INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) AND PRECISION LIVESTOCK (PLF) APPLICATIONS IN FARM CONDITIONS

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PREFACE

Yield per unit animal decreases due to reasons such as traditional practices, climate change, mixing of socio-economic and environmental phenomena in farm environments. There is an increase in the demand for animal protein due to factors such as population growth and income increase throughout the world. Intelligent sensing tools and different sensors, which are one of the effective methods in meeting animal protein needs, information and communication technologies with large amounts of data obtained from platforms, and sensitive livestock applications will have the potential to significantly increase individual animal analysis capability and farm efficiency by enabling advanced management in the farm. Animal welfare also has a significant impact on yield and animals should be constantly monitored and controlled to monitor their welfare condition. Well-being assessment has traditionally been carried out in past times by direct observation by people and providing information only at selected points in time. As 'Precision Livestock' technologies can provide more valid, reliable, and applicable real-time data at an individual scale, they serve as early monitoring systems for animal welfare, thus causing increased interest in this assessment method in recent times. With sensitive livestock application, estrus of animals, milk production, breeding values of bulls, volatile fatty acids in the rumen of dairy animals as well as health and health problems (mastitis and lameness) can be estimated. Thus, the workforce in animal breeding is reduced, the herd is healthy, and unnecessary drug and veterinary costs are reduced.

İn this study, priority will be given to information and communication techniques in farm conditions, methods used in sensitive animal husbandry activities, and their application in farm conditions.

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INTRODUCTION

Production of data from animals, analysis and evaluation of the data are very important in terms of revealing the mistakes of practices in the livestock sector. The use of information and communication techniques and specific analyses/programs should ensure that practices that may be negative in terms of ensuring the sustainability of farm activities are revealed. For this purpose, animals should be recorded both manually and via specific programs. This is of importance for the traceability of animals. When any undesirable situation occurs, the source of the problem is identified by backtracking with information and communication techniques. For this purpose, different systems (face recognition, sensors, RFID, etc.) are used for the identification of animals. With the use of such systems, it is of utmost importance to know the origin of the products in order to increase their quality, to provide more effective risk management, to observe the environmental impact and to ensure sustainable agricultural production.

According to Tekin et al. (2021), precision livestock farming (PLF) is a digital management system in which all stages of the production process are controlled by measuring livestock farming, reproduction, health, welfare and herd environmental effects using information and communication technologies (ICT). Continuity cannot be achieved since it is difficult and time-consuming for a person to continuously monitor animals 24 hours a day for audiovisual reception of reliable data for management. With the latest technologies, such information is more easily transferred from animal to human in the form of audiovisual data flow. Thus, it is possible to effectively transform the collected reliable information into a decision-making process (e.g., reproduction management or calving tracking).

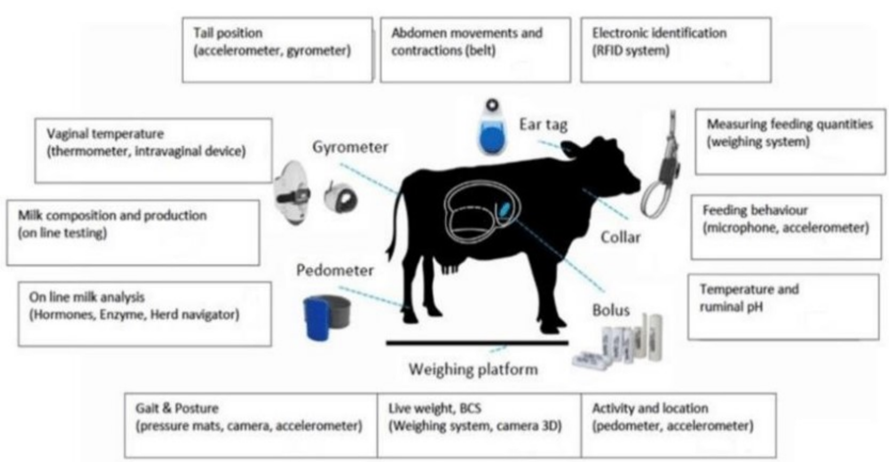

Figure 1: Systems used in dairy cattle (Tekin et al., 2021)

Different systems used in dairy cattle to summarize with which system reproduction, health, feeding and general monitoring can be performed more effectively are given in Figure 1. Devices with the potential to measure the physiological, immunological and behavioral responses of farm animals and different animals are called biosensors. In addition to the physiology of the animal, these devices are highly advanced monitoring devices for monitoring the environment of an animal and for specific measurement of individual and multiple parameters. At the same time, these devices are not only very specific and sensitive for the analyzed parameters, they are reliable and easy to use, and they also accelerate the monitoring process. New biosensors for livestock management provide significant benefits in monitoring the animal's physiological health through disease detection and isolation, health monitoring and detection of breeding cycles, and analysis of the animal's environment additionally. Data obtained from monitoring integrated livestock farming in the future are expected to help farmers and the agricultural industry in order to improve animal productivity. The data reduce the impact of the livestock industry on the environment and are expected to lead to the improvement of applicable agricultural techniques. It also reported that biosensors would contribute to the 4th revolution in agriculture by incorporating innovative technologies into cost-effective diagnostic methods that could reduce the potentially destructive effects of infectious outbreaks in livestock (Neethirajan et al., 2017).

Smart and Atıl (2014) reported in their study that artificial intelligence is widely used in models created to solve complex problems in scientific research. They also reported that the data obtained from animals provide benefits for different application and technical evaluation methods and reveal more comprehensive and applicable relationships. In addition, they also mentioned that there are applications in the field of dairy cattle farming with "fuzzy logic" that provides great convenience to breeders and researchers thanks to decision support systems used in decision-making and evaluation processes, "artificial neural networks" methods that make very successful yield estimates and various classifications.

The globalized and highly competitive world market today has expanded the range of needs across all sectors of the agricultural food industry. More efficient products are important in the dairy industry for adapting to the current market by becoming environmentally friendly, transparent and safe. The Internet of Things (IoT), edge computing (EC) and distributed ledger technologies (DLT) are crucial to achieving these improvements. The reason for this is that they allow the digitalization of all parts of the value chain and provide the consumer with detailed information about the final process to ensure product safety and quality. In Smart Agriculture environments, IoT and DLT enable manufacturers to optimize processes by providing resource tracking and traceability in the value chain, ensure the origin of the product, and also enable consumers to provide quality guarantees, and the EC processes and manages large data generated by IoT devices at the network end compared to a central cloud. Thus, they ensure shorter response times and higher Service Quality (QoS) in addition to the implementation of services related to safety (Alonso et al., 2020).

Different strategies have been proposed over the years to determine the feeding behavior of animals and to provide more permanent information. For this purpose, it is reported by different researchers that animals can be observed directly during the day in different time periods (Boğa, 2008). This implementation is quite simple and cost-free. However, since the human capacity to collect and perceive data varies from observer to observer, it may be become the wrong task as it is more time consuming than other applications and the slightest mistake is not possible to turn back. Animal behaviors such as resting, feed and water consumption, ruminating or different movements under social behaviors at certain times during the day allow us to get information about whether the animal is in suitable conditions in the environment and whether the animal is healthy or not. Nutritional behaviors of animals such as feed arrival, feed consumption, eating duration and time between eatings are also important (Boğa, 2008). In different studies, electrical resistance and pressure were used to monitor jaw movement well in cattle and sheep. In this way, there is an electromyography-based data collection system using electrodes on the jaw muscles to measure the signals related to chewing movements (Nunes et al., 2021).

Animal health in farm conditions is an essential prerequisite for welfare. Animal welfare will be an important issue as the most significant indicator that performance is at the maximum levels given by the animal's genetic levels for healthy animals In recent years, farm owners have been demanding higher welfare standards and reliable methods to measure or evaluate the bodily and physiological health of animals in order to ensure high levels of animal welfare. In 1965, the UK government published a "Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Farming Systems". It is reported that the Livestock Systems should provide the animals with the freedom to stand, lie down, rotate, groom themselves and stretch their limbs. Five Freedom assessments were established by the Farm Animal Welfare Committee in 1992 (FAWC, 1992). The five freedoms are: (1) freedom from thirst and hunger, (2) freedom from discomfort, (3) freedom from pain, injury and disease, (4) freedom to express (most) normal behaviors, and (5) freedom from fear and distress (Jose et al., 2020).

The fact that dairy cattle spread their different behaviors over time during the day and exhibit behavior below and above this suggests that there are some problems. The fact that animals consume feed, ruminate and exhibit social behaviors shows that the animal is healthy.

Table 1. The time spent by dairy cattle during the day (Tekin et al., 2021).

Lying/Resting	12-14 hours
Ruminating	7-10 hours
Eating	3-5 hours, 9-14 eatings a day
Social interaction	2-3 hours
Being Milked	2-3 hours
Drinking	0.5 hours

The changing needs of farm animals depending on their physiological status are affected by genetic and environmental conditions. The genetic structure of the animals and the physiological needs of the animal will also be provided by good care and nutrition. However, it is seen as a neglected situation and depends on the ambient conditions, that is, the climate in which it is located. Climate (temperature, humidity and temperature*humidity index) causes animals to stress above and below certain levels. The increase in colds in animals causes the animals to experience heat stress with the increase in cold stress and heat. This shows that climate is one of the main limiting factors on performance and ensuring the sustainability of efficiency. For this reason, the comfort environment/zone of the animal (the ambient temperature at which the temperature released from the body to the environment does not exceed the temperature level produced in the organism and the body temperature of the animal can easily be maintained) should be determined and measures should be taken to minimize the negative effect of the climate on the animal. It can be used to evaluate live animal performance and welfare with precision livestock farming technologies that enable automatic monitoring of environmental, physiological and behavioral variables (Fourne et al., 2017). Monteiro et al. (2021) reported that agricultural technologies have become increasingly common in modern agriculture to optimize agricultural and animal production and to minimize operating costs.

Precision agriculture (PA) is a technology-supported, data-driven approach to farming management that observes, measures, and analyzes the needs of individual fields and crops. Precision livestock farming (PLF), which is based on automatic monitoring of individual animals, is used to monitor animal behavior and physical environment as well as animal growth, milk production and detection of diseases, among others. Neethirajan and Kemp (2021) aimed to investigate the latest situation in the digitization of precision livestock farming (PLF) technologies on farms, especially biometric sensors, with big data and blockchain technology. Biometric sensors reported that they include non-invasive sensors that monitor the health and behavior of an individual animal in real time and allow farmers to integrate this data for population-level analyses. With the advancement in technology, devices that measure blood pressure with non-invasive oscillometric method are developed. Such a non-invasive sensor is a blood pressure sensor (Anonymous). Real-time information from biometric sensors is processed and integrated using big data analytical systems based on statistical algorithms to sort large, complex datasets to provide farmers with relevant trend patterns and decision-making tools. Blockchain technology, where sensors are activated, provides a significant advantage in monitoring disease outbreaks and preventing related economic losses and food-related outbreaks by ensuring safe and guaranteed traceability of animal products from farm to table. Thanks to the use of PLF technologies, livestock farming also has the potential to address concerns about the reliability of animal products by increasing consumer confidence by becoming more transparent.

The integration of sensors, nanotechnology and instrumentation and the behavioral, mental and physiological parameters of farm animals enable continuous and real-time measurement. Neethirajan (2020) has evaluated the detection technology and sensor data-based models used to discover biological systems such as animal behavior, energy metabolism, epidemiology, immunity, health and reproduction. The use of sensor technology to evaluate physiological parameters contributes positively to animal welfare while minimizing production losses. The evaluation of all these effects indicates that the use of technological processes in animal production and the transfer of this technology to the farmer can contribute to efficiency, performance and economy.

In our study, information and communication techniques in farm conditions and the methods used in precision livestock activities, their advantages and application possibilities were compiled.

Works on traceability systems and Artificial Intelligence (AI)

Artificial intelligence systems find important application areas in natural and human sciences. As in many technologies, artificial intelligence systems can be used in the service of humanity and nature, as well as war technologies can be used for the unlimited exploitation of nature and controlling people. Süslü (2019) reported that artificial intelligence systems can be used to solve many of the problems we face today, such as global warming, environmental pollution, air pollution, imbalance in income and resources.

With the traceability system, it is aimed to record each stage from the production stage to the consumption stage of the product and to control the backward stages when necessary and to eliminate errors. For this purpose, with the registration of animals on the farm, it is possible to follow the animals with herd management programs and to ensure the traceability of animal products and traceability in foods. Consumer-based traceability, on the other hand, can be defined as recording the product in the chain from production to consumption and tracking them. Today, this consumer-based traceability system is encountered with the term field to table and we can frequently encounter this term (Cebeci, 2007; Cebeci et al., 2009; Cebeci and Boğa, 2009; Bergier et al., 2021).

Grain and beef constitute a significant part of the majority of exports in global agricultural trade markets. Especially in accessing sustainable markets, problems may be experienced due to insufficient harmony in supply chains. For this purpose, Bergier et al. (2021) prepared a mobile application based on cloud/end cognition for the supply of live animals. This forms a network like the ring of the chain. The application, called BovChain, is an intergroup (P2P) network that connects landowners and slaughterhouses. The study has two important objectives: to maximize sustainable business by reducing transaction costs and strengthening ties between government-authorized stakeholders, and to create useful metadata for digital certification by utilizing CMOS and GPS sensor technologies embedded in low-cost smartphones. Successful reporting operations in the digital field are recorded as metadata, and relevant big data, certification of livestock origin, is valuable for traceability to sustainability compliance in "global" beef markets.

While ensuring the traceability of products until the consumption of people in the production chain both in our country and throughout the world, it is aimed to quickly collect problematic products by determining the location and cause of the problem by examining the records backwards in case of encountering any problems with these laws. In this case, it is reported that the use of legal regulations in a way that helps consumer preferences is not taken into account (Cebeci and Boğa, 2009). They reported that the feedTRace system, which is a network-based traceability system developed to be implemented in an enterprise producing chicken meat including two high tonnage compound feed factories and feed and integrated chicken enterprises operating in the Çukurova Region, will be useful as a model design in geographical traceability (Cebeci and Boğa, 2009). Cebeci (2007) reported that the traceability systems in the mixed feed industry should also be made available to the sector through the network and that the non-governmental organizations (NGO; Turkish Feed Manufacturers Association, Egg Producers Association, Healthy Chicken Information Platform, Besd-Bir, Set-Bir etc.), which are the representatives of the sector, should have an integrated structure. The system should also serve as an information system and social network environment.

In addition, they reported that automation should be considered with technological applications such as barcodes and RFID that will lead to in-house process innovation.

Alonso et al. (2020) aimed to provide a platform for the application of IoT, Edge Computing, Artificial intelligence and Blockchain techniques in Smart Agricultural environments through the new Global Edge Computing Architecture and designed to monitor the status of dairy cattle farming and feed grain in real time. In addition to ensuring the traceability and sustainability of the different processes involved in production, it is also reported that it is tested by being deployed in a real scenario on a dairy farm with this platform. Ilyas and Ahmad (2020), on the other hand, suggest using the latest IoT technology to be a smart solution for live animal tracking and geographical limitation. In this study, a geographically safe zone was established for cattle based on IoT and GPRS using cattle-specific IoT sensors. Thus, cattle can be easily monitored and controlled remotely without the need for the breeder to physically intervene in livestock management. However, it has been reported that the intelligent system can help prevent the spread of COVID-19 and reduce the costs of farming in livestock management due to the less use of the human factor, as it collects data on the location, condition and health of farm animals and enables remote monitoring of animals.

With regard to the application of learning methods for the improvement of the food industry, computer vision is called AI-oriented food industry. This application contributes to providing farmers with an idea of AI and computer vision technologies with the latest technology that can help in agriculture and food processing. Kakani et al. (2020) aimed to examine various scenarios and the use of machine learning, machine vision and deep learning through the sustainability lens and explained the increasing demand for the AgTech industry using computer vision and AI to feed the future in the sustainability of food production. They also reported the possibility of using Fourth Industrial Revolution [4.0 IR] technologies such as deep learning and computer vision robotics as a key to sustainable food production, with the inclusion of technologies, real-time, important global policies, investments in cultivation. However, they reported that the idea of using robotics for growing crops, viewing crops and raising animals, as well as for livestock farming in dairy cows, etc. can provide better progress by using all the data we collect from plants, soil, cattle, etc. in artificial intelligence.

Asrar et al. (2020) reported in their study that artificial intelligence is a multidisciplinary field with current purpose to automate activities that require human intelligence in the field of livestock farming, and it is aimed to increase the efficiency of the sector with the use of AI in the livestock sector. The latest success in AI includes computerized medical diagnostics and systems that automatically customize hardware to specific user requirements, with AI being less complex.

They reported that intelligence is a broad subject that includes reasoning for observations, learning the observations received, then solving a series of verbal or non-verbal problems, perception and linguistic intelligence. Robotic systems have been introduced with the use of AI in livestock farming. Smart robots are the latest available systems that work like humans and can fulfill the instructions given to them by humans or operators. There are different robotic applications from animal feeding to milking systems. Advantages of AI include easier and faster pregnancy controls with ultrasound devices, early controls of diseases, increase in body temperature, etc., early disease diagnosis within the farm, easy diagnosis, a stronger and more useful application, adapting to any conditions with a new and improved interface, solving possible new problems, processing information better and faster, alleviating excessive and unnecessary information load, and transforming information into information by accelerating the transfer of information to practice (Asrar et al., 2020).

In order to ensure the sustainability of milk and meat production, the quality and quantity of the products to be profitable are important together. In farm conditions, not only increase of the amount of products is required, but also the product should be of better quality and comply with consumer demands. In order to ensure this situation in the best conditions, it can be ensured to go down to the farm conditions by following up and recording the animal from the feed it eats to the growing conditions. This is obtained from healthy animals that are fed with appropriate care with good herd management. In order to ensure success in herd management, the animals must be recorded and monitored and the work flow within the enterprise must be known in advance. Thus, this situation allows the quality management of cattle breeding in a more systematic way.

Boğa and Yavuzer (2011) designed the herd management program to ensure the management of quality animal products within the enterprise in a controlled manner. Using the herd management program (CPP), it is possible to keep individual records of the animals, to report the calving time, the date of pregnancy control, the date of birth and the dates of drying out of the animals. This situation facilitates the follow-up of animals, as well as giving an opportunity to identify and treat problematic animals in a shorter time. The program reports the work to be done in the enterprise on a daily or weekly basis, and ensuring better herd management is also important in terms of controlling animal health in the enterprise. With the use of SYP, income (milk, animal sales, fertilizer, etc.) and expense (feed intake, animal purchase, vaccine, etc.) analysis is performed in the dairy cattle business and in-house financial status is monitored. This program has been prepared based on Axcess using Visual Basic 6 programming language. The aim of this study is to ensure herd management of animals in small-scale (30 animals and below) dairy cattle enterprises in Turkey. Thanks to such programs, small farms can be registered and more information can be exchanged between farms, as well as public institutions and milk collection associations related to livestock farming can have access to information about animals and the farm in a shorter time thanks to such programs.

Farmers engaged in livestock farming live far from technology in nature, and it is thought that the use of precision livestock systems may be beneficial, especially since most of them do not have internet infrastructure. Boğa et al. (2020) prepared a ration preparation program (on tablets or android phones) that works in android operating systems. Their goal is to prepare rationalization on Android mobile phones after only connecting to the internet once and downloading the program where the internet is not available or does not work well. In a different study, Wanga et al. (2015) aimed to design and install the Android Mobile Application on a smartphone in order to prevent problems that may occur for sensitive livestock. The application has an easy-to-use Graphical User Interface (GUI) for farmers. This Intelligent Livestock Information System (ILIS) will be able to provide feedback to livestock breeders and collect data from animal owners via mobile phones. If the connection does not exist or the connection is weak, the data will be sent to the database via synchronization. Thus, livestock specialists will be able to view the data and respond to any queries from livestock breeders. The system will also be able to respond and predict using machine learning techniques. The purpose of ILIS is to provide livestock services to everyone at all times by exceeding place, time and character restrictions. In general, this solution includes an AI approach that combines hardware and software technologies and will be used as a smart livestock information system, which is a new idea in the field of mobile livestock information systems.

Artificial neural network models are machine learning systems that are a type of AI and are inspired and developed by the working principles of the human brain and nerve cells. Artificial neural networks can also provide classification, pattern recognition, optimization and forward-looking predictions with information learned through repeated experiences similar to human learning. Artificial neural network, fertilization, fertilizer nutrient content, estimation of milk production in milk and fattening farms, estimation of volatile fatty acids in the rumen of dairy animals, estimation of breeding values of bulls, mastitis prediction, heat period detection and limp detection, detection of cows with artificial insemination difficulties, and success rate in pregnancy. It was determined that artificial neural network models were more successful than cluster analysis. Most of the studies published in data analysis use linear models to estimate production parameters. However, they reported that better results were obtained using artificial neural network compared to linear or classical methods (Dongre and Gandhi, 2016).

It is a technology that should be applied due to the advantages of AI reported in the livestock industry. It is reported that AI can be used as a tool to inform farmers on monitoring, predicting, optimizing the growth of farm animals, combating parasites, biosafety and diseases, monitoring farm animals and farm management. AI helps livestock farms collect and analyze data to accurately predict consumer behavior, such as purchasing patterns, leading trends, etc. With increasing investments, with the automation of farms, it is possible to reduce large costs and improve the quality of livestock products such as milk due to their advantages in performance and health problems (Kumari and Dhawal, 2021).

Efforts to ensure environmental conditions

In order to increase the welfare of farm animals, monitoring their behavior, recognizing, recording and monitoring their situations is also important for animal health with the increase in productivity. Many studies show that, just like humans, animals can feel pain, fear, and joy, as well as other emotions. Although it is a time and labor consuming task to test the behavior of animals to determine positive or negative situations, artificial intelligence and machine learning are studied by different researchers to automate emotion recognition in production and to ensure its applicability in the farm environment.

Stress negatively affects the performance, efficiency and immune system of animals, causing significant economic losses and animal welfare problems (Fourne et al., 2017). The responses of animals to environmental conditions such as humidity, airflow, radiation, physiological status and social interactions may be different. Since the genetic structure of the animal and the changes in feeding and management practices will be taken into account with modern livestock farming, environmental conditions can be changed to ensure the welfare of the animal with modern buildings. Precision livestock farming technologies, which enable automatic monitoring of environmental, physiological and behavioral variables in farm conditions, are facilitated by the use of devices such as sensors, detectors, cameras and microphones (Fourne et al., 2017). Automatic control of the environment in the livestock building is usually based on feedback of the indoor air temperature measured in a location within the volume of the building. Currently, thermostatically operated climate controls benefit from the setpoints of environmental variables that are assumed to be most suitable for an average animal. It is aimed to meet the expectations for animal products or to reduce the environmental impact of production systems. In other words, it is aimed at meeting the increasingly complex regulations on farming methods aimed at providing a higher standard of animal welfare. However, they reported that relying on new ways of obtaining information on farms should have the capacity to activate livestock management practices that are more sensitive to market signals (Fourne et al., 2017).

Poulopoulo et al. (2019) aimed to determine the ability of a three-dimensional accelerometer with accelerometer to accurately distinguish and predict behavioral activities in grazing fattening cattle using direct observations (DO) as standard. In the study, six of them were one year old (283 ± 42 kg) and two of them were older than two years old (643 ± 35 kg). Nutrition, rumination, water consumption, walking, standing and lying down were correctly determined with sensors in animals. Instant scan sampling technique was used at 10-minute intervals to record the mentioned behavioral parameters. They calculated the Spearman correlation coefficients between the accelerometer data and DO for each behavioral activity. While the correlation coefficients (rs) between accelerometers and DO for nutrition, rumination, standing and lying down were high ($rs > 0.68$), they were medium and weak for water consumption and walking, respectively. Thus, they reported that sensors should be used to predict feeding, ruminating, standing and lying behaviors of beef cattle in rangeland.

Canga and Boğa (2020) examined whether temperature and humidity had an effect on egg yield, fracture/cracked egg ratio, number of dead animals and feed consumption in a data set obtained from laying hens utilizing a hybrid approach obtained by combining BAGGING and MARS. In the study, egg production data obtained from Lohman breed chickens in 2018 from a private livestock enterprise in Cukurova Region of Adana province were used. They used earth (enhanced adaptive regression through hinges) and caret (classification and regression training), Mixture Discriminant Analysis (MDA) packages in the R studio program to obtain a stronger solution to regression problems in the MARS and Bagging MARS algorithm. The estimated performance of the Bagging MARS technique was evaluated with goodness of fit criteria by taking the B value, which is the number of bootstrap samples, as 3. It was reported that evening temperature(t3) had an effect on egg yield, but morning(t1) and noon(t2) temperatures had no effect. These variables are not included in the prediction equation in Mars and Bagging MARS models because the ratio of broken/cracked eggs and the number of dead animals is less than 5. They reported that feed consumption had a positive contribution in both models.

Asfahan et al. (2021) aimed to develop a deep learning AI model to predict the thermal performance of evaporative cooling systems commonly used for appropriate temperature environment (thermal comfort) in different applications. To this end, they estimated the thermal performance of three evaporation-assisted air conditioning systems (direct, indirect and Maisotsenko evaporative cooling systems), for which a deep learning algorithm was developed using an AI approach. The deep learning algorithm was then optimized to improve learning rate and predictive accuracy based on experimental data by adjusting hyperparameters such as enabling functions, the number of hidden layers, and manipulating neurons in each layer by incorporating optimizers. The results obtained in their study confirmed the applicability of the method with a general $R^2 = 0.987$ value between the input data and the location-real data, showing that the most competent model could predict the determined output characteristics (Tdb out, wout and Eair out). The proposed method is simple and has been found to be practical in evaluating the thermal performance of air conditioning systems deployed under different conditions. They reported that the proposed deep learning AI algorithm supports the hypothesis that it has the potential to explore the feasibility of three evaporative cooling systems under dynamic ambient conditions for various agricultural and livestock applications.

Climatic abnormalities such as temperature waves have been reported to affect the temperature stress levels of livestock. These effects may have harmful effects on milk quality and productivity in dairy cattle. Fuentes et al. (2020) used four-year data from 36 cows (Model 1) with similar temperature tolerance and a robotic dairy farm taken from 312 cows. These data consisted of programmed concentrated feed and weight combined with air parameters to develop supervised machine learning fabrication models to estimate milk yield, fat and protein content, and actual cow concentrated feed consumption. In their study, they showed quite accurate models developed for cows with similar temperature tolerances (Model 1: n = 116, 456; R = 0.87; slope = 0.76) and for all cows (Model 2: n = 665, 836; R = 0.86; slope = 0.74). In addition, they proposed an AI system to increase or maintain the targeted milk quality level by reducing the temperature stress that can be applied to a traditional dairy farm with the addition of minimal technology. Hernández-Julio et al., (2014) evaluated techniques to model physiological responses, rectal temperature and respiratory rate of Holstein dairy cows. They used literature (792 data points) and experimentally obtained (5884 data points) data to fabricate and validate models. For each response variable, two models based on artificial intelligence (artificial neural networks and neuro-fuzzy networks) and a regression-based model evaluated dry thermometer air temperature, relative humidity, rectal temperature and respiratory rate. The model based on artificial neural networks showed the best performance, followed by models based on neuro-fuzzy networks and regression.

Olasehinde (2021) studied infrared thermography, its application in livestock production, and its integration with the machine learning algorithm in order to provide an end-to-end solution for improved productivity. Infrared thermography is a simple, non-contact method for detecting surface temperature emanating from an animal skin. Temperature data is used to create images called thermograms, which can be used to diagnose diseased and disease-free conditions. Real-time collection of thermal data has resulted in a huge amount of data that requires the use of machine learning algorithms to help farmers gain suggestions that can be used to make informed decisions. The potential of machine learning and infrared thermography integration in livestock production has been investigated, and the application areas include identifying the unique characteristics of individual animals, monitoring animals in real time, and determining respiratory patterns that can indicate stress and pain.

Wasaki et al. (2019) reported that IoT technology is also used in livestock management by connecting the biological information of farm animals and the environmental information obtained by IoT sensors to farmers far from the farm through the cloud. They reported that livestock production would help increase productivity and reduce physical labor and labor cost.

Pan and Yang (2007) developed a new portable intelligent electronic system that can be used both in the laboratory and in the field to measure and analyze livestock farm odors. The proposed electronic sensor array consists of 14 gas sensors, a humidity sensor and a temperature sensor. They have developed an expert system called "Odour Expert " to support researchers and farmers in deciding on odor control strategies for livestock and poultry operations. In this way, several advanced AI technologies have been used to adapt to livestock and poultry farm scents. Experimental results show that the odor forces predicted by the electronic nose provide a higher rate of consistency compared to the odor intensity perceived by the human panel. The "Olfactory Specialist" reported that it could be a useful tool to assist farmers in their olfactory management practices.

Areas of use in terms of heat (sexual desire) and animal welfare

Continuous manual cattle monitoring is time consuming and requires individual experience. Intelligent perception in the monitoring of animals includes sensory animal body information in complex environments using multisensory data and less waste of time and more subjective information as it has the ability to apply adaptive learning to analyze animal welfare and health status. In recent years, smart detection tools and data analysis technologies (Jones et al., 2017), including smart collars (Clark et al., 2015; Molfino et al., 2017), 3D image sensors (Salau et al., 2017; Gardenier et al., 2018), have become available to monitor each animal in real time. Qiao et al. (2019) proposed a deep learning-based individual cattle segmentation approach for animal monitoring. The high-precision core body indicators obtained for each animal indicated that farmers can help assess well-being, health, productivity, and design management strategies efficiently throughout their lifecycle. In short, continuous monitoring of the changing needs of each animal during the day forms the basis of Precision Livestock (PLF).

Jose et al. (2020) examined how accelerometers can be used for welfare assessment, based on the principles of the welfare quality assessment protocol. Their study is based on algorithm development, mainly on the determination of behavioral characteristics. So far, while there are high accuracy for movement and resting behaviors in cows and pigs, algorithm development for feeding and drinking behaviors in pigs is lagging behind progress in cows where valid algorithms are already available. In welfare studies, accelerometer technology was used to address the effects on nutritional behavior, daily cycle, enrichment, housing, social mixing, resentment, limp and disease. They also reported that battery life and sensor position were among the additional considerations to be considered before making a decision on its use in research and practical applications.

Data mining aims to discover the desired and applicable information from the large amount of information collected in the center, which has started to be used in the information industry and society. Although many data mining methods have been used, they have reported that these techniques have attracted attention in the field of livestock farming in recent years. Many methods have been discussed and tried to be developed for the solution of complex problems related to livestock. In the study, data mining methods such as k-averages approach, k-nearest neighbor approach, multivariate adaptive regression curves (Multivariate Adaptive Splines, MARS), Bayesian classifiers (Naive Bayesian Classifiers, NBC), artificial neural networks (Artificial Neural Networks, ANN), support vector machines (Support Vector Machines, SVM), decision trees are widely used (Çetin and Mikail, 2016).

Reproductive performance is among the main factors affecting the profitability of the enterprise in dairy animals. The most important factor affecting reproductive performance is the correct and timely determination of heat. Failure to determine heat in a timely manner leads to delayed insemination, decreased pregnancy rate and prolonged birth interval. By observing this situation, unnecessary animal care and nutrition will be done in the enterprise, leading to economic losses. This situation significantly reduces productivity and causes an increase in milk and beef prices, thus reducing the purchasing power of consumers for these animal products. In their study, Özgüven (2017) aimed to develop a new automation system to determine the health and heat of cattle in large-scale dairy cattle enterprises. Animals in heat are more active than other animals. Devices called “pedometers/accelometers” are used for this mobility. The pedometer developed was designed to determine the heat by taking into account the movement activities of the animals. Mechanical accelerometers are used in the detection of movements in pedometers in the market, and in this study, digital accelerometers are used because they offer high sensitivity, low energy consumption and three-axis measurement. Since the acceleration values of the animals during stepping and overshooting will be different, step counting with an accelerometer pedometer is also possible to count the overshoot behaviors against other cows separately. In order to transfer data to the computer at short time intervals (every two hours) with RF communication method, mobility data are sent to the computer while the animals are in the barn freely without the need to go to the milking unit. In this study, they aimed to determine the heat detection in Holstein breed cattle raised in a business where the herd management system is used with a minimum error rate by applying artificial neural networks. For this purpose, artificial neural networks modeling in different categories was created by using the number of movements of bovine animals obtained in two-hour periods as input data, acceleration changes during step, milk yield change rate taken during milking and conductivity change rate. They determined the prediction of output data as "in heat or not in heat". Heat accuracy rate was determined with artificial neural network models in different categories; they reported that these accuracy rates varied between 85% and 93% in each training of the data set. Thus, with the developed computer software, their heat is easily estimated by taking into account the number of steps and exceedances of animals, environmental conditions and biological calendars of animals. Both the mechanical mathematical model (traditional approach) and the artificial neural network (ANN) model (modern approach), which is one of the AI applications, were used to evaluate the experimental data obtained and to predict heat. In ANN models, it is reported that there is no negative error due to the precision 1, that is, no animal is evaluated in the in-heat classification even though it is not in heat.

Areas of use for Nutrition and Animal Behavior

Farmers have to constantly monitor their animals, identify problems during the day. This monitoring will be important in terms of early identification of hazards that may come to the farm from outside as well as following up the negativities that may occur within the herd. Monitoring the behavior of animals on the farm is important in terms of heat monitoring, nail care, BMI controls, gait scores controls or early diagnosis of sick animals. Since animals do not stay in fixed places, manual inspection and monitoring cannot reflect real values and is seen as a time-consuming process (Ilyas and Ahmad, 2020).

In the follow-up of animal behavior, different software has been developed to identify health-related problems, especially to monitor the conditions of dairy cattle such as foot diseases and heat detection. Sensors that measure milk yield, temperature and electrical conductivity in farm environments and sensors that measure the animal's activity with step meters allow the identification of cows that are in sickness or heat. Some studies have also associated nutritional behavior measures to monitor the health status of dairy cattle (Gonza´ lez et al., 2007; Neethirajan 2020; Kumari & Dhawal, 2021). Radiofrequency technology was used to measure the time spent in the feed. They reported that this situation enabled the identification of diseased cattle (mainly due to cattle respiratory disease) 4 days before the identification made by experienced personnel. Similarly, they reported that cows with later clinical metritis spent less time feeding than healthy cows (Gonza´ lez et al., 2007). They considered calves fed with automatic milk feeders as a good indicator of health status due to the reduction of diarrhea and bovine respiratory diseases, with the control of the number of visits or milk consumption rate (Gonza´ lez et al., 2007).

With manual tracking of the animal, animal welfare is viewed as a difficult and time-consuming task to monitor in practice due to inadequacies related to animal behavior, social interaction, and health status. However, the effectiveness of welfare assessment varies depending on the intuition, experience, and perception of the severity of the work by the changing observer. This situation does not create a sufficient perception in ensuring the consumer’s trust. It is recommended to use modern livestock farming practices as it will be desirable to provide animal welfare in a controlled manner, problem identification and increase consumer confidence in animal products (Tscharke and Banhazi, 2016).

The animals’ return to dring for eating and feeding behavior during the day provide us with important indicators about the animal’s health. Poulopoulo et al. (2019) reported that changes in feeding behavior may be an appropriate solution for the detection of health problems in animals such as lameness and bovine respiratory disease. They propose the use of sensors to predict the feeding, ruminating, standing, and lying behaviors of fattening cattle in the pasture to determine the ability of a three-dimensional accelerometer with pedometer to accurately distinguish and predict behavioral activities in grazing fattening cattle. Similarly, Barker et al. (2018) reported that the differences in behavior parameters recorded in the freestanding barn environment with the use of sensors combined with accelerometers provided information about the health status of the animal.

Recording activities such as nutrition, feed and water consumption, rumination and rest by monitoring animals at certain hours through manual observation is a method that has been used for a long time. For this purpose, in the studies conducted for calves, Boğa et al. (2014) and dairy cattle (Boğa, 2008) and sheep, manual observations of animals at 5-minute intervals in certain time periods of 24 hours were recorded and their feed consumption behaviors were evaluated statistically. They have ensured the determination of animal behavior caused by feed differences. Boğa et al. (2014) aimed to investigate the seasonal and yield level effects of feeding (TMR and Preferential feeding) methods on lactation performance and feeding behavior of dairy cows. In high-yielding cows, it preferred more barley than TMR compared to low-yielding cows. They reported that the dry matter consumption and fat-corrected milk consumption of the preferred-fed cows were lower than their values. Due to lower feed consumption, nutrient intakes for preferential fed cows were lower than those fed with TMR, and milk fat and milk urea levels were reported to be lower in preferred cows than those fed with TMR. As milk production increased, milk protein content decreased. The season significantly affected milk yield, feed intake (as a percentage of body weight), and changes in live weight, and 4% FCM (DSV) (4% fat-adjusted milk yield). In their study, they reported that the ration choices of the preferentially fed cows also changed according to the changing season and milk yield, but this did not positively affect milk yield. In their study, both TMR group (5 animals) and Preferred feeding groups (5 animals) were connected to communication devices under their feeders and computerized feeding systems, and they enabled the determination of feeding behaviors such as number of meals, meal duration, and duration between meals. Göncü et al. (2010) examined the effects of feeding 9 male calves 3 treatment groups and only with concentrated feed on growth and rumen development in Holstein calves in order to take 30 female and rumen tissue samples in the pre-weaning period. The group that received only the starting feed showed similar performance to that of the preferential group and the TMR group calves ($P>0.05$). Calves fed only with starter feed had flatter and more branched rumen papillae than the other two groups. The results obtained in this study show that calf growth with only calf feed without using roughage in the period before weaning can yield successful results. In this study, feeding behaviors of calves were taken at certain hours during the day by observation and no difference was obtained between any groups in terms of behavior. Boğa et al. (2014), Göncü et al. (2010) examined the behaviors caused by feeding from mortars (3 different groups) and animal welfare through observation (at different times of the day) during the experiment in the animals they used in their studies. There was no statistically significant difference between the feeding behaviors of the animals (feed consumption, food consumption, number of meals) and other animal behaviors ($p>0.05$). No difference was observed between the groups in terms of oxidative stress content in blood samples taken from the calves used in the experiment ($p>0.05$).

Görgülü et al. (2007) investigated the effects of feeding method and feeding level on feed selection and feeding behaviors for 8 weeks in German Alaca*Hair hybrid goats. The nutritional behaviors of the goats were recorded under the feeders with a special software connected with the computer (RS232 port). It has been reported that TMR is not similar in terms of raw material composition with the rations formed by preferentially fed goats. Preferential feed goats preferred energy feeds and roughage in the early hours of the day, while they preferred protein feeds more in the afternoon than in the early hours of the day. In the rations consumed by the preferential and limited-feed goats, they reported that the protein and energy levels were numerically higher than the free-feeding goats, while the protein levels resistant to destruction were lower in the rumen. In their study, they reported that when goats are given the opportunity to choose, they can easily provide nutritional requirements.

Attempts to automatically record feeding behavior from video recording (Chizzotti et al., 2015) to initial application of silicone tubes (Rutter et al., 1997) or radio frequency identification (RFID) systems (Wolfger et al., 2015), monitoring feeding behavior (i.e., chewing and biting events) can provide important information for the management of livestock. Koluman et al. (2016) aimed to investigate the milk yield and nutritional behaviors of German Enhanced Open Deer × Hair Hybrid (GIF) and Saanen × Hair Goat (S) hybrid goats at the beginning of summer in Turkey's subtropical eastern Mediterranean climate. They reported that animals were monitored automatically by a system that records daily feed consumption, feed consumption sequence(s), meal duration, meal length, and number of meals. While milk yield (kg/day) is 1.77 in GIF and 2.0 in S goats, milk production yield (kg feed/kg milk) is 1.15 in GIF and 1.07in S goats. The differences between GIF and S goats in eating behavior parameters were found to be significant. S goats reported that they have a higher meal duration and meal length and time between meals. They reported that although German Enhanced Open Deer × Hair hybrid and Saanen × Hair goat have similar lactation performance under good nutritional conditions, their nutritional behaviors are quite different. Nunes et al. (2021) presented a calculation tool that uses wearable sensor technologies and deep learning to distinguish chewing and biting events in horses. They used a microcamera with a microphone (0-18 kHz) to obtain video/audio data from horses during grazing under rangeland conditions. The collected audio data were processed in a preprocessing filtering step and then used a repetitive neural network (RNN) with a long- and short-term memory (LSTM) layer to detect and distinguish chewing, biting, and noise events. They reported that the initial evaluation of this system showed 88.64% accuracy for bite identification and 94.13% accuracy for chewing identification. They reported that the distinction between events, the evaluation of the reactions to different pasture species and structures can provide useful information about the plant-animal interface. This situation was consistent with information such as bite rate, bite mass, and grazing time, and they also reported that it could help determine management strategies that provide data to model food seeking behavior and optimize feed intake to predict pasture use and animal performance.

You et al. (2021) mentioned an intelligent computer-controlled feeding system that automatically measures chickens and breeders in real-time body weight (CA) with a precision feeding (PF) system. When the animals visited the PF station, they reported that real-time CA data was obtained every day. However, in real-time CA observations, they reported that abnormal observations occurred due to misreading in the measurement of recorded data due to multiple chickens entering the station at the same time. They reported a supervised machine learning method to detect abnormalities in real-time CA recorded by the PF system. In this method, they used 4 machine learning algorithms including K-nearest neighbor (KNN), random forest (Random Forest: RF), classifier support vector machine (SVM) and artificial neural network (ANN). They reported that RF is a more effective abnormality detection algorithm for such data.

Rayas-Amor et al. (2017) aimed to specify the records of the three-axis accelerometer/pedomer (HOBO Pendant G data recorders) used commercially in Holstein dairy cattle in the 7th lactation with an average live weight of 602 kg with visual observations of the grazing and rumination times of dairy cows. They reported that there was a significant ($p<0.001$) relationship between the estimated grazing time against visual observations when only acceleration (X axis) was used. However, they reported that the difference in acceleration (Z axis) was not statistically significant in estimating the rumination time ($p>0.05$). They reported that there was a significant relationship ($p<0.001$) in both when acceleration and acceleration were used to estimate grazing (X- and Y-axis) and ruminationing (Z- and Y-axis) time. The R2 estimate in both activities explains 0.961 and 0.945 of the acceleration (X- and Z-axis) and slope (Y-axis) of the HOBO recorders, the variance in visual observations per cow/day, and they reported that the results of the recorders were successful on a cow/day and daily basis.

Cihan et al. (2017) reported that machine learning is a sub-study area of artificial intelligence, and that the behaviors obtained from old data and this allows future predictions to be made by managing and learning. Machine learning is used in many different areas (education, medicine, veterinary, banking, telecommunications, security, biomedical, etc.). They reported that machine learning methods are generally preferred in human health, especially in predicting diseases and determining related risk factors. It has also been reported that neural networks, logistic regression, linear regression, multiple regression, principal component analysis and k-averages methods are frequently used in machine learning methods. However, recent developments in the field of machine learning (deep learning, collective learning, voice recognition, emotion recognition, etc.) are newly implemented in livestock farming.

Smith et al. (2021) examined the effects of respiratory therapy (RT) and classification in animals on nutritional behavior characteristics, feed consumption and animal performance. Against the threat of bovine viral diarrhea virus (BVDV), Nellore-Angus hybrid cattle ($n = 360$; baseline body weight (CA) 330 ± 48 kg) were assigned to one of three vaccine treatments: unvaccinated (NON), modified live (MLV) and killed (KV) in relation to respiratory viral pathogens, and vaccinated with the same BVDV1b strain. Clinical respiratory tract disease symptoms were observed, but they reported that the frequency and duration of bed visit and performance characteristics decreased following the BVDV threat ($p<0.01$). They reported that dry matter consumption (KMT) decreased in cattle vaccinated with MLV ($p<0.05$) and had longer ($p<0.01$) bed visit and feed and slower feed consumption rates ($p<0.01$) compared to others. Respiratory vaccination can reduce the clinical nutritional behavior and performance effects of BVDV in cattle.

Siberski-Cooper and Koltes (2022) reported that in order to reduce the continuity and cost of milk production, it is necessary to improve feed efficiency as a way to reduce nutrient loss from feed. Advances in cultivation, feeding and management lead to dilution of care energy and thus to more efficient milk production. However, it is known that there are many different applications to increase the feed utilization rate in animals individually. Wearable sensors, image-based and highly efficient phenotyping technologies (e.g., milk testing) are increasingly being used on commercial farms. The application of these technologies as indicative features in feed consumption and efficiency features is advantageous in predicting feed efficiency and managing this additional information. As possible indicators of feed consumption, milk spectral data focus not only on what can be developed in the future, such as activity, rumen measurements and image-based phenotypes, but also on precision livestock farming technologies and high-efficiency phenotyping used today. Wallén et al., (2018) used mid-infrared (Mir) spectroscopy of milk to predict dry matter intake (DMT) and net energy intake (Nei) in Norwegian Red dairy cows at 160 lactations. Their study shows that Mir spectral data can be used to estimate nei as a measure of feed intake in Norwegian Red dairy cattle, and in addition to the prediction model, accuracy generally increases if available data are also included. The use of sensor technologies to monitor the behavior of cows is also becoming widespread in terms of ensuring the sustainability of milk production. Leso et al. (2021) used AFICollar ® (Afimilk, Kibbutz Afikim, Israel), a commercial collar-based sensor system for monitoring the feeding and rumination behavior of dairy cattle, to evaluate sensor performance in 20 Holstein-Friesian dairy cattle under different feeding conditions. Three different types of feed (total mixed ration, long grass, animals allowed to graze) were administered to the animals divided into 4 groups. Records of hourly rumination and feeding time generated by the sensor were compared with visual observation by scan sampling at 1-minute intervals using Spearman correlation, fit correlation coefficient (CCC), Bland-Altman graphs and linear mixed models to evaluate precision and accuracy. In the updated software version, they reported that there was a high correlation between visual observations and sensor-recorded data provided by both feed (r = 0.85, CCC = 0.86) and rumination (r = 0.83, CCC = 0.86) (Leso et al., 2021).

Areas of Use for Estimating Body Condition Score (BCS), Live Weight, Milk Yield and Different Performance Data

The most important indicator of whether the needs of animals are met in bovine and ovine livestock enterprises is the body condition score (BCS) scoring of animals. While the score is given from 1 to 10 in livestock, it is based on the principle of scoring VCS from 1 to 5 in dairy cattle. BCS appears as a subjective method based on the visual or palpation method of the relationship of subcutaneous fat thickness with bone protrusions in the pelvic region in the back, waist and tail joint regions of cattle. Generally, VKS values in enterprises are determined by a method based on expert knowledge and determined by observation. VKS is used continuously on farms as a very important indicator in animal feeding. If the animal is above or below the desired BCS, heat (sexual desire) problems, birth difficulties/difficult births, pregnancy problems, diseases, low productivity or animal losses in the future may be observed due to metabolic problems at this stage. Since regular control of this situation will keep healthier animals on the farm, it will also increase the profitability of the business as the incidence of metabolic diseases will decrease. In dairy cattle farms, animals should be grouped according to their body condition scores (BCS) and their care and nutrition should be done on time. VKS At certain times, it should be done by animal keepers or specialists who come to the business. VKS ratings made by experts on farms based on visual inspection can give unreliable results and contain misinterpretations as they depend on personal skills. For this reason, technology-assisted systems are needed. For this purpose, Çevik ve Boğa (2019) aimed to determine VKS scoring with a computer-aided software to reduce individual errors. Images taken from cattle were edited in certain forms and classified with Convolutional Neural Networks (ESA). Of 180 images, 75% were used for training and 25% for testing. In the study, system performance was increased by using previously trained ESA architectures and the responses of different architectures to the VKS classification problem were tested. As a result, they reported that the determination of VKS scoring by ESA methods can be done successfully with more than60%. Çevik (2020) aimed to automatically estimate the VKS, which is the most important indicator of the correct nutrition of dairy cattle, in a short time without the need for a person. In addition, it is possible to test the designed system in a shorter time in corporate environments by adapting it to simple, fast and user-friendly mobile software. Deep learning models, which have been frequently used in computer sciences in recent years, have been used in the design of the system. The CNN model, which was trained with a success rate of 94.69% based on these data, was transformed into a mobile compatible format for real-time tests. Thanks to the designed mobile software, it is aimed to conduct real-time tests and to provide easy access to milk producers. Pre-trained networks were used to increase the success of the CNN model, and it was reported that the 78.0% performance results obtained were successful in the real-time VKS classification problem. Monitoring, recording, and estimating animal body weight (CA) allows timely intervention in animal ration and health, greater effectiveness of selection, and identification of the optimal time for animal marketing. Excessive care and feeding by delaying the slaughter of animals reaching the slaughter weight constitutes a burden for livestock, and it is recommended that these be determined and disposed of in a short time. There are two main approaches (direct and indirect) to measuring CA in livestock, which are direct and indirect approaches. Direct approaches include partial-weighted or full-weighted industrial scales placed in designated locations on large farms that passively or dynamically measure the weight of farm animals. Although these devices are very precise, their purchase varies according to their intended use and size. Repeated calibration and maintenance costs due to temperature variability and their placement in abrasive environments lead to an increase in farm costs. It is beyond its borders in terms of affordability and sustainability, especially in small and medium-sized farms.

As a more cost effective alternative method than direct weighing approaches, indirect approaches have been developed based on observed or predicted relationships between biometric and morphometric measurements of live animals and CA. The first indirect approaches include manual measurements of animals using measuring strips and tubes and the use of regression equations that associate these measurements with CA. While such approaches have CA estimation accuracy, they are time consuming, requiring trained and skilled farm workers. It can be stressful for both animals and caregivers, especially when repeated daily. Today, it has been used as biometric and morphometric measurements for CA estimates with the simultaneous progression of artificial intelligence domains such as contactless electrooptic sensors (e.g. 2D, 3D, infrared cameras), computer vision (CV) technologies, machine learning (ML) and deep learning (DL) (Wang et al., 2021).

Canga and Boğa (2019) aimed to examine the performance estimation of the MARS data mining algorithm with the data set obtained from ovine animals and to examine it by using the goodness of fit criteria of this algorithm. For this purpose, in order to estimate the continuous variable (weaning weight), some non-genetic factors (year of birth of sheep and lamb, sheep age, lamb weight, gender, lamb birth weight) related to ovine animals obtained from 10 different farms in Çamardı district of Niğde province in 2018 were used as independent variables. With R software, goodness of fit criteria related to these algorithms were calculated. With the MARS algorithm, a quantitative feature (weaning weight) was estimated. According to the data obtained, they reported that it may be a good choice to use the MARS algorithm to determine important independent variables on the dependent variable.

The livestock sector, which attracts attention from different sectors and is seen as profitable, seems attractive to contribute to the country's general GDP (gross domestic product) and to close the gap in meat production. Tawheed et al. (2019) provided model analysis based on cattle breed depending on different factors such as age, live weight, environmental conditions, feeding plan, ration ratio and geographical region conditions. In the study, the applied models were specified as Multiple Linear Regression model, Support Vector Machine model and Decision Tree in order to obtain exact prediction analysis. Through the results of these regression models, humans were accurately predicted the expected weight for a given breed of cattle, giving an overall idea of the ideal conditions and specification that the animal needed.

Fuentes et al. (2021) aimed at non-invasive computer methods to predict the heart rate, respiratory rate and sudden movements of the cow captured using RGB cameras and machine learning modeling to predict eye temperature, milk production and quality. Data were obtained from cows using RGB and infrared thermal videos (IRTV), a robotic milking facility. Results from 102 different cows (n = 150) showed that an artificial neural network (ANN) model using only inputs from RGB cameras offered high accuracy ($R^2 = 0.96$) in predicting eye temperature (C) using IRTV as principle. This model can be easily implemented using affordable RGB camera systems to achieve all proposed goals, including animal welfare and eye temperature, which can also be used to model biotic/abiotic stress. They also reported that these models can be easily used in traditional dairy farms.

Areas of use for early detection of diseases

Animal production farms are established to meet the food needs of people (animal protein). They reported that with the development of technology in farms and the spread of the use of machines instead of manpower, there are more comprehensive solutions to the problems encountered with the introduction of subject areas such as embedded systems, robotics and AI into our lives. In addition to reducing the errors caused by breeders, existing technology can be economically utilized by reducing the workforce used. The production quality and speed of the AI-based farm, which is minimized by human error, is increasing significantly. The use of artificial intelligence systems that can make their own decisions in existing farms can achieve maximum efficiency as disease detection is made as well as production and feeding (Işık et al., 2021).

Mcloughlin et al. (2019) elaborated the sounds of chicken (Gallus gallus domesticus), pig (Sus scrofa domesticus) and cattle (Bos taurus) of the three most important livestock animals for the protection of ecology and animal health. They used methods to monitor animal health based on sound that has the potential to be automated. Benjamin and Yik (2019) conducted an investigation for veterinarians and pig specialists explaining machine learning algorithms such as pig face recognition using convolutional neural networks. They also identified the most appropriate sensors for measuring animal health, such as cameras (2D and 3D), microphones, thermistors and accelerometers, and investigated how these technologies could be used to improve pig health.

In dairy cattle, lameness is very commonly observed due to ground problems and feeding errors in farm conditions. Animals with nail problems prefer to lie down more, which causes some problems such as claw lesions. The aim of this study was to investigate the possible relationship between the laterality of the claw lesion and the presence of abomasum displacement (LDA). They retrospectively examined the health records of 252 cattle diagnosed with Lda and subjected to the examination of claw lesions for 11 years (2009-2019). The data obtained by retrospectively performing these results were taken into consideration and the importance of preventing claw lesions, especially in the postpartum period, was emphasized in order to improve cattle welfare (Tschoner et al., 2021).

Table 2: Methods used to solve different issues in different studies (Işık et al., 2021)

Authors	Methods	Topics	Conclusions
Tabak et al., 2019	ResNet-18	Automatic classification of wildlife species	Accuracy 98%
Jensen et al., 2016	Multivariate dynamic linear model (DLM) + Naive Bayes (NB)	Detection of mastitis	Sensitivity 80-81% Authenticity and 89% receiver study characteristic curve have been reached.
Ebrahimi et al., 2019	Deep learning, Naive Bayes, Generalized linear model Logistic regression Decision tree Gradient increased tree (GBT)	Detection of mastitis	GBT achieved the highest performance with an accuracy rate of84.9%
Yıldız and Özgüven, 2016	Artificial neural network	Estimation of being in heat	0.9733 ROC
Shahriar et al., 2016	K-mean	Estimation of being in heat	100% sensitivity 82-100% overall accuracy
Dandil et al., 2019	Faster regional-convolutionary neural networks (DHB-ESA)	Classification of facial images	98.44% accuracy rate
Kalipsiz et al., 2017	Artificial neural networks	Disease diagnosis in lambs	The highest performance f-measure was obtained in sigmoid normalization with 0.36
Rao et al., 2020	SVR KNN	Monitoring of goat growth Analysis of goat behavior Remote control and maintenance	Estimates temperature, humidity and gas value with 94-97.5% high performance
Volkmann et al., 2021	Random forest	Detection of claw lesions	81% sensitivity, 97% specificity ratio
Raksha and Surekha, 2020	KNN SVM Logistic regression	Farm monitoring system	SVM has the highest performance rate with 89.6%

Authors	Methods	Topics	Conclusions
Sangatash et al., 2012	Fuzzy logic	Determination of raw milk quality	82.5% performance rate
Cavero et al., 2006	Fuzzy logic	Detection of mastitis disease	Error rate 95.5-41.9%
Zarchi et al., 2009	Statistical detector+ Fuzzy logic	Classification of oestrus alerts	Sensitivity 85.3% Specificity 100% Error rate 2.8%
Zaninelli et al., 2016	Fuzzy logic	Observation of breast health	0.9 at cutting level Sensitivity 56% Specificity 92% At 0.1 fraction level Sensitivity 99% Specificity 27%
Zaninelli et al., 2014	Fuzzy logic	Examination of online health status and electrical conductivity value	Sensitivity 81% Specificity 69%
Zaninelli et al., 2015	Fuzzy logic	Monitoring of health status and milk quality	0.7 at cutting level Sensitivity 81% Specificity 73%

Barker et al. (2018) reported that a significantly different nutritional behavior was exhibited in lame animals compared to healthy animals. They reported that lame cows had shorter feeding times and lower daily feeding times in the afternoon compared to non-lame animals. Inadequate nutritional behaviors of animals or distribution in a certain place during the day, providing us with information about the health of these animals in a short time may be important in farm conditions in terms of early treatment and recovery of the health of animals in a short time.

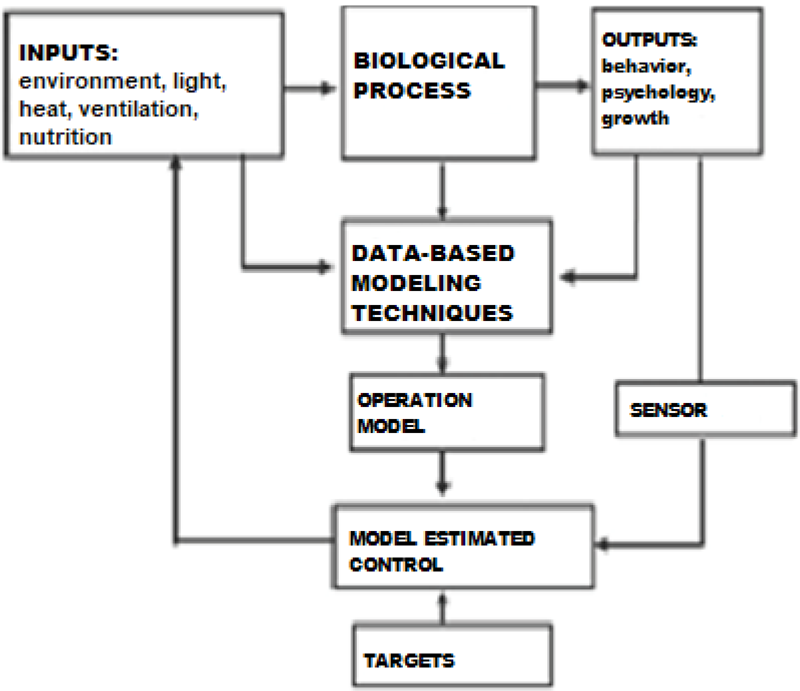

Figure 1. A schematic overview of the key components of Precision Livestock Farming to control biological processes (Wathes et al., 2008).

Mastitis disease seen in milk animals affects animal welfare (inflammation, pain and even loss of breast lobes in that region, etc.) as well as decrease in milk yield and milk quality, thus causing economic losses on the farm. As an alternative to laborious visual observation, automatic milking systems and an accurate mastitis detection system are needed in traditional farms with large herd sizes. Therefore, the negative effect of mastitis with early diagnosis and treatment may cause less economic loss in a short time. Tölle et al. (2008) investigated the effectiveness of neural networks (NN) in early detection and control of mastitis in cows milked in the automatic milking system. A data set consisting of 403,537 milkings containing 478 cows was used. In this study, they determined mastitis according to two different definitions: those with breast treatment or somatic cell count (SCC) above 100,000/ml and those with breast treatment or SCC above 400,000/ml. In mastitis stimuli, an NN model was created using electrical conductivity, milk production rate, milk flow rate and the number of days in milk as input data. The data set for developing and validating the model is divided into subgroups of random training and test data. They reported that they found mastitis definitions for 1 and 2 as 51.1% and 74.9% for specificities, respectively, and error rates as 51.3% and 80.5%, respectively. In their study, they reported that a decrease in the error rate could be achieved thanks to more informative parameters.

AI, machine learning (ML) and big data are used to analyze and understand many aspects of modern daily life. In particular, AI and ML are widely used in livestock farming to monitor both animals and the environment for 24 hours, leading to a better understanding of animal behavior and distress, disease control and prevention, and effective business decisions for the farmer. Artificial intelligence, which is a particularly promising field that is advancing day by day, is the digital twin technology currently used to increase efficiency and reduce costs in more than one sector. Digital twin technology, unlike a model, is a digital replica of a real-world entity that is kept up-to-date with a constant data stream. With the application of digital twins in the livestock sector, it can be used to improve large-scale sensitive livestock practices, the use of machinery-equipment, health and animal welfare.

The mental and emotional states of the animals can be monitored using recognition technology that examines facial features such as ear postures and white areas of the eye. Digital twins, used in combination with modelling, simulation, and augmented reality technologies, can help farmers build more energy-efficient housing structures, predict heat cycles for reproduction, and identify negative behaviors of farm animals. Digital twins design the physical, biological state and behavior of the real-world entity based on input data. Thus, it helps to optimize, improve and facilitate decision-making (Neethirajan and Kemp, 2021).

One of the main challenges in adopting AI-based tools is cited as the complexity of their implementation. In their study, Nogoy et al. (2021) aimed to define relevant parameters that can be used as indicators for real-time detection of temperature stress and subclinical mastitis in dairy cows. However, it also illustrates the use of an advanced data mining center as an AI-based tool that integrates relevant parameters that will accurately identify the status of the cow. Thus, he developed an approach using information obtained from different independent data to accurately determine the health and comfort status of dairy cows. They reported that an AI-based tool, such as the proposed data mining center for dairy cows, could maximise the use of data that is consistently produced on farms and not used sufficiently, thereby ultimately simplifying repetitive and difficult decision-making tasks in dairy cattle.

Shaikh et al. (2019) reported that smart agriculture plays a very important role in ensuring its sustainability by using AI. AI techniques can be widely used in soil and irrigation management, weather prediction, plant growth, disease prediction and livestock management, which are considered as important areas of agriculture. Therefore, they focused on the various AI algorithms used in AI techniques and their performance effects. In their study, they reported that deep learning algorithms performed much better than traditional machine learning algorithms due to recent technological developments, which can process large amounts of data efficiently and make smart decisions similar to human decisions in a timely manner.

It is known that there is an increase in performance data with the control of animal behavior in farm environments. For this reason, studies on monitoring animal health and welfare in dairy cattle farming are increasing day by day. The development of new techniques with the use of different methods aims to improve animal welfare indicators on the farm by monitoring animal behavior. Foot problems, which are frequently encountered especially in dairy cattle, both negatively affect animal health and reduce the performance of the animal, so much attention should be paid. In this case, it will be important to take animals into treatment in a short time and to prevent the factors that cause lameness (care and feeding) in a short time in order to get a response to treatment. The studies on this subject are generally divided into three categories: kinematic, kinetic and indirect methods. In order for limp detection systems to be applied automatically under farm conditions, they must be valid, reliable and applicable. The performance of the methods should be compared with the reference standard (motion score and/or lesion score) and the degree of development (level I, sensor technique; level II, algorithm validation; level III, performance for limp and/or lesion detection; level IV, decision support with early warning system) should be determined. Many scientific studies have been conducted on I-III levels, but they have reported that there are no studies on level IV technology (Alsaaod et al., 2019).

It will be important in terms of continuous observation of animals on the farm, early treatment on the farm, heat detection, and timely treatment of lameness. Limp scoring is an important practice in dairy cattle and is performed as a routine procedure for early diagnosis of new cases of limp and screening herds. Subjective lameness scoring, which is the most popular method of detecting and screening lameness commonly used in dairy cattle, has various limitations. Limitations such as experience of the observer and differences between observers may be encountered. Ghotoorlar et al. (2012) developed an automated limp scoring system comparable to traditional subjective limp scoring through artificial neural networks. The system consists of four balanced force plates placed in a nail cutter box. 105 dairy cattle were used for the study, and 60percent of the data were used in ground reaction force (GRF) data in a computer training process. It was used to test the system trained with the remaining 40percent of the data. They determined the repeatability of the lameness scoring system with GRF samples taken from 25 cows caught at two different times from the same animals. The mean standard deviation was 0.31 and the mean coefficient of variation was 14.55 percent, which they reported represented a high reproducibility when compared to scoring methods based on subjective vision. They established an automated limping scoring system comparing the subjective scoring system depending on the observer in scoring the limp using force plates and artificial intelligence. They also reported that the system can be used in milking rooms or milking robots during the milking period.

Lame is considered to be one of the most common welfare and productivity problems in dairy cattle. Yunta et al. (2012) aimed to evaluate the differences in lying behavior between moderately lame and non-lame dairy cows under commercial conditions. The data were collected from 10 free-stop commercial herds fed with exactly the same ration once a day. All dairy cows were scored for lameness according to the 1-5 movement scoring system. The sagging data recorders were then placed in the right hind leg of each cow for 10 days to record the lying behavior at 1-minute intervals. In addition, daily feeding time was recorded in each flock. The total daily bedtime was evaluated using a mixed effects model that takes into account the fixed effects of the days in milk, taking into account the number of daily beds, laterality (the side of the bed), the bedtime behavior around the feeding time, and the cases of lameness. It has been reported that cows with a limp get up 13 minutes later than cows without a limp and that cows with a limp spend more time. They reported that lame cows had longer lying seizures than non-lame animals, and that the lying behavior around feeding time may be an effective condition to identify moderately lame cows. Mıekley et al. (2013) analyzed the applicability of support vector machines (SVMs), a sub-discipline in the field of artificial intelligence, for early detection of mastitis. The data were collected at the dairy research farm (Kiel, Germany) and the data of 215 cows in the first 200 days (DIM) of milk were analyzed. Mastitis was determined according to veterinary treatments and defined as disease blocks. For the recognition of mastitis, they used milk electrical conductivity (MEC), milk yield (MY), number of lactations, age of the animal, number of days in lactation. They divided it into mastitis and test datasets to develop and validate the model of SVMs. In their study, they showed that the block sensitivity of mastitis detection was 84.6% and the specificity was 71.6% and 78.3%, respectively, according to both mastitis definitions. They reported that SVMs, which have suitable properties for pattern recognition of biological data, can be applied mainly for disease detection.

Today, with the development of technology, manpower is replaced by machines. With the introduction of subject areas such as embedded systems, robotics and artificial intelligence, more comprehensive solutions can be found to the problems encountered in animal production. It is reported that the production quality and speed of an artificial intelligence-based farm has increased significantly by minimizing human error. They also reported that the use of artificial intelligence systems that can make their own decisions on existing farms can detect disease as well as production and feeding (Işık et al., 2021).

Küçükönder (2011) examined the theoretical structure of this technology in general by providing detailed information about the general structure and functioning of neural networks in order to show that artificial neural networks can be used in agricultural field as in other branches of science. In the application part, on the data set selected from the agricultural area, the process steps that are very important in the formation of neural networks such as network design, number of intermediate layers, number of neurons to be found in the layers, selection of activation function, creation of architectural structure and selection of learning algorithms to be used in the training of the network have been examined in all details. In the study, in order to estimate the SNI values in this data set selected from the agricultural field, the backpropagation algorithm was used in the training of the network, and the suitability of 13 different training algorithms in this algorithm for the training of the network was evaluated. As a result of the evaluation, the optimum learning algorithm was determined as "Bayesian Regularization Algorithm". In this algorithm, they reported that the success rate in the process of minimizing the error was higher and the result was approached with fewer errors compared to other algorithms.

With the onset of health disorders such as ketosis, acute problems and chronic lameness, changes in feeding behaviors occur in dairy cattle. This situation was evaluated in animal behaviors in different limp score studies. Gonza´ lez et al. (2007) aimed to define and measure differences in gait score and to test their suitability as early indicators of the disease. They recorded the feed consumption, feeding time and the number of daily feeder visits with computerized feeders. Ketosis in 8 cows was characterized by an average rapid daily decrease of 3.6% in feed consumption [−10.4 kg fresh material (FM)], feed time (− 45.5 min) and feed rate (− 25.3 g FM/min). Daily changes observed for 30 days prior to slaughter and 30 days after slaughter in lame cows were found to be -0.75 and +0.32 min/day for the daily feeding period. They reported that these changes in feeding behavior among cows were not associated with rations with low or high nutrient content.

Chapinal et al. (2010) examined the relationship of nail cutting with other behavioral changes by taking into account cow walking, walking speed, inpatient time and weight distribution between legs while standing in order to examine the changes in the gait score of 48 Holstein dairy cattle in lactation in the freestanding barn. They reported that a decrease in walking speed was observed after nail cutting and this decrease continued for 4 weeks. However, the change in gait speed following nail cutting is negatively correlated with the change in gait (r = -0.33). Prior to nail cutting, the cows with lame cows spent more time lying down each day than the cows without lame cows (801.7vs 731.7 min/day; standard error of difference = 29.7). They reported that the duration of lying down after nail cutting was high up to 5 weeks in both lame and non-lame cows.

Based on a review and comparison of technologies and methods, they reported that the perception of intelligent cattle behavior and welfare monitoring will develop towards the Internet of Things (IoT) and deep learning technologies and standardization, a larger scale and intelligence (Qiao et al., 2021).

Metritis (Uterine Inflammation, Metritis) in cows indicates negative effects on reproductive performance of dairy cows. Cows at risk of metritis have shorter feeding times in the days before calving. Prenatal dry matter consumption (KMT) and water consumption are important in determining this disease. Huzzey et al. (2007) measured feed and water consumption and social behaviors in cows at risk of metritis after calving.101 Holstein collected data using an electronic monitoring system to measure feeding, water drinking behavior and feed consumption measurements 2 weeks before and 3 weeks after cattle calving. In addition, the severity of metritis was diagnosed according to the daily rectal body temperature as well as the state of vaginal discharge assessed every 3 days after birth. They reported that prenatal feeding time and CMT decreased compared to healthy cows 2 weeks before the observation of metritis symptoms. For each 10-minute decrease in average daily feeding time during the week before calving, the probability of metritis increases by 1.72, and every 1 kg decrease in CMT during this period has been reported to increase the diagnosis of the disease by 3 times. In addition, when the behavior of cows with metritis and healthy cows was examined, they reported that cows with metritis in the feed area evaluated from video recordings were less aggressive than healthy cows.

Studies on animal recognition

Benjamin and Yik (2019) mentioned that large-scale pig production should be automated and cost-effective animal identification systems for farmers as a prerequisite for linking animal data to precision livestock farming systems. Currently, radio frequency identification, optical character recognition and facial recognition systems are widely used in the pig industry and other animals or among the individual identification methods used in research.

In their study, Mcloughlin et al. (2019) aimed to show the state-of-the-art computational voice analysis methods that are currently in use. They reported that they recommended the use of automated methods for the evaluation and monitoring of animal welfare. They explained that it is the use of automated analysis of the vocalizations they produce to monitor the health and well-being of animals. Although ecology and conservation seem to rapidly adopt advanced sound methods to monitor animal populations, the use of these methods in animal welfare is somewhat slow and limited.

The purpose of breeding animal species in traditional livestock is to obtain meat, milk and dairy products for human consumption. In general, it is known that animal production provides 33percent of the protein consumed as human food as animal protein (Demirci, 1982). Recently, the concept of Precision Livestock (PLF) has emerged as a holistic approach that adds information and communication technologies (ICT) to improve the farming process. PLF plays an important role in the fourth industrial revolution, also known as Industry 4.0. In the concept of PLF, they reported that they use ICT to reduce investment costs and increase both production and animal health (García et al., 2020).

Benjamin and Yik (2019) reported that the increasing application of technological developments developed for video games (PlayStation, Xbox) helped to advance livestock farming production both more efficiently and with a greater focus on animal welfare. This technology, called precision livestock for remote monitoring of livestock, automatically monitors livestock individually in real time (Benjamin and Yik 2019), and also aims to provide a general introduction to existing technology, a review of research and commercially available technology, and information to physicians and customers working on pigs with implications and opportunities for farmers.

Xu et al. (2020) reported that accurate and reliable counting of animals in the images obtained with Quadcopter is one of the most promising methods in intelligent livestock management in the future. However, they studied the application of Mask R-CNN, which is the latest sample segmentation framework in cattle counting in intensively produced pastures and fattening areas. Experimental results in this study indicated that the framework has the potential to reliably perform in offline Quadcopter vision systems with 94% accuracy in counting cattle in pastures and 92% accuracy in fattening areas. Compared to the typical competing algorithms available, Mask R-NN also reported that it performed better in both counting accuracy and average precision, especially in datasets with occlusion and overlap.

García et al. (2020) examined grazing and animal health as a systematic review of recent studies on the use of machine learning (ML) in precision livestock farming (PLF). In this review; opportunities for machine learning in the livestock sector are highlighted by detailing the increasing openness of available sensors and software, techniques and data sources for data analysis. It has been reported that the use of machine learning in precision livestock farms is in development and there are various research difficulties. They reported that the prevention of this situation is the development of hybrid models for diagnosis and prescription as a tool for the prevention and control of animal diseases, bringing together grazing and animal health issues, giving autonomy to PLF using autonomous data analysis tasks and meta-learning cycles, and bringing together soil and pasture variables (García et al., 2020).

In their study, Dandıl et al. (2019) classified cattle face images with Faster Regional-Convolutional Neural Networks (DHB-ESA). A total of 1579 images from 5 different cattle were used in the data set. Training with 1129 images and testing with 450 images were performed. 98.44% accuracy rate was obtained. Bovine face images were successfully classified, and they reported that the identification of cattle with face identification instead of expensive systems and the identification and follow-up of animals enabled more economical herd tracking.

Today, the use of technology in livestock farming is increasing day by day. Storage, information acquisition and interpretation processes are carried out by transferring the data to the digital environment in the relevant area. In this context, expert systems provide important inferences in the symptom-disease relationship. In the study, the symptoms obtained from pets are evaluated by the expert system and inferred about the diagnosis of the disease. The expert system software developed with ASP.NET MVC has a responsive mobile and web interface. In the software, the user obtains information about possible diseases by entering the interface symptoms (Bilen et al., 2017).

Studies on milk yield estimation

Luis et al. (2021) provided modern data collection through sensors with remote monitoring method, fast data transfer and wide data storage via the Internet of Things (IoT) with precision livestock farming (PLF). The PLF relates to many areas of livestock production, including airborne and satellite-based measurement of the amount and quality of pasture fodder; these include body weight and composition and physiological assessments; devices on animals to monitor location, activity and behaviour in grazing and food-seeking environments; early detection of lameness and other diseases, milk yield and composition; reproductive measurements and calving diseases; feed intake and greenhouse gas emissions, etc. AI is a data-driven approach that can manipulate and represent big data collected by sensors and IoT.

Vásquez et al. (2019) aimed to develop a “Expert System” based on a Fuzzy Logic model designed to analyze the results of a number of variables on the performance of livestock production (milk and meat) in a particular region. The Expert System considered input variables such as Temperature (T), Rain (RA), Type (B), Health

Plan Application (HP), Feed Plan (FP) and Production System (PS). The specified variables then have an effect on three output variables, such as lactation days, daily milk production, and interbirth intervals. Thanks to the application of Fuzzy Logic, it is possible to benefit from the knowledge and experience and learnings of producers based on long years of observations and applications. The Expert System reported that it showed 86.67% reliability when it compared its results with a panel of experts in livestock production.

Smart and Atıl (2014) aimed to introduce alternative new methods to some statistical analysis methods used during the conduct of research on breeding and feeding in the field of dairy cattle breeding. They reported that artificial intelligence technologies, which are developing day by day, partially eliminate the disadvantages of time and cost elements thanks to their contributions to livestock farming science. They suggested that fuzzy logic, which is one of the methods introduced for dairy cattle breeding, should be used in decision support systems and artificial neural networks for estimation purposes.

Fuzzy logic uses approximate information instead of precise information by imitating human thought. The main difference between fuzzy logic and definite classical logic is defined as the fact that mathematics only allows extreme values in the known sense. They reported that fuzzy logic, which has a wide range of uses in the technological field, has started to be used in livestock farming in recent years. Additionally, they reported that the aim of fuzzy logic is to make the computer think like a human by processing the data in the livestock sector. In the data to be obtained, it can also provide a relatively simpler approach in accessing certain results from uncertain or less specific information (Memmedova and Keskin, 2009).

Egg Fertility Estimation

Improving the incubation conditions in order to increase animal production in poultry contributes to detecting fertilized eggs earlier and providing more egg output to make production more economical. It is more effective to increase the number of studies conducted to improve this situation with the technology used day by day. Today, it has been reported by studies that early exit power can be estimated by improving the incubation rate by using machine learning in the artificial field and its use in different technological facilities in this field (Glenn et al., 2019; Lei et al., 2019; Waranusast et al., 2017; Fadchar and Cruz, 2020). In modern livestock farming, the use of such precision livestock farming practices can save electricity and space by preventing unnecessarily fertile eggs from waiting in the hatchery in the enterprise (Boğa et al., 2019). Early detection of non-fertile eggs is important for farm owners, but it will be economically beneficial. However, there are many factors that affect fertility and are related to genetics and the environment (such as care and feeding) (Boğa et al., 2019). Adegbenjo et al. (2020) reported that a fast and online prediction technology is needed and different methods can be used to help early identification of chicken egg output power. For this reason, in their study, they examined current approaches such as ultrasound and dielectric measurement, thermal imaging, machine vision, spectroscopy and hyperspectral imaging. They also reported that care should be taken to obtain quality data with more sample sizes in the relevant categories and to use appropriate analysis/modeling and evaluation techniques.

Physical parameters of the egg (such as the size of the egg, shape index, shape and thickness of the shell) affect the output power. For this purpose, they used minitab to determine the egg output power by using Image Processing and Fuzzy Logic in the physical properties of chicken eggs. In its results, it can be used to determine the effect of the output power of the physical properties of the egg, to determine the ratio of all image processing, fuzzy logic and K-ennin output power (Glenn et al., 2019). In the study, Boğa et al. (2019) aimed to determine the fertility control of eggs in the incubator in the range of 0-5 days with image processing techniques using easily obtainable and low-cost tools. In the trial, three different data sets consisting of 15 eggs, which were imaged at different times, were prepared in the home type standard incubator. Various filtration and morphology methods in the processing of egg images,

Gray level conversion and dynamic thresholding method were used. In addition, original image processing codes based on the problem were written. The white/black ratios of the binary images obtained were used to determine fertility control. Day 3 in the first dataset according to experimental results

73.34%, 4th day 100%, 93.34% on the third day in the second data set, 93.34% on the fourth day and 93.34% on the third data set. Fertility conditions were determined with 93.34% accuracy on the third day and 100% accuracy on the fourth day. When the results obtained were evaluated, they reported that egg fertility control could be successfully automated with low-cost and obtainable tools.

Today, with the development of technology, the use of mobile phones, which we see as indispensable, and the transition to smartphones, phone applications are becoming widespread in livestock farming. Waranusast et al. (2017) evaluated the egg size classification on android mobile devices using image processing and machine learning in determining the physical property of the egg. Egg sizes were classified according to their properties calculated from the dimensions measured using a support vector machine (SVM) classifier. They reported that measurement errors in egg sizes were low at 3.1% and the overall accuracy of size classification was 80.4% (Waranusast et al., 2017).

Lei et al. (2019) proposed a new method that combines a convolutional neural network (CNN) with the heartbeat signal of the hatching eggs for more accurate and effective detection of the hatch rate. They collected the heartbeat signals of the eggs with the PhotoPlethysmoGraphy (PPG) method to detect the change in blood volume in living tissues by photoelectric means. They designed the network E-CNN used to analyze the order of heartbeat of hatching eggs. They reported that they could determine the fertility rate of hatching eggs with E-CNN and SR-CNN. In the test set, they reported that the method was suitable for determining and classifying the output power ratio with 99.50% and 99.62% identification accuracy, respectively. Similarly, Fadchar and Cruz (2020) established an experimental imaging system established to capture the image of five-day-old chicken eggs without damaging the egg shell for early detection of the fertility status of chicken eggs. They have undergone a pre-treatment and color segmentation process to extract the color area parameters of 150 images transferred to the computer. The results of the accuracy of the system using the Matlab R2018a neural network toolbox were shown in the confusion matrices, and it was reported that the overall accuracy of the predictive model was 97% (Fadchar & Cruz, 2020).

Conclusion and Recommendations

Livestock is a sub-branch of agriculture that enables animals to meet their basic food needs by meeting their needs after domestication. For an economical and profitable livestock farming, animals are fed, cared for and produced in a good way. Bovine, ovine, poultry and beekeeping are within the scope of livestock farming. Due to the dominance of small herds in our country, we see that precision livestock farming practices are less in order to meet the needs of animals on farms. The livestock sector leads to the fourth agricultural revolution in the world, in which sustainable food production is supported by mission automation and compliance, as well as useful technologies for improving farm and supply chain performance. In estimating data such as live weight, milk yield and performance parameters, information and communication technologies (ICT) and precision livestock farming (PLF) should be encouraged to be used in all areas of the farm environment in order to facilitate livestock practices such as heat, nutritional behaviors, animal welfare monitoring, and control of environmental conditions. In order to improve the applicability of the system, an environment needs to be prepared in terms of improving innovation processes and developing new technologies with the cooperation of politicians, farmers, consumers and technology developers (R&D employees). Accordingly, advantages such as efficiency increase, performance improvement etc. can be provided by evaluating the data of the farms, gathering them under a roof, ensuring data security and integration with the technologies developed. It is recommended to address multi-farm shared PLF solutions and also to carry out studies to make them commercially viable for the future studies.

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