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**ADVANCEMENTS IN ARTIFICIAL INTELLIGENCE- IMAGING ANALYSIS (IA) SYSTEMS TECHNOLOGY FOR COMPREHENSIVE QUALITY EVALUATION OF PET FOOD PRODUCTS**

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*The increasing demand for high-quality pet food products and the need for strict safety standards have led to the exploration and development of technologies that can accurately and quickly assess the quality of these products. One such technology is Imaging Analysis (IA) systems, which offers automation, non-destructiveness, and cost-effectiveness to meet these evolving requirements. Imaging Analysis (IA) systems electronically replicate human visual perception, enabling precise and efficient evaluation of images. Extensive research has highlighted its potential and demonstrated successful applications in examining and grading pet food products. This review paper*

*introduces the fundamental components of computer vision systems, while also discussing their advantages and disadvantages. Additionally, it explores image processing techniques and provides a comprehensive analysis of recent advancements and potential applications in evaluating the quality of pet food products.*

**Keywords:** Pet food, Imaging Analysis (IA) systems, quality assessment technologies, automation, image processing.

**ЖАНУАРЛАРҒА АРНАЛҒАН ЖЕМ САПАСЫН КЕШЕНДІ БАҒАЛАУҒА  
АРНАЛҒАН ЖАСАНДЫ ИНТЕЛЛЕКТ - КЕСКІНДІ ТАЛДАУ (IA)  
ТЕХНОЛОГИЯЛАРЫНЫҢ ЖЕТІСТІКТЕРІ**

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*Үй жануарларына арналған жоғары сапалы жем өнімдеріне сұраныстың артуы және қатаң қауіпсіздік стандарттарының қажеттілігі осы өнімдердің сапасын дәл және жылдам бағалай алатын технологияларды іздестіруге және дамытуға әкелді. Осы дамып келе жатқан талаптарға сәйкес келетін технологиялардың бірі - Imaging Analysis (IA) жүйелері, олар жем жасау үрдістерін автоматтандыру мен үнемділікті қамтамасыз етіп, анализ кезінде өнімді бұзбай талдауға мүмкіндік береді. Imaging Analysis (IA) жүйелері адамның көрнекі қабылдауын электронды түрде қайталайды, бұл кескіндерді дәл және тиімді бағалауға мүмкіндік береді. Кең ауқымды зерттеулер бұл жүйелердің мүмкіндіктерін ашып көрсетті және үй жануарларына арналған жем өнімдерін сараптауда және бағалауда тиімді екендігін дәлелдейді. Бұл шолу мақаласы компьютерлік көру жүйелері технологиясының негізгі құрамдас бөліктеріне тоқталады, сонымен бірге олардың артықшылықтары мен кемшіліктерін талқылайды. Оған қоса, ол кескіндерді өңдеу әдістерін зерттейді және үй жануарларына арналған жем өнімдерінің сапасын бағалаудағы соңғы жетістіктер мен әлеуетті қолданбалардың жан-жақты талдауын қамтамасыз етеді.*

**Негізгі сөздер:** үй жануарларына арналған жем, кескінді талдау (IA) жүйелері, сапаны бағалау технологиялары, автоматтандыру, кескінді өңдеу.

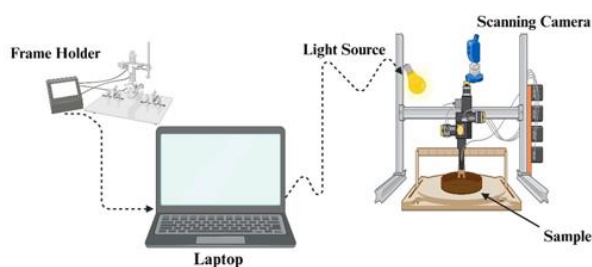
**ДОСТИЖЕНИЯ ТЕХНОЛОГИИ СИСТЕМ ИСКУССТВЕННОГО  
ИНТЕЛЛЕКТА - АНАЛИЗА ИЗОБРАЖЕНИЙ (IA) ДЛЯ КОМПЛЕКСНОЙ ОЦЕНКИ  
КАЧЕСТВА КОРМОВ ДОМАШНИХ ЖИВОТНЫХ**

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*Растущий спрос на высококачественные корма для домашних животных и необходимость соблюдения строгих стандартов безопасности привели к поиску и разработке технологий, позволяющих точно и быстро оценить качество этих продуктов. Одной из таких технологий являются системы Imaging Analysis (IA), которые не требуют измельчения продукта для анализа, обеспечивают автоматизацию и экономическую эффективность для удовлетворения этих растущих требований. Системы анализа изображений (IA) электронно воспроизводят визуальное восприятие человека, обеспечивая точную и эффективную оценку изображений. Обширные исследования выявили их потенциал и продемонстрировали успешное применение для проверки и сортировки кормов для домашних животных. В этом обзоре представлены фундаментальные компоненты системы Imaging Analysis, а также рассмотрены их преимущества и недостатки. Кроме того, в статье рассматриваются методы обработки изображений и дается всесторонний анализ последних достижений и потенциальных возможностей их применения для оценки качества кормов для домашних животных.*

**Ключевые слова:** корм для домашних животных, системы анализа изображений (IA), технологии оценки качества, автоматизация, обработка изображений.



Artificial Intelligence based Image Analysis (IA) System for Products

Visual abstract. Systemic graphical representation of imaging analysis systems technology.

### Introduction

The surge in global demand for pet food products arises from a convergence of factors, including rising per capita income levels, a heightened understanding of pet nutrition [1,2,3], and evolving societal lifestyles. This increased demand underscores the critical importance of ensuring the quality and safety of pet food to protect the health and well-being of companion animals. Despite significant advancements in scientific and technological realms, the pet food industry grapples with persistent challenges related to food safety, which have been further exacerbated by recent events such as the COVID-19 pandemic [4,5]. These challenges serve as a stark reminder of the crucial necessity to maintain a pristine food environment that supports the health and vitality of both human and animal populations. Efforts to address these challenges require ongoing vigilance, research, and innovation to uphold the highest standards of pet food safety and quality assurance [6,7].

In addition to microbial contamination, other factors such as cross-contamination from equipment and improper storage conditions can also pose risks to pet food safety. The implementation of robust quality control measures throughout the production process is essential to mitigate these risks effectively [8]. Automation technologies not only streamline production processes but also enable real-time monitoring and control, allowing for timely intervention in case of any deviations from quality standards. Furthermore, automation technologies offer benefits beyond food safety, including increased efficiency, consistency, and productivity [9]. By reducing manual labor and human error, manufacturers can improve overall product quality and reduce costs associated with recalls or product defects. Additionally, automation facilitates traceability and transparency in the

supply chain, which is crucial for ensuring product integrity and meeting regulatory requirements. As the pet food industry continues to evolve and innovate, the adoption of advanced automation technologies will likely become more widespread. Continued investment in research and development, coupled with collaboration between industry stakeholders and regulatory agencies, will further drive advancements in pet food safety and quality assurance. Ultimately, the integration of automation technologies holds the potential to revolutionize the way pet food products are manufactured, ensuring the highest standards of safety and quality for companion animals worldwide [10]. The shift towards non-destructive evaluation methodologies in the pet food industry reflects a broader trend towards more efficient and objective quality assessment practices. These non-destructive techniques leverage advancements in technology to analyze visual attributes such as color, shape, and texture, providing valuable insights into product quality without altering or damaging the sample. This approach not only reduces waste but also allows for real-time monitoring of product quality throughout the production process.

In contrast, traditional invasive testing modalities, while effective, are often labor-intensive and subjective, relying on human sensory analysis to assess product quality. Furthermore, these methods can be time-consuming and may require extensive sample preparation, leading to delays in production and increased costs [11]. By transitioning towards non-destructive evaluation techniques, manufacturers can streamline quality control processes and improve overall efficiency without compromising accuracy or reliability. Chemical and instrumental approaches, while offering heightened accuracy, also come with their own set of challenges. These methods often require

specialized equipment and expertise, making them inaccessible to smaller manufacturers or those operating on a limited budget. Additionally, the use of chemicals and solvents in these analyses can pose environmental and health risks, further underscoring the importance of exploring alternative, non-destructive evaluation methodologies [12]. Overall, the adoption of non-destructive evaluation techniques represents a significant step forward in the pet food industry, enabling manufacturers to meet the growing demand for premium-grade and safe products while ensuring efficiency, sustainability, and cost-effectiveness. As technology continues to advance, further innovations in non-destructive testing methods are expected to drive continued improvements in pet food quality assessment and production processes.

Furthermore, this paper seeks to elucidate the potential synergies between Imaging Analysis (IA) systems and other cutting-edge technologies in pet food quality assessment. By exploring interdisciplinary approaches and novel applications, we aim to uncover new insights and opportunities for improving food safety and quality assurance practices. Through collaboration with experts across various fields, including food science, engineering, and computer science, we can harness the full potential of these technologies to address complex challenges in pet food production. Moreover, this review will delve into the practical implications of implementing Imaging Analysis systems and allied technologies in real-world pet food manufacturing settings. By examining case studies and success stories, we can glean valuable lessons and best practices for optimizing the integration of these technologies into existing production processes. This practical perspective will provide invaluable guidance to industry stakeholders seeking to enhance their quality control measures and meet the evolving demands of the market.

Additionally, this paper will explore the regulatory landscape surrounding pet food quality assessment and the role of technological advancements in shaping industry standards. By staying abreast of regulatory developments and compliance requirements, manufacturers can ensure that their products meet the highest safety and quality standards. Furthermore, we will examine the potential challenges and barriers to adoption associated with implementing Imaging Analysis systems and other advanced technologies, as well as strategies for overcoming these obstacles [13]. In conclusion, this paper

endeavors to provide a comprehensive overview of the current state of pet food quality assessment and the role of Imaging Analysis systems and allied technologies in driving innovation in this field. By fostering collaboration, sharing knowledge, and promoting technological advancements, we can work towards a future where pet food products are not only safe and nutritious but also sustainable and ethically produced.

### **Imaging Analysis (IA) systems technology**

In recent years, there has been a notable surge in the adoption of Imaging Analysis systems within the pet food industry, driven by the pressing need to uphold rigorous quality control and assurance standards. IA technology represents a sophisticated approach to data extraction, employing advanced computational algorithms akin to those found in computer vision. This state-of-the-art technology harnesses advanced optical sensing devices to capture and interpret real-world scenes, with the overarching goal of electronically mimicking human visual perception. By automating manual grading processes, IA systems play a pivotal role in fostering standardization while alleviating the burden of labor-intensive inspection tasks. Within the realm of pet food production, IA technology has demonstrated remarkable efficacy in enabling precise, real-time measurements across a spectrum of product categories, ranging from routine inspection protocols to more complex applications guided by vision-based robotics (Gunasekaran, 2001). Operating through a sequence of image capture, processing, and analysis, IA systems facilitate the extraction of relevant parameters, which are subsequently compared against predefined quality thresholds to drive informed decision-making and prompt corrective actions throughout the manufacturing continuum [13,14].

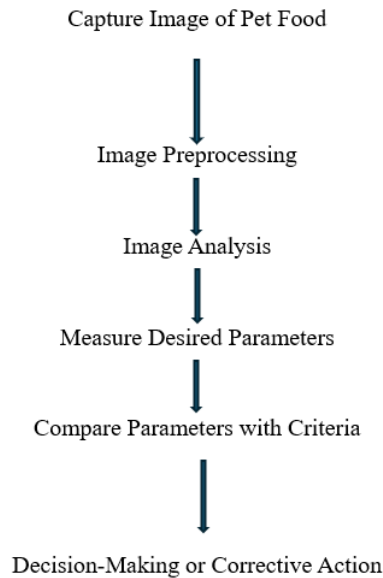
A pivotal advantage offered by IA systems in pet food inspection lies in their non-destructive nature, preserving the integrity of product samples throughout the assessment process. Anchored in sophisticated image processing methodologies, IA systems leverage a diverse array of algorithmic frameworks meticulously tailored for classification and quantitative measurement, thereby enhancing their efficacy and reliability (Krutz et al., 2000). As the pet food industry embraces technological advancements, IA technology stands poised at the forefront, expanding its reach to encompass various facets of production, including ingredient inspection,

predictive analytics for product attributes, and comprehensive nutritional analysis. This proliferation underscores the pivotal role of IA systems in fortifying quality assurance practices within the pet food landscape, signaling a

transformative shift towards precision-driven manufacturing methodologies.

**Imaging Analysis (IA) systems workflow**

Flowchart for the workflow of Imaging Analysis (IA) systems [14,15,16].



**Capture Image of Pet Food:** The process initiates with the Imaging Analysis systems capturing an image of the pet food product utilizing optical sensing devices.

**Image Preprocessing:** Subsequently, the captured image undergoes preprocessing to refine its quality and eliminate any artifacts or undesirable elements.

**Image Analysis:** The processed image is subjected to analysis by Imaging Analysis systems using sophisticated algorithms to extract pertinent information and features.

**Measure Desired Parameters:** used on the analysis, the Imaging Analysis systems quantify specific parameters of interest, such as color, texture, or shape, pertinent to quality assessment and assurance of pet food products.

**Compare Parameters with Criteria:** The measured parameters are juxtaposed against predefined inspection criteria or quality benchmarks to evaluate the quality of the pet food product.

**Decision-Making or Corrective Action:** Depending on the comparison outcomes, the MV (Machine Vision) system autonomously makes decisions or provides insights to human operators for executing corrective actions, such as sorting, reprocessing, or modifying production processes.

**Feedback Loop:** The system may incorporate a feedback mechanism to

continuously improve its performance based on previous outcomes and user feedback.

**Units of Imaging Analysis systems technology**

Imaging Analysis (IA) systems consist of several essential components, each contributing to their functionality and effectiveness [18,19,20].

- a) Image Capture Device
- b) Image Preprocessing Unit
- c) Image Analysis Software
- d) Measurement Module
- e) Comparison Module
- f) Decision Making/ Action Module

**Image Capture Device:** Captures images of meat products using optical sensing devices such as cameras or scanners.

**Image Preprocessing Unit:** Processes captured images to enhance quality and remove noise.

**Image Analysis Software:** Analyzes processed images using algorithms to extract relevant information.

**Measurement Module:** Measures parameters like color, texture, size, or shape of meat products based on analyzed images.

**Comparison Module:** Compares measured parameters against predefined criteria or standards.

**Decision Making/Action Module:** Makes decisions or provides information for corrective actions based on comparison results.

As a cutting-edge technique, MV presents opportunities for guiding and controlling various aspects of pet food production, contributing to improved quality and safety standards.

#### **Advantages of Automation and Imaging Analysis (IA) systems in Pet Food Industry**

The integration of automation and Imaging Analysis (IA) systems technology has profoundly impacted the pet food industry, revolutionizing food packaging processes and enhancing overall product quality. Automation, when coupled with Imaging Analysis systems, brings about several significant advantages that contribute to the efficiency, safety, and quality of pet food products. Automation in pet food packaging encompasses a range of tasks including filling, sealing, labeling, and palletizing, all of which are executed with precision and speed. This precision not only increases throughput but also ensures higher production volumes, meeting the escalating demand for pet food products [20,21]. Additionally, automation minimizes the risk of product damage and contamination, while seamlessly integrating quality control measures throughout the production process. By facilitating controlled packaging processes and customization tailored to consumer preferences, automation plays a crucial role in extending the shelf life of pet food products. Imaging Analysis systems, when integrated with robotics, offer unique advantages over traditional labor-intensive methods. These systems operate tirelessly and adapt to diverse environments, enabling tasks such as meat animal slaughtering and the evaluation of meat quality traits. A significant benefit of Imaging Analysis systems lies in their non-destructive nature, which allows for unique inspection processes and assists humans in visually intensive tasks. Furthermore, these systems enable the creation of permanent records of measurements, facilitating further analysis and ensuring traceability in the production process. In addition to their operational benefits, Imaging Analysis systems technology generates precise descriptive data, reducing reliance on labor-intensive human involvement while ensuring consistency, efficiency, and long-term cost-effectiveness. The adoption of automation and Imaging Analysis systems in pet food manufacturing processes has proven to be quicker, more objective, flexible, and accurate, prompting widespread adoption by industry stakeholders.

Computer vision emerges as a promising technology for food safety and quality assurance applications, offering higher operating speeds, consistency, reliability, objectivity, and suitability for industrial environments.

In conclusion, automation, and Imaging Analysis systems technology represent transformative tools in the pet food industry, offering a range of benefits that enhance efficiency, quality, and safety. As the industry continues to evolve, the adoption of these technologies is expected to drive further improvements in production processes, ensuring the delivery of high-quality pet food products to consumers worldwide.

#### **Disadvantages**

Imaging Analysis systems technology in the pet food industry entails certain disadvantages that merit consideration:

**Complexity in Image Analysis:** Analyzing overlapping or irregularly shaped pet food items can pose a significant challenge for Imaging Analysis (IA) systems. These systems may struggle to accurately segment and identify individual objects within complex scenes, leading to errors in quality assessment [22]. Developing robust algorithms capable of handling such scenarios remains a key area of research and development in the field of machine vision for pet food evaluation.

**Maintenance and Calibration Requirements:** Imaging Analysis systems require regular maintenance and calibration to ensure optimal performance. Changes in lighting conditions, environmental factors, or hardware components can impact system accuracy over time. Continuous monitoring and adjustment are necessary to mitigate these effects and maintain the reliability of the quality assessment process [23].

#### **Challenges**

**High-Resolution Image Requirements:** Imaging Analysis systems demand high-resolution images for precise analysis. Yet, achieving and maintaining this quality can be challenging in fast-paced production settings or with limited resources [22]. Insufficient image resolution may hinder the system's ability to detect intricate details, compromising its overall effectiveness.

**Assessing Rounded Objects:** Imaging Analysis systems encounter difficulties in evaluating pet food items with rounded shapes. Conventional cameras capture images from a single viewpoint, posing challenges in accurately assessing all surfaces of rounded objects. This limitation may impede the system's accuracy in

evaluating pet food quality, particularly for items with irregular shapes [23,24].

### **Prospects**

The integration of machine learning into the pet food industry heralds a future defined by unprecedented advancements and opportunities for growth. As machine learning algorithms become increasingly sophisticated, their application in pet food production holds the promise of transforming traditional practices and ushering in a new era of efficiency and precision. One of the most significant areas of potential lies in predictive analytics, where machine learning models can harness vast datasets to forecast trends in pet food preferences, nutritional requirements, and ingredient sourcing with unparalleled accuracy. By leveraging these insights, manufacturers can tailor their product offerings to meet the evolving needs and preferences of pet owners, thereby enhancing consumer satisfaction and loyalty. Moreover, machine learning algorithms are poised to revolutionize quality control processes within the pet food industry, enabling real-time monitoring and detection of defects or contaminants to ensure the highest standards of safety and quality. Through continuous innovation and the relentless pursuit of excellence, the integration of machine learning into pet food production holds the promise of driving sustainable growth, fostering innovation, and ultimately enriching the lives of pets and their owners worldwide.

### **Imaging Analysis (IA) systems in the Pet Food Industry: A Catalyst for Startups and Established Enterprises**

The integration of advanced technologies, such as machine learning, holds profound significance for both start-ups and established entities within the food industry. For start-ups, these techniques offer a gateway to innovation and competitiveness in a rapidly evolving market landscape. By leveraging machine learning algorithms, start-ups can gain invaluable insights into consumer preferences, market trends, and product development strategies, enabling them to tailor their offerings to meet the evolving needs of consumers more effectively. Additionally, machine learning facilitates streamlined operations and resource optimization, allowing start-ups to operate more efficiently and competitively in a resource-constrained environment.

In established food industry players, the adoption of machine learning represents a strategic imperative for maintaining market relevance

and driving sustainable growth. Machine learning algorithms empower established companies to unlock the full potential of their data, enabling them to extract actionable insights that drive informed decision-making across all facets of their operations. From supply chain management and inventory optimization to product development and quality control, machine learning technologies offer unparalleled opportunities for enhancing efficiency, reducing costs, and improving overall competitiveness. Furthermore, by leveraging machine learning for predictive analytics, established food industry players can anticipate market trends, mitigate risks, and capitalize on emerging opportunities, thereby maintaining their leadership position in an increasingly dynamic and competitive marketplace. In summary, the importance of machine learning techniques in both start-ups and established food industry players cannot be overstated. By harnessing the power of machine learning algorithms, companies of all sizes can unlock new avenues for innovation, efficiency, and growth, ultimately driving success and sustainability in an ever-evolving industry landscape.

### **Conclusion**

In conclusion, the convergence of technological advancements and the imperatives of the pet food industry underscores a transformative paradigm shift towards automated, data-driven quality assurance methodologies. From the application of machine learning algorithms to the deployment of computer vision systems, these innovations offer unparalleled precision, efficiency, and scalability in pet food production. As evidenced by the comprehensive review of Imaging Analysis systems, automation technologies have not only addressed longstanding challenges in quality control but also paved the way for novel approaches to ingredient analysis, defect detection, and process optimization. Moreover, the adoption of these technologies holds immense promise for startups aiming to disrupt the market landscape, offering a pathway to rapid growth and differentiation. As the pet food industry continues to evolve, the symbiotic relationship between technology and quality assurance emerges as a cornerstone of success, driving continuous improvement and innovation in the pursuit of safer, healthier, and more sustainable pet food products. By embracing these advancements and fostering collaboration between academia, industry, and regulatory bodies, we can collectively propel the pet food industry towards a

future defined by excellence, integrity, and consumer trust.

### Conflicts of interest

Authors declare that there is no conflict of interest.

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## EFFECTIVENESS OF DIGITAL TRACEABILITY IN LONG-TERM STORAGE OF SEMI-SMOKED SAUSAGES

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*Semi-smoked sausages are one of the most popular meat products in the world. However, during long-term storage, semi-smoked sausages can be subjected to various unfavorable factors that can lead to deterioration of their quality and safety. This study evaluates the effectiveness of digital traceability in long-term storage of semi-smoked sausages. The main areas of research include conducting experimental studies to evaluate the effectiveness of digital traceability. The scientific significance of the study reveals the effectiveness of using digital traceability to ensure the quality and safety of semi-smoked sausages during long-term storage. The practical significance of the study is that its results can be used to implement digital traceability in the production of semi-smoked sausages. The study utilized blockchain technology to track the storage parameters of semi-smoked sausages. As an experimental object, semi-smoked sausages with the addition of vegetable components were developed. The storage parameters of the sausages were tracked for 3 months. The results of the study showed that digital traceability provides reliable and transparent control over the condition of semi-smoked sausages at all storage stages. Digital traceability allows monitoring of the following sausage storage parameters: temperature, humidity, light, oxygen, carbon dioxide. These parameters are critical to ensure the quality and safety of semi-smoked sausages. Digital traceability enables real-time monitoring of these parameters, facilitating timely interventions to prevent the deterioration of product quality. In addition, digital traceability ensures transparency of the sausage storage process. Any interested person can get access to information about product storage parameters. This helps to increase consumer confidence in the safety of semi-smoked sausages. The results of the study can be used to implement digital traceability in the production of semi-smoked sausages. The introduction of digital traceability will improve the quality and safety of semi-smoked sausages, as well as increase consumer confidence in this product.*

**Keywords:** digital traceability, semi-smoked sausages, storage, blockchain, quality, safety.