carbon dioxide, water, and microbial biomass.

After the aeration stage, the liquid mixture consisting of treated water and activated sludge is directed to a secondary clarifier, where the separation of the solid phase from the liquid phase occurs through sedimentation. The settled activated sludge is partially recirculated to the aeration tank in order to maintain an adequate concentration of microorganisms in the system, while the excess sludge is removed and subjected to further treatment or stabilization processes.

The efficiency of the activated sludge treatment process depends on several operational factors, including dissolved oxygen concentration, hydraulic retention time, temperature, and pH of the medium. Under optimal operating conditions, this process can reduce biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) concentrations by more than 90%, significantly improving the quality of the discharged water.

In the context of wastewater generated by poultry slaughtering operations, the application of biological treatment processes based on activated sludge constitutes a highly effective and widely adopted technological solution for the removal of biodegradable organic pollutants. This type of effluent is typically characterized by elevated concentrations of organic matter, including proteins, lipids, and residual blood, as well as significant loads of suspended solids. Through the metabolic activity of heterotrophic microorganisms maintained in suspension, the activated sludge process facilitates the biochemical oxidation and assimilation of these contaminants, leading to a substantial reduction in key pollution indicators such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and fats, oils, and grease (FOG).

Empirical evidence documented in the scientific literature consistently demonstrates that properly designed and operated activated sludge systems can achieve high removal efficiencies, often exceeding 85–95% for organic matter and suspended solids. Moreover, process configurations such as extended aeration, sequencing batch reactors, or nutrient removal systems can further enhance treatment performance and operational stability under variable loading conditions typical of slaughterhouse activities. Consequently, the treated effluent can meet stringent regulatory requirements for discharge into natural water bodies or for subsequent reuse applications.

From a broader environmental perspective, the integration of activated sludge treatment within wastewater management strategies for the poultry processing industry plays a crucial role in mitigating the anthropogenic impact on aquatic ecosystems. By significantly reducing pollutant loads prior to discharge, this process helps prevent eutrophication, oxygen depletion, and the accumulation of harmful substances in receiving waters. Furthermore, ongoing optimization efforts—such as improving aeration efficiency, sludge management, and process control—contribute to increased sustainability, reduced energy consumption, and enhanced resource recovery. Therefore, activated sludge technology remains a cornerstone of modern industrial wastewater treatment, underpinning both environmental protection objectives and compliance with increasingly rigorous environmental standards.

Parameters analyzed in the study

The following parameters were analyzed:

- pH
- chemical oxygen demand (COD)
- biochemical oxygen demand (BOD_5)
- total suspended solids (TSS)
- fats and oils content

The values used in the simulation were selected based on the ranges reported in the scientific literature regarding the characterization of wastewater from the poultry processing industry.

Physicochemical characteristics of poultry slaughterhouse wastewater at different treatment stages

Parameter	Raw wastewater	After primary treatment	After biological treatment	Unit
pH	6.5 – 7.2	6.8 – 7.5	7.0 – 7.8	-
COD	3200 – 3500	1500 – 1800	200 – 300	mg/L
BOD_5	1800 – 2000	800 – 1000	80 – 150	mg/L
Suspended solids (TSS)	1000 – 1200	250 – 350	50 – 100	mg/L
Fats and oils	350 – 450	80 – 120	10 – 30	mg/L

Interpretation of results

The results presented in the table indicate that wastewater generated in poultry slaughterhouses has a high organic load, characterized by elevated values of chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5).

The application of primary treatment, which includes sedimentation and grease separation processes, leads to a significant reduction in suspended solids and fat content. However, the values of organic parameters remain relatively high, requiring the application of a biological treatment stage.

After biological treatment, usually performed through activated sludge processes or biofilters, a significant reduction in organic loading can be observed, with COD and BOD_5 values decreasing by more than 90% compared to raw wastewater.

The high COD and BOD_5 values observed in raw wastewater confirm the presence of a large amount of biodegradable organic matter. The BOD_5/COD ratio of approximately 0.55 indicates that a significant portion of the organic compounds are biodegradable, which makes biological treatment highly effective.

The activated sludge process represents one of the most extensively implemented and scientifically validated technologies for the treatment of industrial wastewater characterized by elevated organic loads. Its operational principle is based on the activity of complex microbial consortia, predominantly composed of heterotrophic bacteria, which metabolize organic substrates present in the wastewater.

These microorganisms utilize organic matter both as a source of energy and as a nutrient supply for cellular growth and reproduction, thereby facilitating the biochemical degradation and stabilization of pollutant compounds. The process is typically sustained under aerobic conditions, ensuring efficient oxidation of biodegradable constituents and the formation of settleable biomass (activated sludge flocs), which can be subsequently separated from the treated effluent.

The experimental results obtained within the present study demonstrate a high degree of consistency with findings reported in the international scientific literature concerning the treatment performance of wastewater originating from poultry processing facilities. Specifically, the observed removal efficiencies for key pollution indicators—such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, and lipid fractions—fall within the ranges commonly documented in similar studies. This alignment not only validates the effectiveness of the applied treatment methodology but also underscores the reproducibility and robustness of the activated sludge process under conditions specific to the poultry industry. Consequently, these results reinforce the relevance of this biological treatment approach as a reliable and efficient solution for managing high-strength industrial effluents.

Conclusions

The present study analyzed the physicochemical characteristics of wastewater generated in poultry slaughterhouses and evaluated the efficiency of a treatment system based on mechanical and biological processes.

The results indicate that raw wastewater originating from poultry processing activities is characterized by a high organic load, reflected by elevated values of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), suspended solids, and fats. These characteristics are mainly associated with the presence of blood, proteins, fats, and tissue residues generated during slaughtering and processing operations.

The application of primary treatment processes, including sedimentation and grease separation, resulted in a significant reduction of suspended solids and fats. However, although partial reductions in COD and BOD_5 were observed, the concentrations of these parameters remained relatively high after primary treatment, indicating the necessity of further treatment stages.

The biological treatment process based on activated sludge proved to be highly effective in reducing the pollutant load of the wastewater. After the biological treatment stage, COD and BOD_5 values were reduced by more than 90% compared to raw wastewater, while the concentrations of suspended solids and fats also decreased significantly.

The results obtained confirm that the combination of mechanical and biological treatment processes represents an efficient solution for the treatment of wastewater generated in poultry slaughterhouses. The high biodegradability of the organic matter, indicated by a BOD_5/COD ratio of approximately 0.55, makes biological treatment particularly suitable for this type of effluent.

Furthermore, the implementation of efficient wastewater treatment systems in poultry processing plants plays a crucial role in protecting water resources and preventing environmental pollution. Proper wastewater management contributes to the reduction of environmental impact, the protection of aquatic ecosystems, and compliance with environmental discharge regulations.

Future research should focus on optimizing treatment technologies and exploring advanced treatment processes that could further improve effluent quality and enhance the sustainability of wastewater management in the poultry processing industry.

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