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Review Article

Novel Technologies and Automation Systems In Livestock Farms

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Abstract

The concept of precision agriculture was first introduced in the 1980s and arose from the need to solve environmental problems such as the use of fertilizers and pesticides. Precision agriculture has made rapid progress by the development of information technology in recent years. Precision agricultural practices are used in animal production with the name of Precision Livestock Farming. Precision livestock farming can be defined as a novel approach to manage livestock farms with sustainable production both economically and ecologically. The development of this management system is provided by the information obtained from sensor technology and automation systems.

The main purpose of this study is to define how novel technologies and automated systems are being utilized to improve the livestock farming. The first question asked for the study is "Which technologies are related to livestock farming?" Second one is "These technological systems can improve the livestock farms in reality?" In the research, peer-reviewed articles obtained from Web of Science, Google Scholar and Scopus databases were used. The evaluation of novel technologies and automation systems was performed according to their location, production system or measured variables. The results showed that the main success of these novel systems came true on the improvements of animal health. However, less attention seems to be paid to the transportation problems of livestock sector. Considering the precious outcome achieved by the use of novel technologies and automation systems, the utilizing of these technologies in livestock farms must keep being heartened, by taking into accounting the systems costs. Because novel technologies and automation systems offer significant gains in labour productivity and improve decision-making quality.

Keywords: Health; Individuality; Productivity; Precision livestock farming PLF; Welfare.

Introduction

The increasing need for food with the increase in the world population puts pressure on all food production sectors and reveals that especially the activities in agriculture and animal husbandry should be more productive, more efficient and sustainable. In terms of protein source, poultry is currently one of the main sources of animal protein produced worldwide, and demand for this source is projected to increase in the coming years. It is expected to constitute approximately 38% of the world's animal protein demand by 2028 [1]. Along with the question of how to meet this demand, the question of how to protect the welfare of farm animals has come to the fore in many scientific discussions. It is clear that animal welfare is closely related to sustainable animal husbandry. Since animal welfare is one of the foundations of sustainable animal husbandry, it is known that providing adequate living conditions for livestock is the human task [2].

However, maintaining high welfare levels for livestock is often quite a challenge in large scale facilities. Because in the past, animal husbandry was a subsistence activity where there were fewer animals per farm and could be managed almost individually, today it has turned into intensive production systems that provide marginal income to farmers and the number of individual animals per farm worker has increased incredibly [3].

This shows that it is impossible to deal with animals individually without new generation management tools and technologies. Thus, the determination and management of animal welfare is a major challenge that must be addressed in meeting the world's

animal protein demand [4]. Spilke and Fahr [5] defined precision dairy farming as aiming to achieve ecologically and economically sustainable milk production with reliable quality, high consumer and animal protection, with particular emphasis on technologies used for individual animal monitoring. The main objectives of precision dairy farming are: Maximization of individual animal potential, early diagnosis of diseases, and minimization of drug use for preventive health measures. They see precision dairy farming as a multidisciplinary approach that emerges from the combination of informatics, biostatistics, ethology, economics, animal breeding, animal nutrition and engineering.

Eastwood [6] precision dairy farming in his study; They defined it as the use of information technologies to evaluate the diversity of good-scale animal and physical resources, with the aim of developing management strategies to optimize economic, social and environmental farm performance. Schulze [7] stated that there may be a return from the trend of precision dairy farming and herd management to the trend of using technologies focusing on the return of individual dairy cows. Precision dairy farm as controlling the continuity of the production process in order to achieve optimum outputs in the fields of profitability, health, quality, product safety, animal and environmental protection.

Bewley [8] described PLF as the use of technology to measure the psychological, behavioural and production indicators of each individual animal to improve management strategies and farm performance. Sensors and precision agriculture technologies used in animal husbandry Electronic IDs, automatic feeding systems, milk yield and quality measurement systems, automatic weighing systems, activity meters, smart drinkers, animal image analysis systems, animal temperature measurement systems, herd management software, milking robots precision animal with its use in production, it enables producers to benefit from the individual potential of animals at the highest level by meeting the needs of animals accurately and on time, to reduce the use of drugs by diagnosing diseases earlier and taking preventive health measures [9].

Systems that can be monitored in animals are sensitive (individual) feeding, regular milk recording (yield and ingredients), pedometer, pressure plates, milk conductivity indicators, automatic estrus detection, body weight, temperature, lying behaviour, ruminal pH, heart rate, feeding behaviour, blood tests. It provides the opportunity to collect data such as respiration rate, rumination time, movement skill scoring using image analysis at the individual cow level. In this way, it provides a proactive animal health strategy and minimizing the antibiotics through preventive health by focusing on health and performance [10].

Materials and Methods

The main question that guides this systematic research is what technologies are related to precision livestock farming and how do these technological systems improve the productivity of livestock farms? In the study, peer-reviewed articles obtained from Web of Science, Google Scholar and Scopus databases were used. Related articles were searched using keywords related to the topic. The title and summary of each article obtained was read and passed through a selection process according to the relationship status. Afterwards, duplicate articles were determined and the separation phase was started. At this stage, the selected articles were read completely, classified and analysed according to their fields. Finally, visualizations were created in the summarizing stage and the results were written. Since the aim of the study is to evaluate all the articles on the subject, no limitation has been determined for the year of publication. In the beginning, only the terms dairy farm, technology and milk were used. Then, by reading the selected articles, other studies related to the purpose of the current review were determined and new keywords were added to the search.

Peer-reviewed articles, conference papers, editorial notes, and reviews were included in the analysis. Articles that do not refer to the purpose of the study, for example about precision livestock farming or do not contain any new generation technology are excluded. Afterwards, a comprehensive evaluation was made on the accepted studies. Key data were extracted from each article reviewed and analysed.

Precision dairy farm

The concept of precision agriculture emerged as a separate field in research and agricultural practices in the 1980s. It generally refers to applications based on information technologies and global positioning systems. Since the 1980s, precision agricultural activities are generally carried out on crop production [11].

Although studies on dairy farming were included in the 1980s and 1990s, these studies could not be implemented on a large scale. Precision farming practices in dairy farms turned towards individual animal monitoring and became widespread after the 2000s, with the renewal and effective use of sensor systems. The historical development of precision farming technologies for dairy farms started with the development of individual cow ID in 1970s. Afterwards, sensors were developed for disease detection in 1980s. In the 1990s, automatic milking systems were developed. Sensors were renewed in 2000s and in 2010s the new generation sensors were inserted into the dairy farms. Sensors, applications, humans and animals were used to start creating data in many studies [12-14].

For example, the creation of value with data from pasture-based farming systems was used by Dias [15]. In another study, machine learning system was used to predict individual cow feed intake [16]. Verhoosel and Spek [17] are also studied on Big Data applications to examine the semantics. In another research, health and fertility were optimized by Big Data methods [18].

Novel technologies in livestock farms and adoption problem

Monitoring noticeable changes in the physiological parameters of dairy cows allows the dairy operator to intervene earlier [8]. Looking at the adoption of precision farming technology in dairy farms, progress is slow. Based on the studies of Bewley [8] and Dolecheck [19] the main factors affecting slow adoption are being unfamiliar with usable technologies, cost - benefit concern, fear of technology, difficulties in learning and using technology, previous bad experiences with technology, effectiveness of the resources used in production processes.

The characteristics that affect the adoption of technology by the primary decision maker are age, education level, learning style, goals, farm size, innovativeness in production, off-farm business ownership, spending on knowledge, use of technology by other employees and family members, business complexity and risk appetite [8].

The success factors that will enable precision dairy farming to work can be examined under three groups as system features, cost-effectiveness and socio-economic factors [20]. In summary, an ideal Precision Dairy Farming system is a dairy farm management method that effectively interprets the collected data in the decision-making process and turns it into a useful action as a result.

Feeding technologies in livestock farms

Here, when the animals that are defined electronically, come to the feeders containing automatic precision weighing scales and eat feed, the information such as how long it has stayed in the feeder, how much feed has arrived at what time can be obtained from here. Sensors that will read the electronic description are mounted close to the feeder and continuously record the incoming data. It is preferred that the calves be fed in small amounts throughout the day. In the case of manual feeding, this is done once or twice a day due to labour constraints. The system makes a significant contribution to the business in terms of economy, because it saves on labour and prevents possible animal losses [21]. The software adjusts the daily intensive feed consumption level of the animals in line with the criteria defined by the user, controls the amount to be given at a meal and the frequency (frequency) of the meal, and also determines the amount not consumed from the daily total amount determined for each animal [22].

The system recognizes each animal through its identification collars and knows exactly how much to feed. This animal-specific feeding facility allows animals of different ages to be kept together in groups. In addition, the same system can be used for feeding animals in two different groups. The system determines if there are calves that do not come to the station, and creates a list of animals that require special attention for the owner. Individual calf huts have always been the most preferred management system in the sector for raising calves. This management system is a management system that requires a large amount of labour and where the workforce is highly focused on feeding and cleaning each calf. Automatic calf feeding systems; it is presented for reallocation of this workforce in a more flexible work schedule to manage monitoring, calf health and performance [21].

Based on the results, in the positive effects section on the left, a total of $ 17,328 positive effects is calculated due to the decrease in labour need and management costs. Looking at the adverse effects on the right, there is an increase in expenses in different items and a total of $ 19,265 adverse effects were calculated. Its net financial impact is seen to be - $ 1.937 annually. In other words, even if the establishment of the system reduces the need for labour, it will result in an annual loss of $ 1,937 in the enterprise as a result of the additional costs it brings [21]. Bentley and Schulte [21] stated in their study that the system improved the quality of life despite financial loss. However, in another study carried out in 2011, the effects of automatic feeding and the other feeding system on different milk feeding rates, calf health and performance were examined. As a result of the study, it was stated that there is a lot to be learned and that these units have a potential to improve their health and economic efficiency as they are managed well [23].

In a study conducted at the University of Florida in 2011, cows were divided into two groups in terms of nutrition; while a standard mixed ration was applied to the cows in the control group, the other group was given weekly changing rations according to the individual energy balance measured by the sensors. Results showed that the milk production amounts of precision-fed cows give 3.3 kg / day more milk. [24].

Feed mixing and pusher robots.

Feeding is a very time-consuming process even in modern dairy farms. Success is related to the attention and care of the operator, as the filling of the mixed unit, its delivery to the shelters and its distribution. Mixing and pusher robot, not only by saving labour, it is also implements an ideal feeding plans effortlessly. The robot makes a significant contribution to profitability with both an increase in dry matter intake and a decrease in the amount of waste feed [25].

Easy and constant access to food increases animal traffic and dry matter intake, especially at night, while also reducing surplus. Feed pushing robots are environmentally friendly solutions that use extremely low energy. For example, a tractor for the same pushing job, compared to a pusher robot; it consumes ten times more energy on an annual basis and emits four times more emissions [25].

Automatic milking systems in livestock farms

It has been developed to ensure the automatic milking of bovine animals in Dairy Farms. It is preferred because it is more practical

than hand milking. Milking machines were tried to be created with two basic simulations. Systems imitating manual milking and systems that imitate calf sucking were developed. Today's milking systems mimic calf sucking. When the liner is open, that is, milk comes out due to the vacuum reaching the udder when it is not squeezed, and this position corresponds to the sucking moment of the calf. It should not be forgotten that the calf cannot suck continuously; it stops the sucking movement from time to time to breathe. In the position where the teat is squeezed, the vacuum to the udder is interrupted due to the contraction of the tire, which corresponds to the moment the calf breathes [5].

The most important lesson to be learned here is that the milking system is produced by imitating animals. In other words, in the increase of mechanization in animal husbandry, very serious products / ideas can be brought into being by imitating natural life. Milking with a machine is a must in enterprises with a large number of cows, for example ten or more. The milking machine allows obtaining higher quality milk, more economical use of labour, automation and milking more cows per unit time. Besides, it contributes to the increase of milk production. The time spent for milking is more in enterprises where there is no mechanization opportunity and where the workforce is heavily utilized. Advantages of automatic milking systems are individual cow care, improved animal welfare, improved food safety, timely decision making, objective decision making, and it is a reduced labour force [26].

Robot milking systems

A milking robot consists of some hardware that performs the milking process and computer software that controls these hardware parts. It consists of a milking robot, milking parcel, teat sensors and robot arm or arms. The milking parlor can be placed in the middle of the barn as well as in a different place in the barn. Sensors detect the location of the teats. Special camera systems monitor all the movements of the animal during milking. Sensors first determine the location of the right front teat of the cow, then take this teat as a basis and determine the location of the other three teat heads [27].

Automatic Milking Robot enables an animal to get milked by approaching the robot whenever it wants. When the animal approaches, the control of the doors for restraining the animal during milking, cleaning and disinfecting the udders, fixing the udder by determining the position of the udders, milking the milk under vacuum and pulsator control, re-spraying the udders after milking is completed by the Automatic Milking Robot [26].

The cow itself decides when to eat milk and rest in the free animal traffic that occurs thanks to robots. Automatic milking robot was first used commercially on dairy farms in the Netherlands in 1992. Since then, automatic milking has attracted a lot of attention. However, from an economic point of view, the cost-effectiveness of automatic milking systems is low. Many studies have been done in this area, with a few exceptions, the general trend in studies; when compared with the conventional milking system, it is that automatic milking has a negative effect on economic performance [26].

With the measuring devices integrated into the automatic milking system, the milk coming from each container during milking is separately and continuously monitored. In this way, information such as mastitis symptom, fat and protein amount, lactose level, which are vital for keeping animal health and milk quality under control, is obtained and rapid intervention is provided for maximum quality milk. It provides automatic fat, protein and lactose measurement on the milk line to the tank. Fat, protein and lactose analysis performed for each milking are gathered together and allows you to monitor overall herd performance. The amount of milk given at each milking for each cow is recorded by the system. This enables the monitoring of the change in yield and milk production amounts for each animal. The timer measures the time elapsed during each milking for each cow, while the flow meter measures the amount of milk produced in a given time [26].

Thermography in Animal Health

Thermography is a diagnostic imaging method that investigates and records the heat patterns on the skin surface of the patient and creates an image called thermogram. Most of the radiation below 400nm, which the human eye is not sensitive to, arises from the thermal vibrations of the materials. Thermography, which is based on imaging of heat reflection, allows the detection of changes in the localized area of pain in various diseases without causing any discomfort and radiation damage to the patient. This method is preferred especially in the diagnosis of orthopaedic disorders in horses. It also gives successful results in studies on sheep, pigs, and poultry livestock. Imaging with thermal cameras is also used in methods covering areas such as reproduction, thermal balance, animal health and milk processing [28].

Detecting Lameness with PLF approach

Lameness is among the most common and costly clinical diseases in dairy cattle. The floor is of particular importance because of the distribution of pressure and the distribution of pressure on the feet. The unbalanced weight bearing on the hoof surfaces of cattle raised on hard ground such as concrete causes pressure distribution irregularities in the feet. Thus, greater pressure on the feet leads to concentration and stresses. For this reason, weight bearing and footpad pressure distribution is an important measure. Research on biomechanics began with the use of force plates and went further with the development of footpad pressure sensitive mats used in modern animal shelter research. Lameness, one of the common diseases seen in cattle, is classified according to its severity. For this purpose, there are scoring tables prepared depending on the posture and walking positions in lameness degrees. Animals that

score 3 or more in movement scoring should be observed and the problem should be investigated, and solutions should be sought [29].

Automatic Weighing, Separation and Marking Systems

The measurement takes place during the passage of the cow over the automatic scale placed at the exit of the milking parlour; the measured values are combined with the cow identification information and sent to the herd software system using radio frequency [30].

Other technologies for animal health

Sensors come to mind when it comes to precision dairy farm technologies for animal health. The interpretation of the data obtained from the sensors measuring the behaviour and physical parameters of each animal individually is of great importance in the detection of animal diseases. In order to create a structural summary of the studies published on sensors used for animal health management in dairy farms in a study of Rutten [31], the results of the examination showed that the sensors were used into four categories as determination of mastitis, heat, lameness and metabolic problems [30].

Since 1980, many studies have been carried out to develop sensors in order to measure various parameters for each animal. Sensor systems development stages can be defined in four levels. In the first level PLF system development and definition of equipment to measure in one or more parameters, in the second level data interpretation, converting the data collected by the PLF system hardware into usable information, in the third level combining interpreted data at the second level with on-farm or off-farm data to support decision making and in the final stage, it is the main decision-making stage by the farmer or automatically by the PLF system. While the first step of the sensor system is the sensor itself, the second step is the use of sensor data by an algorithm that provides information about the health of individual cows. It is also possible to combine sensor data with other non-sensor data in the third step. In the last step, the action is decided. We can categorize the sensors into two categories as installed and not mounted. Mounted Sensors are sensors mounted on the cow or located inside the cow's body. Uninstalled sensors are systems that cows pass by, over or through [20].

Benefits obtained from sensitive animal production technologies; Increased efficiency, reduced cost, improved product quality, minimizing adverse effects on the environment and improving animal health and welfare. These technologies are likely to have a major impact on health, reproduction and quality control. For large flocks where individual animal monitoring is more difficult and less likely to occur, the benefits from summarizing data and reporting exceptions are expected to be higher [8].

Sensitive animal production; precise (individual) feeding, regular milk recording (yield and ingredients), pedometer, pressure plates, milk conductivity indicators, automatic heat detection, body weight, temperature, lying behavior, ruminal pH, heart rate, feeding behavior, blood tests, respiratory rate It provides the opportunity to collect data such as rumination time, movement ability scoring using image analysis at the individual cow level. In this way, it provides a proactive animal health strategy and minimizing the drug (antibiotics) through preventive health by focusing on health and performance [10].

Conclusions

This research was carried out in order to determine the new generation technologies involved in studies on the precision livestock farming and to reveal the benefits of these technologies. The new generation technologies related to the PLF were examined and their potentials and limitations were evaluated. The results showed that PLF technologies are not sufficiently known by farmers [32-34]. It has been demonstrated that the technologies studied can distinguish the welfare level of dairy farms. These systems can reduce the need for labour. In general, all of the technology-based studies examined and evaluated in this article mainly examined the farm stage of the animal life, the current production system, and the technical and disruptive aspects of animal production. Although all technological studies aimed at determining and improving the [35-37] health welfare and production of animals are relatively new, they have a high potential in terms of improving the current situation. In this respect, it is very important to develop new technological systems that can be tested and used in farm conditions. It has been revealed that the technological studies evaluated within the scope of this article do not adequately focus on different systems and especially on the problems of the supply chain. When the studies on the subject are evaluated, it has been observed that image-based technologies are used less than sensor-based technologies. In this respect, focus on image technology in technological-based studies to increase the benefits of PLF in the future. In addition, in future studies, how to adapt the farmers to these new systems and how to increase the interaction between the stakeholders of the production chain can be discussed. However it seems that the high cost of PLF technologies and the fact that they do not provide the desired level of benefit is one of the most important obstacles for the farmers' adoption. Activity of the animals was the first one between variables detected by PLF systems. This is followed by daily milk yield, temperature, heat, mastitis, milk components and other measurements.

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Conflict of Interest

No Conflict of Interest.

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