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# Technological Processes Applied to Laboratory Animal Feeds and New Feeding Approaches

## Laboratuvar Hayvanı Yemlerine Uygulanan Teknolojik İşlemler ve Yeni Besleme Yaklaşımları

**Atakan TEPE**
*0000-0001-5497-6234*
**Tolga ALTAŞ**
*0000-0001-6267-2118*

Department of Veterinary, Düzce University Çilimli Vocational School, Düzce, Türkiye

**ABSTRACT**

Laboratory animal nutrition plays a crucial role in ensuring the health, welfare, and scientific validity of research studies involving animals. Technological advancements in feed processing have provided researchers with innovative tools and techniques to enhance the nutritional quality and stability of laboratory animal diets. Recent developments in feed processing technology have focused on improving the precision, consistency, and nutrient bioavailability of laboratory animal diets. Techniques such as pelleting, extrusion, and coating have been utilized to create homogeneous feed formulations with controlled nutrient profiles. In addition to advances in feed processing, new feeding approaches have emerged to address the specific nutritional requirements of laboratory animals. Precision feeding technologies, incorporating real-time monitoring systems and data analytics, allow for the customization of feed formulations based on individual animal needs. Overall, the integration of technological processes and new feeding approaches in laboratory animal nutrition represents a promising avenue for advancing animal welfare, research quality, and scientific outcomes in preclinical and biomedical research. By leveraging cutting-edge feed processing techniques and tailored feeding strategies, researchers can ensure the optimal nutrition, health, and well-being of laboratory animals, fostering both ethical research practices and robust scientific results. This review provides an overview of the technological processes applied to laboratory animal feeds and introduces new feeding approaches aimed at optimizing animal health and research outcomes.
**Keywords:** Laboratory animal feeding; technological processes; feeding models.

**ÖZ**

Laboratuvar hayvanlarının beslenmesi, hayvanları içeren araştırma çalışmalarının sağlık, refah ve bilimsel geçerliliğinin sağlanmasında çok önemli bir rol oynamaktadır. Yem işlemedeki teknolojik gelişmeler, araştırmacılara laboratuvar hayvanı diyetlerinin besin kalitesini ve stabilitesini artırmak için yenilikçi araçlar ve teknikler sağlar. Yem işleme teknolojisindeki son gelişmeler, laboratuvar hayvanı diyetlerinin hassasiyetini, tutarlılığını ve besin biyoyararlılığını artırmaya odaklanmıştır. Kontrollü besin profillerine sahip homojen yem formülasyonları oluşturmak için peletleme, ekstrüzyon ve kaplama gibi teknikler yaygın olarak kullanılmaktadır. Yem işlemedeki ilerlemelere ek olarak laboratuvar hayvanlarının özel beslenme gereksinimlerini karşılamak için yeni besleme yaklaşımları ortaya çıkmıştır. Gerçek zamanlı takip sistemlerini ve veri analitiğini birleştiren hassas besleme teknolojileri, yem formülasyonlarının bireysel hayvan ihtiyaçlarına göre özelleştirilmesine olanak tanımaktadır. Genel olarak, laboratuvar hayvanlarının beslenmesinde teknolojik süreçlerin ve yeni besleme yaklaşımlarının entegrasyonu, klinik öncesi ve biyomedikal araştırmalarda hayvan refahını, araştırma kalitesini ve bilimsel sonuçları geliştirmek için umut verici bir yolu temsil etmektedir. Araştırmacılar, en ileri yem işleme tekniklerinden ve özel beslenme stratejilerinden yararlanarak, hem etik araştırma uygulamalarını hem de doğru bilimsel sonuçları destekleyerek laboratuvar hayvanlarının beslenmesini, sağlığını ve refahını sağlayabilmektedirler. Bu derleme, laboratuvar hayvan yemlerine uygulanan teknolojik işlemlere genel bir bakış sunmakta ve hayvan sağlığını ve araştırma sonuçlarını optimize etmeyi amaçlayan yeni besleme yaklaşımlarını ele almaktadır.
**Anahtar kelimeler:** Laboratuvar hayvanı besleme; teknolojik işlemler; besleme modelleri.

**Corresponding Author**
**Sorumlu Yazar**
Tolga ALTAŞ
tolgaaltas@duzce.edu.tr

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## INTRODUCTION

Laboratory animal feeds play a crucial role in providing essential nutrients for the health and well-being of animals used in research settings. These specialized feeds are carefully formulated to meet the specific nutritional requirements of different species of laboratory animals, ensuring their growth, reproduction, and overall health are adequately supported (1).

Laboratory animals have unique dietary needs based on their species, age, weight, and health status. Properly formulated feeds provide the necessary balance of proteins, carbohydrates, fats, vitamins, minerals, and other nutrients to meet these requirements (1). Feed manufacturers adhere to strict quality control measures to ensure the consistency and safety of laboratory animal feeds. This includes sourcing high-quality ingredients, monitoring production processes, and conducting quality assurance tests (2).

Different species of laboratory animals, such as rodents, rabbits, and non-human primates, require feeds with specific nutrient compositions tailored to their physiological and metabolic characteristics. Specialized formulations may include ingredients like amino acids, fiber, and micronutrients (1,2).

Laboratory animal feeds are essential components in biomedical research and play a crucial role in maintaining the health, well-being, and scientific integrity of laboratory animals (2). Proper attention to the formulation, quality control, and specific nutritional requirements of these feeds is vital to ensure the reliability and validity of research outcomes.

This review aims to provide an overview of the technological processes applied to laboratory animal feeds and introduces new feeding approaches aimed at optimizing animal health and research outcomes.

## IMPORTANCE OF TECHNOLOGICAL PROCESSES IN ENHANCING ANIMAL FEED QUALITY

Technological processes play a significant role in the production of high-quality animal feeds by improving digestibility, nutrient absorption, and overall feed efficiency. These processes encompass various methods and techniques, such as grinding, mixing, pelleting, and coating, that contribute to enhancing the nutritional value and palatability of the feeds (1,3).

Technological processes such as grinding and pelleting break down feed ingredients into smaller particles, increasing the surface area available for enzymatic action and improving nutrient absorption in animals. Coating and flavoring processes can improve the taste and aroma of feeds, making them more appealing to animals and encouraging adequate feed intake, which is crucial for meeting their nutritional requirement (4). Precision in feed processing techniques, such as accurate mixing and pelleting, can reduce feed wastage and ensure that animals consume a balanced diet without selective feeding.

Technological processes in feed production are essential for optimizing feed quality and ensuring that animals receive the necessary nutrients for growth, health, and performance. By implementing advanced processing techniques, feed manufacturers can enhance the nutritional value, consistency, and palatability of animal feeds, leading to better overall feed efficiency and animal well-being (4,5).

## TECHNOLOGICAL PROCESSES IN PRODUCTION

Grinding and mixing are essential processes in animal feed production that impact feed quality, nutrient availability, and animal performance. The efficiency and precision of these techniques can significantly influence the digestibility, palatability, and overall effectiveness of the feed in meeting the nutritional requirements of animals (6).

### Grinding Techniques

Grinding is a mechanical process used to reduce feed ingredients into smaller particles, thereby increasing surface area for enzymatic action and improving nutrient accessibility. Various grinding methods, such as hammer mills, roller mills, and attrition mills, are employed in feed production to achieve the desired particle size distribution and consistency (1).

### Mixing Processes

Mixing involves blending different feed ingredients to create a uniform and balanced feed formulation. Proper mixing ensures that nutrients are distributed evenly throughout the feed, minimizing nutrient segregation and reducing the risk of animals selectively consuming certain components of the feed. Techniques like horizontal and vertical mixers are commonly used in feed mills to achieve thorough mixing (1).

Efficient grinding and mixing processes are crucial for maintaining feed quality and optimizing nutrient utilization by animals. Properly ground feed particles and uniform feed mixtures contribute to improved feed intake, digestion, and absorption of nutrients. In contrast, inadequate grinding or mixing can lead to feed wastage, reduced feed efficiency, and compromised animal health (4,6). Grinding and mixing techniques are fundamental processes in animal feed production, influencing feed quality, nutrient availability, and animal performance. By adopting effective grinding methods and thorough mixing practices, feed manufacturers can optimize feed formulation, enhance nutrient utilization, and support the health and well-being of animals. Continued research and innovation in grinding and mixing technology are essential for advancing animal nutrition (7).

### Pelleting and Extrusion Methods

Pelleting and extrusion are advanced processing techniques used in animal feed production to enhance feed quality, digestibility, and overall performance of animals. These methods involve the compression, heating, and shaping of feed ingredients to create pellets or extruded products that offer numerous benefits in terms of nutrient preservation, feed efficiency, and animal health (8).

### Pelleting Process

Pelleting is a mechanical process that involves compressing feed ingredients into cylindrical pellets, often using heat, moisture, and pressure to facilitate binding and shaping. Pelleted feeds are known for their improved palatability, reduced dustiness, and enhanced nutrient bioavailability compared to mash feeds. The pelleting process can result in increased feed intake, digestive efficiency, and growth performance in animals due to the optimized nutrient delivery and physical characteristics of the pellets (1).

### Extrusion Technique

Extrusion is a thermal and mechanical process that involves passing feed ingredients through a high-pressure extruder, where they undergo heat, pressure, and shear forces to form expanded, cooked pellets or kibbles. Extruded feeds are distinguished by their increased digestibility, deactivation of anti-nutritional factors, and improved starch gelatinization, making them highly digestible and bioavailable to animals. Extrusion can enhance the nutritional value and functional properties of feed ingredients, promoting better growth, feed conversion, and nutrient utilization in animals (1).

Pelleting and extrusion methods offer several advantages in animal feed production, including improved feed digestibility, reduced ingredient segregation, enhanced pellet durability, and decreased microbial contamination. By processing feed ingredients through pelleting or extrusion, feed manufacturers can achieve greater feed consistency, nutrient retention, and performance benefits for animals, contributing to overall feed efficiency and health outcomes (9,10).

**Coating and Encapsulation Processes**

Coating and encapsulation are advanced techniques used in animal feed production to improve feed quality, palatability, nutrient retention, and targeted delivery of bioactive compounds (11). These processes involve applying protective coatings or encapsulating active ingredients around feed particles to enhance stability, bioavailability, and performance benefits for animals.

**Coating Techniques**

Coating in feed production involves applying a protective layer of encapsulating material around feed particles to enhance stability, reduce nutrient degradation, and improve palatability. Coatings can be made from various materials, including lipids, polysaccharides, proteins, and synthetic polymers, to provide a barrier against moisture, oxidation, and other destabilizing factors. Coating feed ingredients can help mask undesirable tastes or odors, increase feed acceptance, and ensure the targeted release of nutrients in the digestive tract (11,12).

**Encapsulation Methods**

Encapsulation is a process that involves encapsulating active ingredients, such as vitamins, minerals, probiotics, or enzymes, within a protective shell or matrix to enhance their stability, bioavailability, and targeted delivery. Encapsulated ingredients are protected from environmental factors, such as heat, moisture, and pH fluctuations, ensuring their efficacy and controlled release in the digestive system. Encapsulation can improve the performance of sensitive nutrients and functional additives in animal feeds, leading to enhanced nutrient utilization and health benefits for animals (12).

Coating and encapsulation processes offer several advantages in animal feed production, including improved nutrient retention, reduced nutrient interaction, enhanced stability of sensitive compounds, and controlled release properties. By utilizing coating and encapsulation techniques, feed manufacturers can tailor feed formulations to meet specific nutritional requirements, enhance feed efficiency, and optimize animal performance (13). Coated and encapsulated feeds can provide targeted nutrition, support gut health, and improve nutrient absorption in animals.

## INNOVATIONS IN LABORATORY ANIMAL FEED TECHNOLOGY

Several advancements have been made in laboratory animal feed technology to enhance the nutritional quality, palatability, and digestibility of feeds. Formulations are tailored to meet the specific requirements of different species, strains, and research purposes. Microencapsulation techniques have been utilized to protect sensitive nutrients and ensure their stability during storage (14). Additionally, the use of probiotics and prebiotics in animal feeds has gained popularity to promote gut health and improve overall well-being. In recent years, efforts have been made to reduce the environmental impact of animal feed production by incorporating sustainable and alternative protein sources. These include insect-based proteins, algae-based ingredients, and plant-based alternatives, which not only provide a sustainable source of nutrients but also offer health benefits to laboratory animals (15). Furthermore, advancements in precision nutrition have enabled researchers to customize feed formulations based on individual animal requirements and research goals. This personalized approach ensures that laboratory animals receive optimal nutrition for their specific needs, leading to improved research outcomes and animal welfare (15,16).

Innovations in laboratory animal feed technology have significantly improved the nutritional quality, sustainability, and personalized approach to feeding laboratory animals. These advancements play a crucial role in ensuring the health, well-being, and research reliability of laboratory animals (16). Continued research and development in this field are essential to further optimize animal nutrition and welfare in scientific research settings.

## NEW STRATEGIES IN THE NUTRITION OF LABORATORY ANIMALS

In the nutrition of laboratory animals, the content and quality of feeds, and appropriate feeding programs are very important and directly affect animal health and welfare. Accordingly, with good and proper nutrition, the metabolism and physiological systems of animals will function normally and the desired real data can be obtained in experimental studies. Otherwise, the findings obtained as a result of the experiments will be erroneous and the reliability of the study will decrease. For almost 40 years, the scientific community has taken action to control environmental factors that contribute to variation, and because of the contribution of laboratory animals to scientific studies, the nutrition of laboratory animals has been recognized as an important element. Over the past years, various individuals and scientific institutions have developed various guidelines. These guidelines aimed to improve the quality of research by standardizing the selection, use, and reporting of diets used for research animals. One of these is the work of Knapka et al. (17), a laboratory animal nutritionist, who, in the early 1970s, initiated a standardization program and formulated the first "open formula" formula, aiming to achieve standardization in laboratory animal diets.

As a result of these and other studies, the Central Laboratory Animal Diet Advisory Committee supported the use of 'standard reference diets' in biomedical research as an idea to improve the ability to replicate research. As a result, fixed-formula laboratory animal diets (AIN76) were formulated. In 1993, the AIN93 Growth and AIN93 Maintenance diets were subsequently formulated (18). During this period, the AIN93 re-emphasized the need to standardize experimental laboratory animal diets so that intrinsic variation could be reduced.

Around the same time, laboratory animal nutritionists began formulating open-formula, natural-ingredient experimental animal diets to meet the need for standardized laboratory animal diets. With the development of open-formula diets, the fixed-formula, fixed-nutrient-concentration, closed-formula, and natural-ingredient diets were developed to reduce the potential variation that diet could cause in research.

**Open Formula Diets**

In open-formula diets, the concentrations of all ingredients are publicly available. Open-formula diets also enable a retrospective analysis of possible diets. New open-formula diets are being formulated and made available as needed. For example, the NIH31 open formula diet is an autoclavable rodent diet, formulated in response to requests from the NIH Animal Research Center. However, when the diet is autoclaved, minimal starch gelatinization occurs, so problems with pellet clumping and increased hardness can occur.

**Closed Formula Diets**

Commercial diets manufactured and marketed under seller trade names are typically 'closed formula diets' and proprietary products. While ingredients are listed, quantitative ingredient formulation is not specified. Therefore, ingredient composition may vary. Differences in formulation may occur feed manufacturers prefer closed formula diets to achieve the 'least cost' formulation. Least-cost strategy refers to formulating diets that maximize profit by using the least costly ingredients.

**Fixed Formula Diets**

In a fixed-formula diet, the quantitative ingredient formulation does not change. For open-formula diets, the terms fixed-formula and open-formula are mistakenly thought to be synonymous, as quantitative formulations do not change. Both fixed- and open-formula diets may occasionally require changes in nutrient composition or formulation to meet changing nutrient requirements. However, while changes to the quantitative ingredient formulation are publicly disclosed when open-formula diets are changed, information on changes to the fixed closed formula is diet-specific and therefore not publicly disclosed.

**Constant Nutrition Diets**

Constant nutrition is a trademarked expression of PMI Nutrition International and describes laboratory animal diets (LabDiets) for which the concentrations of known nutrients and ingredient groups remain constant. However, the quantitative content of the formulations of constant nutrition diets may be changed without public disclosure. Changes in diet formulation may alter undefined nutrients or dietary components such as fat.

The ability to replicate research is essential for science. One key to replicating research is to control all variables, i.e. to reduce variation. To meet this requirement, microbiological and genetic characterization of laboratory animals has become increasingly well-defined over the years. Health status and environmental factors (e.g. feeding, bedding, light cycles, noise, humidity, temperature, and staff interaction with animals) are factors that can affect research. They should be controlled as far as possible. Diet in laboratory animals is an important environmental factor affecting reproduction, growth, disease, and experimental manipulation.

A new and comprehensive approach to biological research is also developing, namely systems biology. This "systems biology" refers to how all relevant components of a biological drug interact functionally over time and under changing conditions. New technologies such as genomics, proteomics, metabolomics, and nutrigenomics are emerging and being used to advance the systems biology approach (19). These technologies are influenced by both intrinsic and environmental factors.

Progress in the battle against human disease and suffering is accelerating with the availability of genomic information for humans, mice, and other organisms. The techniques and knowledge emerging from these genome projects have reinvigorated the process of locating and identifying genes involved in disease. To date, approximately 1,000 human disease genes have been identified and partially characterized, 97% of which are known to cause monogenic diseases (20). However, most cases of obesity, cardiovascular disease, diabetes, cancer, and other chronic diseases are caused by complex interactions between various genes and environmental factors. It is therefore not surprising that strategies to characterize and identify monogenic diseases fail when applied to chronic diseases. Despite more than 600 association studies published since 2002, the molecular basis of chronic diseases is still not understood. Such results have led to the development of the "common disease/common variant hypothesis", which states that chronic diseases are caused by clusters of gene variants that collectively contribute to disease onset and development (19).

Nutrition is the most important environmental factor affecting the health and productivity of animals. Traditional research in the field of animal nutrition has concentrated on the components that, in excess or deficiency, affect the health and productivity of animals. In recent years, due to the advances in molecular genetics, increasing knowledge about the composition and functions of genomes has begun to be transferred to practice. These advances have allowed us to understand how nutrients alter gene and protein expression and how they affect cell and organismal metabolism (21). The term "nutrigenomics" was first used by DellaPenna (22) as a branch of science dealing with the role of nutrients in gene expression. Nutrigenomics or nutritional genomics, which was later defined by various researchers, can be considered as a combination of molecular genetics and genomics in the fields of health, nutrition, and genomics.

The basic approach of this new field of research is that common food chemicals may directly or indirectly affect the genome, altering gene expression or structure, that nutrition may be a risk factor in some individuals under certain conditions, and that genes regulated by nutrition are likely to influence the onset, impact and progression of various chronic diseases, the magnitude of the effect of nutrition on the balance of health and disease states depends on the genetic makeup of the individual, and that nutrition based on information about nutrient needs, nutritional level and genotype (i.e. individualized nutrition) can be used to prevent, mitigate and treat chronic diseases (19). In line with these assumptions, the goal of nutrigenomics is to find nutritional practices that are appropriate for each individual's genetic profile to optimize their health and productivity (23).

A number of new dietary models are emerging in the modeling phase of feeding experimental animals;
***Obesity diets and high-fat diets;*** are 24% fat, 35% fat, and 45% fat diets. Diets in which vegetable or animal fats are used as fat sources according to the choice of model.
***Metabolic disorder diet;*** also known as purified-purified diet.
***Diabetes-forming diets;*** which are also obesity diets, are diets that are lower in protein and higher in carbohydrates than high-fat diets.
***Atherosclerosis diets;*** are diets that appropriately raise blood cholesterol and other blood fats, unlike high-fat diets, also known as hyperlipidemia, diets with the addition of cholesterol and cholic acid.
***Diets that cause fatty liver disease;*** are methionine- and choline-poor diets and contain animal fat. Variations of high-fat diets and methionine- and choline-deficient diets are used to study different stages of NAFLD/NASH, depending on the type of diet and feeding duration.
***High-carbohydrate diets;*** diets high in carbohydrates along with fat, are the closest dietary group to the human diet. Such diets cause metabolic disorders in rats and mice. They are diets with a carbohydrate ratio of 25-70%.
***Ketogenic diets;*** are diets high in fat and low in carbohydrates. Both fats and oils can be used in these diets.
***Research initiation and synchronization diets;*** are diets used as microbial diets during the adaptation phase of the animals in order to provide proper results for the experiments.
As a result, there are traditionally closed and open formula diet feeds and recently emerging nutrigenomics, individualized, and tailored feeding models, and various feeding models used in modeling with diet, especially in the modeling phase.

## CONCLUSION

The integration of technological processes in feed processing and the implementation of novel feeding approaches represent significant advancements in enhancing laboratory animal nutrition. The utilization of cutting-edge techniques such as pelleting, extrusion, and coating has revolutionized the formulation of laboratory animal diets, leading to improved digestibility, nutrient bioavailability, and overall diet quality. These technological processes have enabled researchers to create standardized and tailored feed formulations that meet the specific nutritional requirements of laboratory animals, ultimately contributing to the health, welfare, and research outcomes of these animals. Moreover, the adoption of new feeding approaches, including precision feeding technologies and behavioral enrichment strategies, has further optimized the nutritional management and well-being of laboratory animals. Precision feeding algorithms personalized to individual animal needs have enhanced nutrient utilization and growth performance, while enrichment programs and diversified diets have promoted behavioral enrichment and stress alleviation in research animals. By addressing the diverse nutritional and behavioral needs of laboratory animals through innovative feeding approaches, researchers can ensure the ethical treatment, welfare, and scientific validity of research studies involving animals. Moving forward, continued research and innovation in laboratory animal nutrition are essential to furthering our understanding of the complex interplay between diet, health, and research outcomes in laboratory settings. By leveraging technological advancements and embracing novel feeding approaches, the scientific community can strive towards promoting optimal animal welfare, research reproducibility, and ethical standards in laboratory animal research. Ultimately, the combination of advanced technological processes and new feeding strategies holds promise for advancing the field of laboratory animal nutrition and fostering improved health and well-being outcomes for research animals.

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