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DOI: 10.15199/180.2022.1.1

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AUTOMATION OF DAIRY COW FEEDING AS THE METHOD FOR REDUCTION OF GREENHOUSE GAS EMISSION, ORIGINATING IN ANIMAL PRODUCTION

AUTOMATYZACJA ŻYWIENIA KRÓW MLECZNYCH JAKO SPOSÓB REDUKCJI EMISJI GAZÓW CIEPLARNIANYCH POCHODZĄCYCH Z PRODUKCJI ZWIERZĘCEJ

***Summary**: The increasing number of the population and the related intensification of animal-origin food production are indicated as the source of climatic changes. The present paper contains the information concerning the impact of animal production on anthropogenic emission of greenhouse gases (GHG). A special attention was paid to the problems connected with milk production. The selected methods for mitigation of GHG emission, derived from dairy farms, were presented. The recent part of the paper was dedicated to the comparison of energy consumption in automatic (AFS) and conventional (CFS) feeding systems and the potential profits, resulting from the application of automatic feeding systems.*

***Keywords**: automatic feeding, cow, greenhouse gas, animal production, milk*

***Streszczenie**: Rosnąca liczba ludności i związana z tym intensyfikacja produkcji żywności pochodzenia zwierzęcego wskazywane są jako źródło zmian klimatycznych. W niniejsze pracy zawarto informacje dotyczące wpływu produkcji zwierzęcej na antropogeniczną emisję gazów cieplarnianych (GHG). Szczególną uwagę poświecono kwestiom związanym z produkcją mleka. Przedstawiono także wybrane metody łagodzenia emisji GHG pochodzącej z gospodarstw mlecznych. Ostatnią część pracy poświęcono porównaniu energochłonności automatycznych (AFS) i konwencjonalnych (CFS) systemów żywienia oraz potencjalnym korzyściom wynikającym z użytkowania automatycznych systemów żywienia.*

***Słowa kluczowe**: automatyczne żywienie, krowa, gazy cieplarniane, produkcja zwierzęca, mleko*

Introduction

Animal-origin food products constitute a significant source of energy and protein in human diet. They deliver micro-elements, including many essential vitamins and mineral compounds [2]. At present, all over the world, about 56 billion of terrestrial animals are managed and slaughtered for consumption purposes; according to the forecasts up to 2050, their number will be doubled [22]. The increase of demand on food products results directly from the increase of population in our Globe. It is estimated that in 2050, the human population will reach 9.5–9.8 billion persons, and in 2100 – even 11.2 billion inhabitants. It raises concerns that one of the main problems which the humanity will be faced with, will be ensuring of food safety [2, 13].

Production of any kind of food, irrespectively of the manufacturing system, has a certain impact on natural environment. It is foreseen that in the coming years, the number of animals kept for meat, eggs as well as for milk production will cause the increase of the emission of GHG [22]. Nevertheless, the system of the sustainable agriculture becomes the subject of greater and greater interest among the producers and consumers. To be called sustainable, the agricultural products must ensure the combination of the appropriate feeding value of the supplied goods (safe and nutritious) and minimization of its social and economic impact (easily available and approvable in respect of price) and environmental effect [2]. The increasing interest in the products produced in environment-friendly way among the consumers is one of the driving forces of the changes in breeding. Due to its influence, the general purposes of breeding were de-oriented from maximization of production towards production, focused on effectiveness and considering the restrictions of natural environment [4].

The changes which occurred in the earlier mentioned context are perfectly illustrated in the area of milk production. As early as at the beginning of the 20th century, the mean daily milk production in the United States did not exceed 5 kg of milk from one cow and the mean dairy herd included no more than 5 dairy cows. On the contrary, in the first ten years of the 21st century, the average American cow produced ca. 30 kg of milk/day and 60% of the total production was implemented in the herds consisting of more than 500 animals [2]. During the recent 60 years, the milking performance of cow was by 4 times increased and is still increasing at the rate of ca. 130 kg annually [25].

The mentioned progress was possible owing to understanding of dairy cow biology and utilization of the obtained knowledge with the aim to develop the new technologies, e.g. insemination, improvement of genetic value, feeding and methods of management. The breeding work allowed the increase of production potential whereas the introduction of new technologies and management methods enabled its implementation [2, 25]. A final result of the discussed changes was reflected in the increase of “production effectiveness”, expressed by the rise of milk production with the simultaneous reduction of consumption of the indispensable resources and lower amount of waste, derived from animal production. It has a key meaning in relation to lowering of demand on non-renewable and high-energetic resources (soil, water, fossils and fertilizers); at the same time, it supports the appropriate management of the environment. FAO experts estimate that in the future, due to the limited resources, it will be necessary to produce as much as 70% of the additional food with the participation of developed and highly effective technologies [2].

GHG emission from animal production

A significant part of the global emission of greenhouse gases (GHG) is connected with the eruption of volcanoes, forest fires, and sea and ocean storms, i.e. a natural one [21]. Nevertheless, agricultural production which accounts for 14–51% of participation in the total anthropogenic emission of GHG is indicated as an important factor, affecting the observed climatic changes [17, 26, 34]. We should also pay attention that the level of the discussed emission is not the same all over the world, e.g. the estimated participation of agriculture in total GHG emission in Poland is equal to 7.7%, including 29.8% of the total methane production and 78% of the national production of nitrogen oxides [34].

Total animal production constitutes 5–10% of all forms of agricultural activities [3, 26, 31]. The greatest part i.e. 44–59% of all GSG originating in animal breeding sector is generated by CH_4; CO_2 and N_2O are, respectively, characterized by 27-35% and 19.7-29% participation in the total emission. It is estimated that the supply chain, connected with the animal production, emits 9.2 GT of CO_2-equivalent to atmosphere; it constitutes 5% of anthropogenic emission of carbon dioxide [9, 26, 27]. According to other studies [22], the total animal production sector (connected directly and indirectly) may account even for 9% of the total CO_2 emission.

Cattle as emitter

Milk production and the related meat production account for 4% of the total anthropogenic emission, whereas the production of milk itself – 2.7 -2.9% [3, 26, 31]. We should also pay attention that the indicated values may be underestimated due to treating CO2 inhaled by the animals as biogenic [27] and not considered in the adopted assumptions [26, 35].

When speaking in general about animal production, we may state that the cattle, as being responsible for 65% of emissions (4.6 GT of CO_2-eq), is indicated as the most important emitter of greenhouse gases. Production of cow milk accounts for 20% and that one of beef for 45% of animal-origin emission. The remaining sectors of animal production such as production of milk and meat from small ruminants, production of milk and meat of buffaloes, production of pork and poultry meat and eggs generate 6-9% of GHG emission, each of them [26]. In the world scale, the ruminants produce about 80 million tonnes of CH_4 per year what constitutes 33% of anthropogenic production of the discussed compound [32] whereas according to different calculations, it may even amount to 35–40% [22].

The release of greater quantity of gases to atmosphere by ruminants as compared to monogastric animals is a result of their evolutionary adaptation of ruminants to utilization of structural hydrocarbons as a feeding source with the participation of cellulolytic and metanogenic microorganisms [21]. The processes occurring in rumen cause that 100g of digestible cellulose generate 10 litres of CO_2 and 3.5 l of CH_4. It means that one dairy cow is able to produce up to 650 litres of methane which is expelled by belching. The cow which has the annual milk yield at the level of 9 000 kg, produces 120–130 kg of CH_4 per year. Production of methane is connected with the energy loss amounting to 6.5% of gross energy supplied to the body but the mentioned losses may vary within the range of 2-12% [22, 32].

Carbon footprint of milk production

The consequence of the increase in production performance of cows during the recent 100 years is the increase in utilization of fuels in agricultural production [2]. Milk production, its collection and storage are connected with the consumption of energy, resulting from the need of supplying the electric energy to milking machines, water heaters, vacuum pumps, milk coolers and lighting. Most frequently, fossils are the source of the mentioned energy [9, 10]. The fossils are also used directly in cultivation of fodder plants, in transport of animals, utilization of manure, and in processing and transport of food [10].

The estimates concerning energy consumability in relation to milk, being carried out by evaluation of life cycle of the product (LCA, life cycle assessment) indicate that the greatest demand on energy, amounting to 40%, occurs at the stage of production. The simultaneous observations indicate that 25% of energy consumed directly for milking, milk refrigeration, and management of manure, ventilation and lighting in modern European dairy farms derives from non-renewable sources. 15% of energetic demand in the farms is covered by diesel oil (in Polish: ON). We should mention that the analyses indicated the mentioned oil combustion as the most important source of contamination, accounting for 72% of carbon emission whereas electric energy satisfied 27% of it [31].

The cited paper [31] indicates that the mean emission, resulting from diesel oil combustion, as expressed in CO_2-equivalent, amounted to 819 kg of CO_2-equivalent per lactating cow annually (125 kg of CO_2-equivalent per one tonne of FPCM) (fat and protein corrected milk). Apart from the emission resulting from fuel combustion, the farms participating in the studies emitted 201 kg of CO_2-equivalent per lactating cow (30 kg of CO_2-equivalent per one tonne of FPCM) as a result of electric energy consumption. The total mean annual emission from farm was equal to 56 tonnes of CO_2-equivalent per lactating cow. It is worthy to mention that a significant part, i.e. 31% of energetic carbon footprint is responsible for feed preparation and distribution. The efficient utilization of direct energy sources (diesel oil, petroleum, electricity, etc.) is, therefore, one of the solutions, serving the reduction of environmental load and manufacturing costs in the studied sector.

Iranian scientists [10] indicate that the greatest participation in GHG emission, generated in connection with combustion process, directly and indirectly in dairy farm, belongs to fossils (74%), electricity (18%) and equipment (8%). The annual emission in the analysed farms amounted to 561.2 kg of CO_2-equivalent per cow.

Production of one kg of FPCM milk in Lithuania requires consumption of 37–62 g of oil-equivalent of fossils; the farms which manage 51–100 cows are characterized by the highest demand. Intestinal fermentation and manure are the main source of GHG emission in the discussed conditions. They account for 61–68% of the total emission, generated for production of 1 kg of milk. In turn, production connected with manufacture of concentrates is a source of 9–15% of the emission.

The studies conducted in Italy [9] revealed that production of 1 kg of FPCM necessitates 5.97±1.32 MJ energy, coming from non-renewable energy sources. The main factors determining their energy consumption include manufacture and transport of concentrates outside the farm (38.9%), feed production at the farm (16%) and energy used in the farm (20.55) connected with milking and refrigeration of milk, manure management and feed preparation and distribution.

Todde et al [31] as being cited earlier, inform that the mean annual energy consumption in the analysed group of farms amounted to 13 675 kg of diesel oil and 26 245 kWh of electric energy. As calculated to lactating cow and 1 kg of milk (FPCM), it was equal to 260 kg and 40 kg, respectively. It was also higher than that one obtained in the earlier Italian studies [1] where it was found within the limits of 154–183 kg of diesel oil per lactating cow. The analysis of energy consumption showed also that milking process and milk cooling were the most requiring processes in this aspect; they accounted for 23% and 29% of annual energy consumption. Additionally, the newer studies [31] cited in the present paragraph, revealed that the total diesel oil consumption in connection with the operations at farm and in field resulted from feed preparation and distribution (39%), field work connected with the cultivation (38%), management with manure (16%) and irrigation (7%).

The results of the researches conducted in Luxembourg [15] indicate that production of 1 000 kg of ECM milk (energy corrected milk) necessitated, in average, 4.96 GJ of energy (3.2–9.86 GJ) and the mean emission was equal to 1.31 kg CO_2-equivalent ECM^{-1} (0.8–2.09 kg). The authors of the mentioned development emphasize the fact that the observed differences have a source in effectiveness of utilizing the production means and not the intensity of production itself. It means that carbon footprint may be reduced. It requires, however, improvements in such important categories as feed base, fuel and electric energy utilization and investment in buildings and machines.

The methods of emission reduction

"Agriculture makes the contribution to the changes of climate and is dependent on the mentioned changes" [26]. As the milk producers experience the discussed changes and are dependent on them, they get involved in adaptation of management practices which facilitate administration of environment and care of it at each stage of milk production. The undertaken activities are aimed, *inter alia*, at the reduction of GHG emission, especially of methane and, also, minimization of loss of nutrients owing to effective balancing of feed rates or optimization of soil fertilization. Although there is no one effective practical way of reducing the impact on the environment, the combination of few strategies and available technologies may undoubtedly help achieving the assumed targets [2].

The increase of animal productivity and improvement of feed efficiency are the methods for reduction of negative influence of milk production. The simulation conducted by Rotz [25] revealed that the increase in cow milk yield was accompanied by the effective utilization of the nutrients. The comparison of cows with production potential amounting to around 16 000 kg and 7 260 kg of milk (3.5% of fat and 3.1% of protein content) per year shows that in the case of more productive animals, feed conversion was by 50% more effective. The yield of the managed animals resulted in the level of carbon footprint as calculated per one unit of the milk produced; in the case of highly productive cows, it was by 26% lower. The indicated dependence results from the difference in the quantity of animals necessary for obtaining the same summary amount of milk.

In the case of the animals under the above comparison, the energy footprint, defined as the amount of energy coming from fossils, necessary for production of one unit of milk, was different, depending on the adopted assumptions, by 10–30%, in favour of the cows with a higher annual productivity. The discussed differences were caused by the mentioned earlier lower demand on feed, resulting from its better feed efficiency what, in turn, means lower demand on energy used for its production and further handling.

Quality of the feeds and feeding value of the supplied feed rates are the factor, having a measurable effect on the level of GHG emission. Irish researchers [27] proved that the high cow yield was accompanied by the increase of GHG emission, as calculated per one litre of milk. According to the mentioned reports, the scale of CH_4 release to the environment is dependent on the quality of feed and manure handling. On the other hand, N_2O is affected by amount of protein in feeding ration and losses at the state of field cultivation. At the same time, literature data [22, 23] indicate that ensuring of the appropriate feeding may be the effective method for reduction of intra-systemic production of CH_4, both in the case of dairy and beef cattle. In this case, the solution consists in feeding the animals with more digestible concentrates of high quality, or feeding rates with a greater quantity of cereal grains. The discussed approach may result in the reduction of methane emission by 2–15%.

The health state of the animals is also a key factor. Better health state of animals, the reduced mortality rate and morbidity and the improved longevity result in the increase of productivity what, in effect of the mentioned above mechanisms and effect of distribution, gives lower GHG emission per unit of the product (milk, meat, etc.) [4, 21, 22]. It is perfectly illustrated by the example of methane emission [21]. In the situation when the annual production of dairy farm is equal to 800 000 kg of milk and it is produced by 200 cows with annual production of 4 000 kg, the quantity of CH_4, emitted to the atmosphere amounts to ca. 18.7 tonnes. The same quantity of milk, produced by 100 cows with the annual milk production at the level of 8 000 kg cause the emission of methane equal to 12.3 tonnes.

The effective feeding of cattle requires the possession of many groups of animals at the age before production period as well as those in the lactation period. Such approach prevents the loss of nutrients, guarantees lack of over-feeding certain animals and underfeeding the other cows; it is the most effective approach. One of the methods of implementing the mentioned above assumptions include the application of robotized feeding which facilitate the supply of the nutrients in a precise way and meet the requirements of the cows [29]. The technologies of the precise feeding are constantly developed and the mentioned systems are available at present in the market. Each technology which is favourable for improvement of the health state, reduced morbidity or mortality rate makes its contribution to the reduction of CH_4 and N_2O production. The precise feeding is a key to the improvement of production effectiveness, good health state of animals and reduction of animal-origin emissions [7].

The above given facts are reflected in the results of the studies [3, 11], indicating that more frequent feeding may have a positive effect on digestive processes owing to more stable conditions in rumen and higher total digestibility in the alimentary tract. Consumption of smaller meals with a higher frequency, based upon the constant model during a day, stabilises the conditions present in the rumen, reduces the frequency of incidence of sub-acute rumen acidosis (SARA) and is favourable for improvement of milk fat production.

The application of the targeted feed additives is another instrument, supporting the reduction of CH_4 production in the alimentary tract of cows. We should remember, however, that feeding rates (components and nutritive value) still must satisfy the requirements of animals, with the consideration of reproduction cycle stages [20].

Impact of energy source

Reduction of energy consumption contributes to reduction of carbon footprint and, additionally, it may positively affect the profitability of milk production [28]. In this context, it is worthy to mention that the consumption of non-renewable energy sources not only decreases the resources limited in respect of the quantity of fossils [2, 10] but it is also a significant source of CO_2 emission [9] and makes a contribution to the increase of carbon footprint, being strongly negative for the environment [10].

The solution indicated as mitigating the harmful emission from agricultural farms may be found in the utilization of energy carriers such as compressed natural gas, biodiesel, ethanol, hydrogen or electric energy; the mentioned factors are identified as alternative energy sources for transport. Although we cannot say that electric vehicles are emission-free (emission zero), completely friendly to the environment, etc., but based upon the studies of car vehicles [23], we may consider the battery-driven vehicles as being more effective in this respect in comparison to hybrids and the traditional (conventional) vehicles. The results submitted in the present paper indicate that the total emission, as expressed in CO2-equivalent and estimated by LCA method for the particular types of driving systems was presented as follows: conventional vehicles – 62 866 kg of CO_2-equivalent, hybrids – 40 733 kg of CO_2-equivalent whereas those ones, driven by batteries – 31 821 kg of CO_2-equivalent.

The alternative to fossils may be perceived in utilization of solar radiation (photovoltaic panels) which may reduce the costs of production as well as a negative impact of farms on the environment. Therefore, the optimization of production is possible, inter alia, owing to the choice of equipment, adaptation of infrastructure and the method of farm management [28].

The choice of the equipment to be used in the farm and their adaptation to the existing conditions is an important element serving the reduction of contamination and improving the production effectiveness. It has been confirmed by the studies conducted in Poland [12], indicating that agricultural tractor and the cooperating machines should be selected exactly to the needs of a given farm. It is important because the agricultural tractors and other oil-driven vehicles generate gases responsible for more than 6% of NO_x emission of all transport means, used in Poland. Other contamination generated by the mentioned vehicles (N_2O, PM, SO_2 and Pb) constitute 2% of the total transport emission [20].

When we assume that CO_2 does not have a negative impact on the animal health and only contributes to the increase of greenhouse gas effect, we cannot say the same about other gases (HC, CO, No_x), emitted in farm buildings during feeding with the use of classical feed mixer. The mentioned gases constitute a real threat to animals and humans. High emission of exhausts of agricultural tractors as compared to other transport means may affect the health and, also, quality of beef and milk [12]. We should also pay attention to the reports [20] focused on technical condition of agricultural equipment, employed at Polish farms; it affects the level of fuel consumption. Although – owing to the EU subsidies – the discussed situation is constantly improving, many measures are still required in order to modernize and adapt more environment-friendly technologies.

Automation of cow feeding

The level of energy consumption is strictly related to the effectiveness of the considered production system, technological level, the management method and the size of the herd. The so-far conducted analyses inform that the energy consumption, as

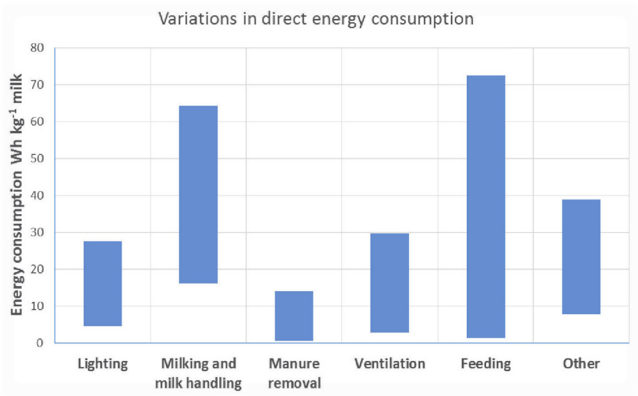

Fig 1. Direct energy consumption variation in milk production [24]

calculated into one lactating cow is equal to 800–1200 kWh in the USA and 401 kWh per lactating cow in Italy, 420 kWh in France and 90 kWh in Germany, respectively [31]. The estimates carried out by Bavarian State Research Centre for Agriculture indicate that electric energy consumption at dairy farm amounts to 640 kWh·year^{1} as calculated per one cow whereas in the farms dealing with fattening of animals is lower and in the case of intensive fattening system, it is equal to 150 kWh·year^{1} per one head of fattened cattle [18].

In the case of milk production, energy consumption may be classified into two categories, i.e. direct and indirect. The direct energy is intended directly for production in a form of electricity, gas or diesel oil. The indirect energy used, *inter alia*, in the manufacture of feeds, is mainly used in field work. The direct energy consumption for milk production is variable and is dependent on such factors as machines, production system, and the way of performing the work and the state of equipment management. The greatest direct energy consumers include lighting, milking and milk refrigeration, ventilation and feeding (Fig. 1) [24]. Feeding with 20–50% of energy consumption is indicated as the second most energy-consuming process at farm, immediately after milking [18, 31]. The energy consumption intended for feeding may be classified further according to the method of its utilization in 4 basic operations: transport from the warehouse, treatment of feed material (milling, disintegration), mixing and distribution [24].

At present, there are more than 20 producers of automatic feeding systems, i.e. the so-called feeding robots all over the world [30]. The systems of automatic feeding (AFS) may be differentiated according to the following classification: automatic distribution, semi-automatic and automatic feeding (Fig. 2) [18].

Until now, some analyses aiming at the definition of the method of functioning and energy consumption of automatic cattle feeding systems have been carried out. The obtained results may become the initial point of further considerations on justification or non-popularizing of the discussed solutions.

A study conducted at Bavarian farms [18] showed that the daily consumption of electric energy at AFS system varied between 8.8 kWh (semi-automatic system, Mixfeeder GEA/Mulerup) and 52.6 kWh (automatic system, Pellon). At the same time, it was revealed that the highest (77%) energy consumption was recorded in the case of process of transporting the raw materials from the storage site to the mixing unit and the mixing itself. Finally, the discussed analysis showed also that the costs of feeding the dairy cows with the employment of AFS (21.36–83.52 kWh ·LU-1 · year^{1}) are lower as compared to the standard system composed of tractor and feeding wagon (4–6 moto hours · LU-1 · year^{1}); 10 l ON · moto hours^{-1}). The authors of the present study notice also the possibility of employing solar energy as a power source

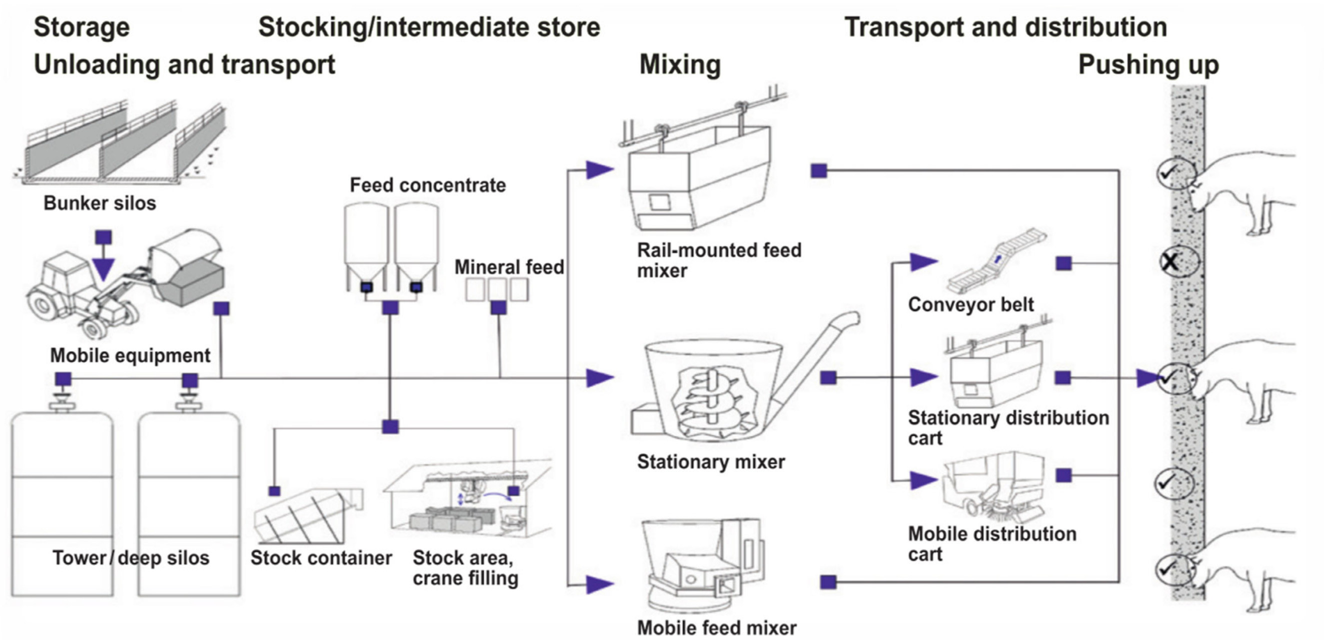

Fig 2. Techniques for realising various levels of automation in feeding (Haidn et al., 2014) [18]

Table 1. Daily consumption of energy and/or diesel oil and annual production of GHG depending on the cows' feeding method; the commercial brochure [14]

	Process	Daily electric energy (kWh) and/or diesel oil (l) consumption	CO_2 equivalent (ton · year-1)
Lely Vector (2 Mixing-Feeding Robots)	Filling the feed kitchen (every 2 days)	8,25 l	7,98
	Feed kitchen and Mixing-Feeding Robot (mixing and feeding)	37,50 kWh	7,35
Tailored Mixing Wagon (18m³)	Feeding (3 times per day)	45,00 l	43,52
	Feed pushing (6 times per day)	5,50 l	5,32
Self-propelled mixing wagon (20m³)	Feeding (3 times a day)	50,00 l	48,35
	Feed pushing (6 times per day)	5,50 l	5,32

** Comparison for 300 LU; Conversion to CO2 equivalent according to the guidelines of the German Federal Agency for Agriculture and Food; based on „Untersuchungen zum Elektroenergieverbrauch eines automatischen Fütterungssystems" Bühler J. (2017)*

for AFS system what lowers additionally the costs and is, simultaneously, the environment-friendly process.

The Italian studies [9] revealed that feeding of cows, using AFS (DeLaval Optimat Master) was less energy consuming than in the case of the conventional system composed of feeding wagon and tractor. In the herd consisting of 90 dairy cows with the mean milk yield amounting to 8 435 kg · year^{-1}, which received 10 m^3 TMR (total mean ration) per day, AFS system used 68.05 kWh · day^{-1} (including 2kg ON) whereas the conventional system (CFS, feeding wagon with capacity of 10 m^3 with a single vertical auger and tractor with power of 80 kW) used 246.64 kWh · day^{-1} what corresponded to 18.77 kg of diesel oil. Tangorra and Calcante [30] analysed utilization of energy (mixing and distribution of feed) at the Italian farm where AFS (Lely) replaced a classical set composed of feeding wagon (2 vertical augers, 30 m^3) being permanently combined with the agricultural tractor (110 kW). The compared equipment supplied feed to ca 490 cows per day (lactating and dry cows), delivering 19 000 kg TMR. The results of the discussed study revealed the mean energy consumption at the level of 40.2 ±2.3 kWh · day^{-1} what corresponded to 2.11 ±0.07· kWh·tonne-1 TMR in the case of automatic feeding system and daily energy demand equal to 1 387.62 kWh (assuming 11.86 kWh·kg^{-1} ON) in the case of CFS. In the discussed study, utilization of telescope charger was not considered due to the daytime of using the equipment which was the same in the both systems. In the opinion of the authors of the present paper, the further profits from the application of AFS system include the possibility of utilizing the renewable energy sources which allow, additionally, lowering the operating costs.

The illustrative comparison of the effect (emission of CO_2-equivalent) of automatic and conventional feeding system on the environment, as derived from the promotional materials of one of the producers of AFS system is given in Tab. 1 [14].

The Czech study [33] showed that the automatic cow feeding (Lely Vector) allows saving the feed. The conducted experiment revealed that the cows fed under the AFS system received feed in the quantity of 43.2 kg · cow^{-1} and in the conventional system (feeding cart Cernin 13 m^3 and tractor with power of 64 kWh) – 46.6 kg · cow^{-1}. In spite of the fact that the amount of the feed, supplied by the automatic system was lower, its real intake was increased because in the case of Lely Vector equipment, the losses in feed were equal to ca. 5% whereas in the case of CFS, they exceeded 10%. Besides it, the quantity of milk, produced by the cows at total lower amount of the supplied feed remained unchanged or was higher. The discussed statements are consistent with the Finnish reports [16] indicating that more frequent feed supply (5 times vs. once) during a day (24 h) was more favourable for better utilization of energy and protein. The discussed study revealed that more frequently fed cows consumed 1 kg DM less (20.9 vs. 19.9 kg a day) without any significant effect on their milk performance.

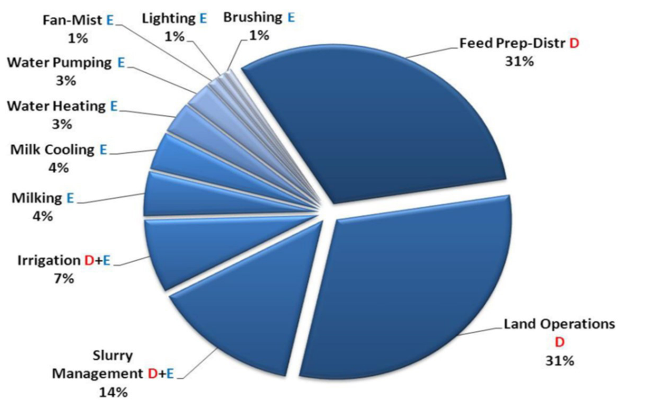

Fig 3. Distribution of GHG emissions from electricity (E) and diesel (D) to on-farm operations [31]

Apart from the lower energy consumption and lower operating costs of the automatic systems, we should also pay attention to the profits, resulting from the increase of the frequency of feeding. The increase of their number e.g. from 1 to 4 may affect positively the animal welfare by, *inter alia*, lowering of the competition at feeding table. Besides it, the authors of the available respective papers emphasize the possibility of utilizing such energy sources as biogas or photovoltaic panels for operation of automatic feeding systems [8, 19].

Summing up

Low-carbon agriculture is characterized by a low energy consumption, low emissivity and high effectiveness [24]. Reaching the mentioned targets, with the simultaneous mitigation of negative impacts of milk production on the environment is possible. We should however remember that the lactating cows and heifers are the main sources of greenhouse gas emission at the dairy farms (intrasystemic fermentation, manure). The remaining factors such as electricity, soil fertilization, transport and application of manure have a smaller meaning [6]. Due the mentioned reasons, the breeders should focus their attention on practices, connected with the herd management; the undertaken activities should consider ensuring more efficient feeding and constant improvement of genetic animal breeding in order to obtain the animals characterized by better feed conversion for milk production. The healthy animals, revealing a high resistance to diseases, are the key factors of the milk performance of the whole herd. We should also bear in mind the practices, serving the improvement of the key reproduction indicators such as calving percentage rate or the age of the first calving [6, 26, 35]. The undertaken measures should also consider the modification of manufacturing processes, oriented to those ones, characterized by a lower energy demand, lower quantity of the wasted products, and introduction of the environment–friendly and more effective practices in animal husbandry [26, 35]. The Lithuanian researches [5] indicate the extension of the knowledge on animal feeding among the breeders as the important solution; they also pay attention to the application of automatic feeding systems, connected with the milking robots which allow increasing the possibilities of controlling the nutritive value of the supplied concentrates at the level of the particular cows.

When bearing in mind information on lower energy consumption in the case of automatic feeding systems, operated by electric energy and ensuring better feed utilization, it seems that AFS may contribute to lowering of carbon footprint, generated by the dairy farms. At the same time, the determination of the real scale of their effect, taking into consideration a lot of relations and indirect effects of the employed feeding practices (health state, productivity of animals, fertility, welfare, demand on home produced feeds, etc.) is not easy to be estimated and requires further attempts aiming at its determination.

The other problems, connected with automation of animal feeding include the economic aspects. It is commonly known that the automatic feeding systems are superior in respect of the costs in comparison to the conventional systems at the stage of investments. On the other hand, it is worthy to examine the long-term, financial consequences of employing the discussed type of instruments, with the consideration of the profits and direct and indirect costs as well as the mentioned relationships in the context of the natural environment protection.

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Article reviewed

Received: 14.12.2021 r./Accepted: 20.01.2022 r.