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ANALYSIS OF SUSTAINABLE DAIRY FARMING PRACTICES IN THE EU AND FOREIGN COUNTRIES

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This article aims to analyse the concept of a sustainable dairy farm and review sustainable dairy farming experience in EU countries. Theoretical aspects of sustainable farming are analysed during the research; namely, the analysis of EU legal, strategic, and other documents is performed; an overview of research, EU reports, and other documents on sustainable farming is conducted as well as an analysis of international experience in assessing sustainable farming systems in the dairy farm is carried out. The most targeted countries leading the dairy industry and their experience are dealt with. Experience of the USA, New Zealand, China, and EU countries (the Netherlands, Finland, Poland) in implementing sustainability principles in dairy farms is viewed. The study revealed that the leading dairy countries pay a lot of attention to implementing sustainability principles in introducing the planned EU strategies and recommendations and being willing to operate competitively in the global market. At the same time, agriculture is aimed to be viewed as an attractive sector for work and to be adjusted to the development of common sustainability strategies of the countries. EU countries are also focusing on research, modernization, and sustainability of the dairy sector.

Keywords: sustainability, sustainability of dairy farm, sustainable dairy farming, sustainable agriculture.

INTRODUCTION

Relevance of the topic. Over recent years the issue of sustainable farming in the scientific literature, legislation, EU strategies such as the European Green Deal (2019), Horizon 2030 (Bichisao et al., 2019), The 2030 Agenda for Sustainable Development (General Assembly, 2015) has been discussed in depth. In the aforementioned documents, it is stated that further growth of the bioeconomy should be linked to the achievement of sustainable development goals (SDGs), climate change prevention, and the growth of sustainable farming (Borawski et al., 2020; Agostinho et al., 2019; Bai et al., 2018). To reduce the environmental impact of the dairy sector and ensure the implementation of sustainable development goals, it is necessary to consider the requirements of sustainable farming and select the best methods for implementing sustainable dairy farming (Agostinho et al., 2019).

Scientists often discuss the development of a sustainable dairy farm: ways to achieve sustainable development goals in dairy production are discussed (Fogarassy et al., 2016); the sustainability of dairy cooperatives is studied (Bijman, 2018); it is interested in actions farmers take to develop a sustainable dairy farm (Bankuti et al., 2020); the role of innovation in ensuring the sustainability of the economy is analysed (Lappe and Thorne, 2018); the impact of technology on the intensification of sustainability is explored (Balaine et al., 2020); it is aimed at improvement of the sustainability of EU dairy farms (Foote, 2020); new models of sustainable dairy management are sought (Ludington, 2004); the sustainability of the dairy industry is analysed (Von Keyserlingk et al., 2013); it is attempted to understand and improve the sustainability of EU agro-ecological farming systems (Prazan et al., 2019), sustainable farming terminology is considered in detail (Sanz et all., 2010); problems of dairy farm efficiency are being solved (Poteko et al., 2019).

The study aims to analyse the examples of sustainable dairy farming in the EU and other foreign countries and reveal the peculiarities of such farming.

Research method: the theoretical part of the paper deals with scientific literature, EU strategic, legal documents, reports and programs, and other documents related to the aspects of sustainable farming such as characteristics of sustainable farming systems, components of sustainable farming, sustainability dimensions. The comparative analysis of sustainable dairy farms in the EU and non-European countries was carried out in the empirical section.

THEORETICAL ASPECTS OF SUSTAINABLE FARMING

There is currently no uniform and well-established definition of a sustainable farming system. Such a system is debated in academia, politics, and the public sphere. Different authors provide slightly different translations of the term sustainable development, for example, into the Lithuanian language and the vision of the sustainable farming system. The term "sustainable" is most often translated in the scientific literature as "tvarus vystymasis" (Žičkienė et al., 2019; Melnikienė et al., 2018), "tolydi plėtra" (Zhang et al., 2008) and "darnus vystymasis" (Augaitytė, 2020). Thus, there are often not only discussions of the components of the concept but also issues and discussions of the use of concepts in different languages.

Sustainability has been discussed in EU strategic, legal, and other documents since 1992 (see Table 1).

Table 1. The concept of sustainability in EU documents

Year	Document	Content of the document
1992	Rio Declaration on Environment and Development	27 principles of sustainable development were presented.
2001	Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development	It aimed to initiate enlargement that would enable the EU to achieve economic growth, greater social cohesion, and a better environment.
2002	National Report on the Implementation of Sustainable Development: from Rio de Janeiro to Johannesburg, from the transition period to sustainable development	A new approach to policymaking, impact assessment, global context assessment, better communication, mobilization of citizens and businesses has been introduced.
2006	Renewed EU strategy for Sustainable Development	The EU Sustainable Development Strategy addresses economic, social and environmental issues. The document lists seven key policy areas: climate change and clean energy, sustainable consumption and production, sustainable transport, protection and management of natural resources, social inclusion, public health, demography and migration, and global poverty.
2015	Transforming our World: the 2030 Agenda for Sustainable Development	17 sustainable development goals are set to be achieved by 2030.
2018	The EU dairy sector	Resilience and sustainability are stated to be key concepts for the future of the dairy sector. It can be achieved by introducing novelties and innovations to reconcile farmers' need for adequate consumer demand for affordable and high-quality dairy products with environmental and animal health requirements.
2018	EIP-AGRI Focus Group: Robust and Resilient Dairy Production Systems. Final Report	There are four main challenges that meet social needs: environmental impact (GHG, water pollution, land use intensity), animal welfare (living conditions, human intervention), health (use of antibiotics, disease outbreaks), and breed management issues (genetically modified organisms (GMOs)).
2019	Climate Change and the Global Dairy Cattle Sector. The Role of the Dairy in a Low-Carbon Future.	The dairy sector's role in the future reduction of carbon dioxide, which provides recommendations for the dairy sector on GHG reduction.
2019	Innovation, Productivity and Sustainability in Food and Agriculture	Recommendations for more productive and sustainable food and agriculture are provided.

In summary, a significant number of documents on sustainable development have been issued at the European Union level, covering three main areas: economic, social, and environmental. The European dairy sector strives to be part of sustainable development and contribute to the goals set; however, successful implementation depends largely on national regulation.

The sustainable farming system consists of components such *as farm/barn condition, the number of cows, farm area, cow housing conditions, milking conditions, feed type, animal breed, feeding and ventilation strategies, waste emissions* (e.g., Bittante et al., 2015; Poteko et al., 2019; Balaine et al., 2020; Bankuti et al., 2020).

According to Melnikienė et al. (2018), the system of sustainable farming can be described through the interrelationships of its components: the economy, society, and the natural environment. Sustainable farming should be established on a specialized livestock grazing system based on grass fodder (Peeters, 2018). Also, such a system must be based on a certain economic logic that maintains the income level of a sustainable farm (Agostinho et al., 2018). Bankuti et al. (2020) observed that if farming is not sustainable, it may be characterized by low production productivity and high milk collection costs. A sustainable dairy system must ensure that there is as little waste as possible in the milk supply chain, and farmers should leave behind technologies such as traditional milk registration and apply more sophisticated and accurate livestock technologies such as automatic milking (Balaine et al., 2020). The scientists' views on sustainable farming systems are presented in Table 2.

Table 2. Characteristics of a sustainable farming system

Year	Author	Main characteristics of the sustainability system
1987	WCED	Meeting current needs without compromising the ability of future generations to meet their own.
2001	Sustainable Europe for a Better World	The principles of sustainable development are applied: sufficient amount of production is created; available reserves are preserved and ecological disasters are prevented.
2006	Parna et al.	Soil fertility is maintained, renewable resources are used.
2010	Strzepek et al.	Current growth meets current needs without compromising future generations.
2013	Jedik et al.	For maximum results by making the best use of available resources.
2015	Bittante et al.	It is inseparable from the assessment of the impact of newly introduced agricultural measures on agriculture.
2019	Kebreab et al.	Sufficient food production, economic viability, social justice, natural environment.
2020	Balaine et al.	A sustainable system must be based on a win-win-win strategy that at the same time improves agricultural efficiency and provides a wider range of environmental and social benefits.

It can be concluded that a sustainable farm aims to meet current needs concerning the needs of future generations. Thus, even to achieve maximum results, the sustainable farming system must ensure efficiency as well as social and ecological justice.

Other significant aspirations for sustainable farming are that a sustainable dairy farm should strive to reduce carbon emissions, protect grasslands to be grazed from erosion (The European Dairy..., 2018), promote local consumption, more sustainable use of water, and sewerage (Adomaitis, 2019), prevent waste of resources, and turn to the reuse of water (The Dairy sector..., 2019). Modern and sustainable dairy farms should introduce digital methods for cropping and care that fix nitrogen in the soil and improve cattle silage quality. This silage is more easily digested by cows, which improves their health, which means they emit less methane and influence climate change less (Foote, 2020). On a sustainable farm, efforts should be made to keep milking indoors as little as possible to avoid manure-handling problems. Moreover, cattle kept indoors may not get enough fresh air and due to insufficient sun get too little vitamin D (Borawski et al., 2020).

When developing a strategic model of dairy farming, which would reflect the dimensions of sustainability (*economic*, *environmental, and social*), it is necessary to estimate production costs (Sutherland et al., 2011; Galnaitytė et al., 2017):

1. The price of fodder grown/purchased is estimated including the costs of seeds, fertilizers, etc.
2. The needs of farmworkers are assessed.
3. Run time on machinery, repairs, fuel, and electricity consumption shall be evaluated.

The specifics of animal husbandry shall be further assessed (Zhou et al., 2010):

1. *Service interval* is the time from the fertilization of a cow to becoming pregnant.
2. *Insemination time* is the time when the cow can be inseminated after the birth of the calves again.
3. *Heat detection* – it is assessed whether it is already expedient to inseminate the cow.
4. *Fertility index* is an indicator calculated as the ratio of fertilized to inseminated cows.
5. *Insemination index* is an indicator that shows the ratio of insemination procedures to the ratio of fertilized cows.
6. *Pregnancy rate* is an indicator that shows how many cows are pregnant out of all those in the herd.
7. *Herd key performance indicator* is the period from one calving to the next.

Dutch researchers propose the following interactive strategic management system (Zhao et al., 2007):

1. *Dairy farm development* – to increase production, number of cows, farm area.
2. *Improvement of the herd* – to increase the amount of milk, to improve the quality of milk, to increase the fertility of cows.
3. *Increasing farm productivity* – renovating farms, purchasing modern equipment.
4. *Diversification in animal husbandry* – raising beef cattle.
5. *Diversification in other areas* – production, sales.
6. *Vertical cooperation* – to cooperate with milk processing plants.
7. *Horizontal cooperation* means cooperation with other farmers, for instance, by buying machinery, requesting support.
8. *Extensification* is the orientation to nature.

The scientific literature also singles out integrity as an essential aspect of management system modelling. An integrated dairy management system consists of the following (Kebreab et al., 2019; Pekarskas et al., 2007):

1. *Livestock module* – life cycle, nutrition.
2. *Soil module* – the area of pastures is evaluated; the best crop combination is selected.
3. *Feed storage module* – evaluates feed storage conditions and losses.
4. *Water balance module* – accounting of water consumed on the farm and automatic lines.
5. *System integration* – convenient management of all modules.

Sustainability in a dairy farm is measured concerning economic, social, and environmental indicators. The SAI Platform (2010) identifies the following nine key indicators for sustainable milk production:

1. *Animal health* – morbidity and physical health are assessed.
2. *Animal welfare* – it is assessed whether cows are not thirsty or hungry, whether they are experiencing discomfort or pain, whether their behaviour is normal, and whether they feel fear.
3. *Economic viability* – real return is calculated (income after expenses, taxes, debts).
4. *Working conditions* – hours worked, physical and emotional safety at work is assessed.
5. *Air pollution* – greenhouse gas emissions as well as ammonia emissions are measured.
6. *Water quality* – the amount of nitrogen and phosphates in water is examined, the amount of biological and chemical pollutants entering the water is assessed.
7. *Water use efficiency* – water consumption per unit of production is calculated.
8. *Soil fertility and quality* – the number of nutrients and organic matter in the soil, the structure of the soil, the absence of erosion and toxic substances are monitored.
9. *Conservation of biological diversity* – changes in species diversity over time, genetic diversity, the extent of land-use change are observed.

It can be concluded that authors from various countries highlight different indicators for sustainability assessment. Therefore, it is appropriate to discuss dairy practices in individual countries in more detail.

RESEARCH METHODOLOGY

The research of sustainable dairy farms in the EU and non-European countries was carried out in the empirical section. The empirical research consists of two parts.

Firstly, 10 Lithuanian dairy farms' analysis applying different technological solutions was performed, and two Finnish farms and a Polish one was considered. Empirical research is designed to determine the condition of cows on farms, how manure is handled, what technologies are used for milking and feeding, and determine the average milk yield.

Secondly, as one of the leading countries in the dairy sector has been selected to assess the EU's experience in sustainable dairy farming: the Netherlands and Poland as one of the largest milk producers and Finland as one of the countries with the highest milk yields. Moreover, New Zealand, the USA, and China was investigated to assess sustainable farming experience in non-European countries. These three countries were selected as the largest marketers of milk.

Research methods include in-depth analysis of scientific literature, document analysis, statistical data analysis, comparative analysis and synthesis, farm monitoring, and analysis.

The analysis of EU and non-European sustainable farming practices' evaluation provides statistics on the number of dairy farms, milk yields, etc.

RESEARCH RESULTS

When analysing the situation of dairy farms, it was found that 241,847 dairy cows were bred in Lithuania in 2019 (Annual Report..., 2020). However, more than 70% of all dairy farms in Lithuania are very small, raising up to 5 dairy cows, about 16% of farms keep 6-14 cows, and 13.5% keep more than 15 cows (Vitunskienė, 2019). Similar trends prevail globally: the dairy farm raises an average of 3.1 cows (78% of farms raise 1 to 10 cows, 22% raise 11 to 100 cows, and more than 100 cows raise only 0.3% of farms). When assessing the productivity per cow, there is a tendency that the amount of milk produced has been increasing in recent years (in 2016 – 5 536 kg, 2017 – 5 601 kg, 2018 – 5 934 kg). In Lithuania, 1 cow is kept on an area of 1 ha, while in the Netherlands, there are 15 cows per hectare of the country's area, in Italy - 10 (Adomaitis, 2019).

When assessing the European experience of the dairy sector in implementing a sustainable agricultural system, the EU is showing a strong focus on developing new farming systems to enable farmers to meet many of the challenges they face, including climate change and the growing pressure for more sustainable use of natural resources. The future farms will have to produce more at lower costs. This is expected to be achieved through measures such as "innovation partnerships to foster innovation in agriculture by reducing the gap between research and farming methods and better communication and relations between stakeholders" (On European Union..., 2014). With the wider use of sustainable farming systems, such as the Pastoral Dairy Farming System, the Barn Dairy Farming System (Ilyas et al., 2019), etc. in the dairy sector, it has been observed that more and more milk has been milked in the EU since 2017, for instance, by 1.7% more in 2020 than in 2019 (DG AGRI, 2021). In recent years, the number of cows kept in herds in the EU has been declining as milk yields per cow have improved, and in 2018 one cow produced an average of around 7000 kg of milk per year (Milk and dairy products, 2019). Milk production is projected to continue to grow in 2021, but at a slower pace, with 22.7 million cows being reared in the EU, with an average milk yield of 7429 kg (Adomaitis, 2019).

Examples show that sustainable farms are modernizing their farms to ensure comfortable animal growth conditions, using robots for milking, and monitoring the condition of the animals. Researchers (Parna et al., 2006) simulated the dairy cattle farming system by incorporating genetic and economic parameters, which showed that the focus is on ensuring higher cow productivity without compromising cow health and welfare indicators. Other researchers note that in modern sustainable dairy systems, to optimize the herd and meet individual animals' needs, it is appropriate to apply new technologies, including computing, electronics, and video. Such systems make it possible to assess livestock conditions in real-time to detect cows with reduced productivity (O'Mahony et al., 2019; Rural Development Programme). Examples of sustainable farm systems are listed in Table 3.

Table 3. Examples of sustainable farm systems

Location	Farm condition	Number of cows	Area	Milking	Additional information
Lithuania, Kėdainiai	Modernized	580	Kept on litter in the barn	2 smart robots can monitor cow condition	Yield of 5.7 thousand tonnes of milk
Italy, Verona	Modernized	180	140 ha	4 robots	37 kg per cow a day
Netherlands	Equipped with natural lighting, ventilation system	130	30 ha of pasture and 15 ha of additional area	Automatic system, from milking to bottling	Diet with non-traditional components, a cow produces 43 thousand kg of milk during their life

Source: Adomaitis (2019), UŽB "Labūnava"... (2019)

Sustainable farms are modernized, milking is automated, cows are grazed in large areas.

In Europe, the largest milk producers are Germany, France, the United Kingdom, Poland, and the Netherlands (On European Union…, 2014). The highest milk yields per dairy cow are in Denmark, Sweden, Estonia, Finland, and Portugal (8,278 to 9,361 kg per cow). The largest dairy cooperatives are in the Netherlands (the cooperative has a market share of 86% in that country), followed by Poland (75%), Italy (68%), Germany (67%), and France (54%) (The EU dairy sector, 2018). Of the EU countries, cows are the healthiest in Finland, where antibiotics are only used to treat sick animals (JIACRA Report, 2015). It can be argued that Poland, the Netherlands, and Finland are one of the leading countries in the dairy sector, albeit with a quite different dairy policy. The situation in these three **European countries** is be discussed in detail below.

The Netherlands. There are 16,500 dairy farms, 53 dairies in the Netherlands, and an average of 97 cows per farm producing 13.9 billion litres of milk (Sustainable dairy in Europe, 2019). The country's sustainable farms place a strong emphasis on nutrient supply to the soil and the preservation of soil quality, waste management, moderate water use, and wastewater treatment (The EU dairy sector, 2018). When assessing the Netherlands' experience (Scherpenzeel et al., 2018), it can be observed that in dairy farms, veterinarians suggest the use of fewer antimicrobial agents and implementing certain preventive measures. For instance, more frequent health checks on cows are suggested, which is expected to improve the condition of cows' udders. This antibiotic reduction plan was started in 2008. Studies have revealed that between 2008 and 2017, when antibiotics were gradually reduced, no major changes in udder status or changes in milk quality indicators were observed (Lam et al., 2016; Speksnijder et al., 2017). In the Netherlands, a national bovine health care system has been run since 2002, regulating various diagnostic tests, analysing bovine mortality and fertility, udder status, and use of antimicrobial agents. A modern farm aimed at ensuring good cattle health ensures a balanced diet and proper hygiene conditions. Such farms are inspected every two years (Santman - Berends et al., 2016). When assessing the prevention of individual diseases on farms, it is recommended to maintain a suitable temperature in the barns for ketosis prevention so that the cow is not too cold during the calving period (Vanholder et al., 2015).

Finland. Finnish agriculture is based on private family farms with an average herd size of 35 dairy cows. More than two-thirds (69%) of dairy farms have a stationary barn with a milking system; the remaining (31%) have a barn with a milking parlour or an automatic milking system. In recent years in Finland, automated milking systems have been gaining popularity, in which cows are lured to milking robots with feed, where the milking robot cleans the teats, milks the cows, and sprays the teats with a disinfectant (Karttunen, 2016).

Poland. There are about 170 dairy processing plants in *Poland*. An average of 38 cows were kept on Polish farms in 2017. In this country, sustainable dairy farming includes indicators such as water consumption, sewage and sludge extraction, amount of waste generated during production, exhaust emissions from fuel combustion, noise emissions, electricity consumption (Stawicka et al., 2019).

The conclusion is that the EU countries, in particular Poland, the Netherlands, and Finland, pay great importance to the principles of sustainability implementation, not only during the EU policies and recommendations, but also to remain competitive in a global market, while keeping agriculture an attractive sector for work, and to align with the development of common sustainability strategies in countries. EU countries are also focusing on research, modernization, and sustainability of the dairy sector.

New Zealand, USA, China is analysed in the sustainable dairy sector of **non-European countries**. These countries were selected as the largest marketers of milk. The situation in these three non-European countries is be discussed in detail below.

In *New Zealand*, there are currently 5 million dairy cows, and the average herd size continues to grow. The size of dairy farms can vary, with the average number of cows per farm exceeding 400 in New Zealand. Some farms may have more than 1,500 cows. The dairy industry employs more than 40,000 people (2019) and farms employ more than 35,000 people (New Zealand Immigration, n.d.). In the Dairy Strategy (2017), the International Dairy Federation (IDF) cited New Zealand as one of the good examples contributing to the dairy sector's sustainability. Technological developments have also opened new opportunities for farmers to reduce costs and increase efficiency. Technologies such as automated milking machines and video cameras to monitor pastures have freed up farmers' time, while genetic improvement has boosted production (Is the traditional NZ dairy farm commercially sustainable, 2018). New Zealand is aware of the threat of climate change and has adapted milk production technologies to it (Loeschen, 2019).

The United States ranks to be the second in all kinds of milk production and is the leading country worldwide in terms of milking. The USA is a major exporter of milk to countries such as Mexico, Saudi Arabia, Canada, and China (Loeschen, 2019). The American dairy industry has significantly improved efficiency and milk production since 1940. During this period, the number of farms and cows decreased, and the average herd size increased. Over the past century, the USA dairy industry has significantly improved production efficiency, which it has achieved in part by investing in technology. Advances in genetics, nutrition, and herd management have led to a fourfold increase in milk yield between 1944 and 2007, with a consequent reduction in the number of farms and cows. Compared to 1944, There are 64% fewer cows and 59% more milk in the USA dairy industry, plus 77% less feed and 65% less water per litre of produced milk (Capper et al., 2009). When summarizing the scientists' analysis (Von Keyserlingk et al., 2013) assessing the US dairy industry's sustainability, aspects such as climate change, rapid scientific and technological progress and innovation, globalization, societal values, and multidisciplinary research initiatives integration are taken into account. Sustainability is more than economic profitability; it also addresses environmental and social issues, including dairy farm workers and animals' quality of life. Concerning sustainability, it is also important to mention the cooperation between producers, various industrial sectors (such as processors and producers), consumers, and citizens, which is essential for recognizing and implementing more sustainable practices.

China's demand for milk is steadily rising, with demand projected to increase 3.2 times by 2050 compared to 2010. According to scientists, meeting Chinese milk demand under a business-as-usual scenario could increase greenhouse gas (GHG) emissions by 35%. To contribute to sustainability, researchers suggest China incorporate strategies to improve feed production, dairy production, and manure management into a coherent government policy. This policy should include clear manure management rules to ensure that all manure from kept animals is properly collected, stored, and subsequently used on arable land and grassland, and not discharged into landfills or water systems, as has been the case for the last 60 years (Bai et al., 2018). In recent years, the Chinese dairy sector has made significant progress due to high-quality dairy products and growing market demand. Besides, the dairy sector has been identified as having the potential to reduce its environmental impact further.

It is concluded that both the leading countries in dairy farming are focusing on sustainability research and implementation. Those countries that want to become more competitive, such as China, are already pursuing sustainability principles, realizing that traditional principles are not enough to strengthen the sector.

When assessing the situation of sustainable dairy farming in Lithuanian farms, technology assessment was performed in 10 farms. The characteristics of the farms are presented in the Table 4.

Table 4. Characteristics of the farms

Case name	Number of cowshed boxing seats	Condition of the barn	Number of robots used for milking	Condition of feeding
D. S. farm (Šakiai district)	280	semi-warm	4	feeding is automated
P. R. farm (Klaipėda district)	130	insulated	2	feeding with mobile equipment
R. G. farm (Šiauliai district)	195	insulated	a robot with three milking boxes	automated
R. Ž. farm (Lazdijai district)	210	half-warm	3	automated
V. S. farm (Biržai district)	240	insulated	0	feed is distributed by mobile equipment
V. R. farm (Prienai district)	150	insulated	2	n.d.
Public Institution “ASU mokomasis ūkis” (Kaunas district)	140-bed semi-deep cowshed	semi-warm	0	cows are milked in the milking parlor “Tandem” 2 × 4
ŽŪB “Vozniškiai” (Marijampolė district)	two box cowsheds with 220 seats each	the roof of the barn is insulated, the walls are covered with a net	0	cows are milked in the milking parlour “Karuselė”
ŽŪB “Griškabūdis” (Šakiai district)	700 (two barns)	semi-warm	0	cows are milked in the milking parlor “Karuselė”
ŽŪK “Lumpėnų rambynas” (Pagėgiai municipality)	220	walls, and roof not insulated, roof covered with tin, walls covered with a net	0	cows are milked in the milking parlour “Eglutė”

Different animal husbandry technologies are applied in various Lithuanian farms: milking, manure handling, feeding and water systems, ventilation technical solutions. Cows are mostly milked by robots, feeding is also mobilized. Different bedding or mats (mattresses) are used in the beds; the animals are fed with different feed compositions. Thus, barns differ in the values of many factors on which sustainability indicators depend, for instance, ammonia and GHG emissions.

All cowsheds are equipped with natural slit ventilation systems, axial fans for intensification of air movement and convective heat exchange. Only in the cowshed where there is the ceiling, a shaft ventilation system is installed. The design solutions for ventilation systems are usually good, but the ventilation intensity is not always sufficient due to incorrect control of ventilation slit areas. The highest ventilation intensity in the barn is required to remove excess water vapor. Therefore, it is sufficient to regulate the ventilation intensity of cattle barns according to the amount of water vapor. If a low humidity in the barn is ensured, it will also have a low concentration of carbon dioxide and ammonia. However, in Lithuanian cowsheds, the ventilation intensity is usually regulated according to the air temperature without assessing the humidity in the barn. As a result, cowsheds are damp, water vapor condensate accumulates on building structures, and later mould develops.

Manure is managed in such a way as to avoid pollution of surface and groundwater, minimizing air pollution and the spread of unpleasant odours. Liquid manure tanks are installed on the ground; the manure is sent to the bottom of the tank, thus avoiding the contact of fresh manure with ambient air, without destroying the crust formed on the manure’s surface. Probiotics that reduce gas and odour emissions are also commonly used.

Labour costs and workload are reduced. The attractiveness of work on farms increases by automating work processes, employing robots in barns, installing digital systems, increasing the efficiency of the equipment used, and work productivity.

Cattle productivity is increased by improving housing conditions, optimizing animal behaviour, housing hygiene, creating an optimal micro-climate.

For the cow rest, boxes are installed in which straw is laid, or rubber mats are laid on the concrete, on which sawdust or chopped straw is sprinkled. Box partitions are made of 50 mm diameter metal pipes. The width of the boxes varies from 1.17 to 1.26 m. The length of the boxes at the wall is 2.60-2.75 m, and the length of the double box is 4.60-5.20 m. The cowshed is equipped with 3 rows of boxes on one side of the feeding track, but the robotic cowshed is equipped with as many as 5 rows of boxes.

The feeding path is separated from the animals by a simple fence without animal restraint; the animal restraint is installed only in the sanitary animal service area.

The feeding path is equipped with a flat feeding table: the strip’s width for spreading feed varies from 0.75 to 0.95 m. The feeding path’s width varies from 2.5 (fed by an automatic trolley) to 5.20 m (fed by a mobile distributor attached to the tractor).

The average milk yield per cow varies from 6,800 to 12,000 kg of milk per year. In large farms, cows are milked in milking parlours "Karuselė", in other farms – in milking parlours "Eglutė", "Tandem" or milking robots. Single box milking robots are usually installed, but also a milking robot with three milking boxes is installed, i.e., one robot arm serves the cows in the three boxes. Cows are milked by robots on average 2.4-3.1 times a day. Robotic barns use a variety of cowherd management: regulated cow movement or free movement of cows.

The manure flush alley's width between the rows of milking boxes is 2.70-3.0 m, the width of the manure flush alley near the feeder is 3.40-3.70 m. Manure is removed from the alley by scraper conveyors, controlled by electric motors or a hydraulic cylinder. When gratings are installed in the alley, they are cleaned by a manure removal robot, and manure is removed from the channels by self-flow or with the help of pumps.

To assess the situation of sustainable dairy farming on EU farms, a technology assessment was carried out on the following farms: 40-box tethered cowshed in Finland; 160-box cowshed in Finland; 220-box cowshed in Poland (Dutch farms were not visited due to COVID situation). The farms visited abroad can be divided into three groups: small farm (up to 50 cows), average farm (up to 160 cows), and large farm (200-240 cows).

These are family farms. The main differences in farm activity are due to the size of the farm. The larger the farm, the higher the condition of the barn and the technological level. However, this is not necessarily directly related to better cow health or higher milk quality indicators. Small farms use free grazing during the summer, while large farms usually use a robotic milking and/or feeding system. Newly built barns are built according to animal welfare and environmental requirements. In contrast, older barns are partially reconstructed, but this does not ensure a good micro-climate in the barn due to insufficient ventilation and light. These factors affect animal health, mortality. Dry peat is used as litter on large farms in Finnish farms. Milk above 11000 l is ensured, but the number of lactations is only about 2.6 times. The growth is kept in separate barns. During the summer, calves are kept outdoors.

To invest as little as possible in the maintenance of human resources, farms mechanize and/or robotize as many processes as possible. In that case, 100 cows can be served by one employee. Direct payments remain an important source of support for smaller farms in Lithuania and countries such as Finland. With the cut-offs of support, a family farm raising up to 50 cows would no longer be able to survive. Income earned on small farms is low, although Finland has significantly higher milk purchase prices. In smaller farms, the number of lactating cows is much higher, the number of diseases is low, even if the buildings are old. It can be argued that in countries such as Finland, Poland competitiveness of the dairy sector is not particularly different, sheds of better condition, but government support for the sector and higher purchase prices for milk farmers in cooperatives.

DISCUSSION

International experience analysed in assessing sustainable farming systems in dairy farms in the USA, New Zealand, China, Poland, Finland, the Netherlands has revealed that both leading dairy countries focus on sustainability research and implementation, and those that want to become more competitive, such as China, already implement the principles of sustainability, recognizing that traditional principles are not sufficient to strengthen the sector. EU countries pay a lot of attention to the implementation of sustainability in accordance with the legal acts of the EU institutions, country strategies, while realizing that sustainable long-term solutions on farms ensure not only farm stability but also growth, innovative solutions not only related to climate change but integrated farm management solutions.

In the development of sustainable dairy farming, it is important to integrate scientific knowledge and the resulting technical and technological solutions, improve animal welfare conditions, ensure *the implementation of animal welfare, health, and environmental requirements*, while achieving economic efficiency in an integrated way.

CONCLUSIONS

An analysis of the EU's strategic, legal, and other documents related to sustainability has revealed that a significant number of documents have been issued on sustainable development, covering three main areas: economic, social, and environmental. A review of research, EU reports, and other documents has revealed that there is a strong focus in the scientific literature on research into a sustainable dairy system. It is found that, although there is no uniform definition of a sustainable dairy system, scientists agree that a sustainable farming system must consider not only efficiency but also social and environmental justice to achieve maximum results.

Moreover, the research revealed that the analysed European (The Netherlands, Finland, Poland) and non-European (The United States, New Zealand, China) countries pay a lot of attention to the implementation of sustainability following legislation, country strategies while realizing that sustainable long-term solutions on farms ensure farm stability and farm growth, innovative solutions not only climate change but integrated solutions farm management as well.

Limitations of project research - there is no unified methodology for measuring sustainability. Sustainability measurements can be of various complexity and detail, measuring the sustainability of the dairy sector at the EU level, at the Lithuanian level. In the case of this study, the sustainability methodology is designed to measure sustainability at the farm level and is most applied in the conditions of Lithuanian farms. The sustainability methodology can be applied to the monitoring of farm sustainability by implementing certain support schemes, but the methodology is not the basis for modelling the support schemes. The developed methodology for measuring and evaluating sustainability can be integrated into support schemes, which could help to achieve the sustainable development of dairy farms. The methodology can also be used for sustainability monitoring.

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