Journal of Energy Technology and Environment Vol. 6(2) 2024 pp. 229 - 234 ISSN-2682-583x

NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Advancements and Challenges in the Design of Chicken De-feathering Machines: A Comprehensive Review

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Article information

Article History
Received 22 May 2024
Revised 28 May 2024
Accepted 31 May 2024
Available online 4 June 2024

Keywords: Poultry processing, De-feathering, Feather removal, Carcass quality, Efficiency

OpenAIRE

https://doi.org/10.5281/zenodo.11479313

https://nipes.org

Abstract

Chicken de-feathering is a crucial step in poultry processing, contributing significantly to the efficiency and quality of the final product. This scholarly review presents an in-depth analysis of the existing research design of chicken de-feathering machines, exploring relevant literature focusing on their design, operation, efficiency, key advancements, challenges, impact on poultry processing and potential areas of improvement. By critically evaluating existing research, this review aims to provide valuable insights for researchers, engineers, and poultry industry professionals to enhance the design and performance of de-feathering machines.

1. Introduction

The poultry industry is witnessing significant growth over the past few decades, with technological advancements revolutionizing various aspects of poultry processing for efficient and cost-effective poultry processing methods. One such innovation is the development of chicken de-feathering machines, which have significantly improved the efficiency and hygiene of feather removal during poultry processing to meet consumer preferences and hygiene standards. This review delves into the extensive body of research concerning these machines, providing an overview of their historical evolution, mechanisms of operation, design considerations, and the current state-of-the-art.

1.1 Historical Evolution and Design Considerations

The development of chicken de-feathering machines can be traced back to the early 20th century when manual plucking was the primary method of feather removal in poultry processing plants [1]. The introduction of mechanical plucking machines in the mid-20th century marked a significant advancement, enabling faster and more efficient de-feathering processes [2]. Over the years, advancements in technology and engineering have led to the development of various types of chicken de-feathering machines with improved performance and functionality. Early chicken de-feathering methods were labor-intensive and time-consuming, relying on manual plucking or scalding. However, with the advent of industrialization, the need for automated and high-capacity de-feathering machines became evident to streamline the process. Several studies have investigated the historical evolution of these machines, tracing their development from basic hand-cranked devices to advanced automated systems. Notable contributions by researchers such as [3-5] have highlighted the gradual improvement of de-feathering machine designs and the incorporation of novel materials and components to enhance performance. Further contributions from [6, 7] addressed issues related to feather removal efficiency, machine throughput, and hygiene. Li et al., [6] introduced adjustable drum rotational speeds, improving feather removal while minimizing carcass damage. [7] proposed rubber fingers for enhanced feather extraction, reducing bruising and optimizing plucking performance. With increasing demand, large-scale poultry processing plants require de-feathering machines with higher capacities. [8] presented an innovative multi-stage de-feathering system that significantly increased throughput while maintaining feather removal quality. Additionally, this approach reduced energy consumption and equipment footprint, making it suitable for large-scale applications. However, these early designs were often inefficient and resulted in suboptimal feather removal, leading to further developments in machine design. Scholarly journals documents the evolution of chicken de-feathering machines and the design considerations that have shaped their development. For example, research by [9] discusses the optimization of machine parameters such as rotational speed, finger design, and water temperature to improve de-feathering efficiency and minimize skin damage. Similarly, studies by [10, 11] explore the use of advanced technologies such as computer vision systems and artificial intelligence to automate and optimize the de-feathering process. [12] discussed the effects of hard and soft scalding on defeathering and carcass quality of different breeds of chickens. The study examine the effectiveness of soft and hard scalding on defeathering and carcass quality of the local strain of Red Feather (RF) country chickens and determine age, breed, and body weight factor in accounting for the defeathering effectiveness using adult layers and juvenile broilers as a reference.

Design considerations for chicken de-feathering machines encompass various factors, including feather removal efficiency, processing speed, energy consumption, and animal welfare. For instance, researchers have investigated the impact of different de-feathering methods (e.g., dry plucking versus scalding) on meat quality and skin integrity [13]. Additionally, ergonomic considerations such as machine size, ease of cleaning, and operator safety are essential factors in machine design [14]. Factors such as machine size, motor power, and material selection are carefully considered to achieve robust and reliable machines capable of handling large volumes of chickens [15]. Ergonomic design features are incorporated to facilitate ease of operation and maintenance, reducing downtime and increasing overall productivity [16]. Moreover, advancements in materials science and engineering have led to the development of innovative machine components and structures aimed at improving performance and durability. Research by [17] highlights the use of novel materials such as carbon fiber reinforced composites in the construction of de-feathering fingers to enhance wear resistance and prolong service life.

2. Mechanisms of Operation*:*

De-feathering machines employ various mechanical principles to efficiently remove feathers from chickens. These mechanisms include rotating drums with rubber fingers, rubber belts, or abrasive surfaces. Researchers such as [18] have conducted experimental studies to compare the efficacy of different de-feathering mechanisms, evaluating factors such as feather removal rate, damage to the carcass, and energy consumption. These investigations have contributed valuable insights into the optimization of machine performance and the reduction of undesirable effects on poultry carcasses.

One common mechanism is the use of plucking fingers, which are flexible rubber or plastic fingers attached to rotating drums [19]. As the drum rotates, the plucking fingers catch and pull the feathers from the chicken's skin, leaving it clean and smooth. Another mechanism employed in chicken de-feathering machines is rubber fingers, which are soft and flexible rubber fingers arranged in rows on rotating shafts [20]. The rubber fingers gently grip and pull the feathers from the chicken's skin as the shaft rotates, resulting in efficient de-feathering with minimal skin damage. Rotary drums are also commonly used in chicken de-feathering machines, where chickens are placed inside a rotating drum lined with rubber or plastic fingers [21]. As the drum rotates, the feathers are dislodged and collected in a separate chamber, leaving the chicken's skin clean and feather-free.

2.1 Efficiency and Quality Considerations:

Efficiency and product quality are critical aspects of poultry processing. Extensive research has been dedicated to evaluating the efficiency of de-feathering machines in terms of output, feather removal rate, and processing time. Studies by [22, 23] have examined the influence of machine parameters, such as rotational speed, rubber finger design, and water temperature, on de-feathering efficiency. Additionally, the impact of machine operation on meat quality attributes, such as skin integrity and microbiological safety, has been investigated by [24, 25]. De-feathering efficiency refers to the ability of the machine to remove feathers from chickens quickly and effectively. Several factors influence efficiency, including machine design, rotation speed, and the type of de-feathering mechanism used [26]. Research suggests that machines equipped with rotating drums or rubber fingers tend to exhibit higher de-feathering efficiency compared to those using static plucking fingers [27]. Additionally, optimal machine settings, such as drum rotation speed and water temperature, play a crucial role in maximizing efficiency while minimizing processing time [28]. Quality considerations in chicken de-feathering machines encompass several aspects, including feather removal completeness, skin integrity, and overall product appearance. Feather removal completeness refers to the extent to which all feathers are removed from the chicken's body, with higher completeness indicating better quality [29]. Studies have shown that machines equipped with flexible rubber fingers or rotating drums achieve higher completeness levels compared to those using static plucking fingers [30]. Skin integrity is another important quality aspect, with machines causing minimal skin damage during the de-feathering process being preferred [31]. Maintaining skin integrity enhances the visual appeal and marketability of the final poultry product.

3. Advancements in Technology

Advancements in technology have played a pivotal role in enhancing the performance and capabilities of chicken de-feathering machines, leading to improved efficiency, product quality, and sustainability in poultry processing operations. This paper provides an overview of recent advancements in technology of chicken de-feathering machines, highlighting key innovations and their implications for the poultry industry. Recent advancements in machine design have focused on improving de-feathering efficiency and product quality while minimizing environmental impact. For example, researchers have explored novel designs of plucking fingers and rotary drums to optimize feather removal completeness and reduce skin damage [32]. Additionally, advancements in materials science have led to the development of lightweight and durable components, contributing to the overall performance and longevity of de-feathering machines [33]. The integration of advanced control systems and automation technologies has revolutionized the operation of chicken de-feathering machines. Researchers have developed intelligent control algorithms that optimize machine settings in real-time based on factors such as chicken size, feather density, and processing speed [34]. Furthermore, the implementation of sensor-based feedback systems enables continuous monitoring of de-feathering performance, allowing for timely adjustments to improve efficiency and product quality [35]. Advancements in technology have also focused on enhancing the energy efficiency and sustainability of chicken de-feathering machines.

Researchers have explored innovative heat recovery systems that capture and reuse waste heat generated during the de-feathering process, reducing energy consumption and greenhouse gas emissions [36]. Additionally, the use of eco-friendly lubricants and materials in machine components contributes to overall sustainability and environmental stewardship in poultry processing operations [37]. Looking ahead, future advancements in technology of chicken de-feathering machines are expected to focus on further improving efficiency, product quality, and sustainability. Emerging trends include the development of integrated systems that combine de-feathering with other processing steps, such as evisceration and washing, to streamline operations and reduce labor costs [38]. Furthermore, the adoption of advanced imaging and sensing technologies, such as machine vision and artificial intelligence, holds promise for enhancing process control and quality assurance in poultry processing [39]. Advancements in robotics have led to the development of robotic de-feathering machines, offering greater precision and adaptability. [40] introduced a vision-guided robotic de-feathering system, capable of recognizing feather patterns and adjusting plucking parameters accordingly. The integration of robotics in de-feathering machinery has the potential to revolutionize poultry processing by increasing efficiency and reducing labor costs.

4. Environmental and Socioeconomic Implications*:*

The adoption of chicken de-feathering machines has implications beyond processing efficiency, extending to environmental sustainability and socioeconomic considerations. The reduction of manual labor through automation has led to increased productivity and reduced labor costs. Researchers like [41] have assessed the socioeconomic implications of de-feathering machine adoption in different regions, highlighting its potential to improve working conditions and enhance the livelihoods of poultry processing workers.

5. Challenges and Future Directions in de-feathering machine design

In spite of the significant progress, several challenges persist in the design of chicken de-feathering machines. These include the optimization of machine design for different poultry breeds, the development of intelligent sensing systems to minimize carcass damage, and the reduction of water and energy consumption. Future research directions may involve the integration of machine learning algorithms for real-time monitoring and control, as proposed by [42], and the exploration of alternative de-feathering techniques, such as air-assisted plucking, as suggested by [43]. The future of chicken de-feathering machines lies in continued research and development. Exploring alternative de-feathering techniques, such as water-based systems, holds promise for achieving even higher processing efficiency and improved product quality. Moreover, efforts to optimize de-feathering parameters based on individual carcass characteristics using advanced technologies could yield further enhancements.

6. Conclusion

Chicken de-feathering machines have evolved significantly over the years, with contributions from various research works. From traditional drum-based pluckers to modern robotic systems, the poultry industry has seen remarkable advancements in efficiency and product quality. Advancements in technology have significantly transformed the capabilities and performance of chicken de-feathering machines, leading to improved efficiency, product quality, and sustainability in poultry processing operations. By leveraging innovations in machine design, materials, control systems, and automation, poultry processors can enhance their competitiveness while meeting the evolving demands of consumers and regulatory agencies. This review has provided a comprehensive overview of the literature on chicken de-feathering machine design, highlighting the importance of ongoing research and development to address current challenges and shape the future of poultry processing. It is instructive to note that future research and development effort that will focus on advancing technology to further optimize de-feathering efficiency, product quality, and sustainability in the poultry processing industry should be implemented.

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