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Trends in milk yield productivity and emissions from the dairy sector in Latvia

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Abstract. Dairy cow productivity continuously increased in Latvia in recent years. Despite decreasing numbers of dairy cow population dairy farms have been identified as an important source of greenhouse gas (GHG) emissions. Dairy sector emissions create the largest share of enteric fermentation emissions as well as emissions from manure in housing facilities, during long-term storage and field application within agriculture sector total emissions. The main objective of this study is to present the results of trend analysis in the productivity of the dairy sector and corresponding emission in Latvia. Research is focused on analysis of dairy cow productivity and feeding strategies to quantify the effect of increasing milk yield on GHG emissions. In the framework of this research, emissions were calculated and evaluated for low and high productivity dairy cows according to the methodology of '2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories'. During the last decade dairy cow productivity in Latvia has increased and the average milk yield in standard lactation was 8,320 kg per year in 2021. It was observed that 60% of the total number of dairy cows met the requirements of a high-productivity system, while 40% of the dairy cows belonged to low-productivity systems in Latvia. Research results show that total GHG emissions for high-productivity system can reach 5.3 kt CO_2 eq. per 1,000 cows per year, however, for low-productivity system the total amount of emissions does not exceed 3.1 kt CO_2 eq. per 1,000 cows.

Key words: climate, dairy, emissions, greenhouse gas, productivity.

INTRODUCTION

The rapid increase of anthropogenic greenhouse gasses (GHG) contributes to climate change. The best-case scenario of climate change impact can be only achieved with the decrease of emitted global GHG. Dairy farming is a significant part of agriculture. However, livestock production is estimated to be one of the most important anthropogenic GHG emissions contributor, and dairy production is being responsible for about 30% of livestock emissions (FAO, 2017). With the aim to hold commitments to achieve a reduction of GHG it is vital to improve national emissions inventories. It is also important to control the effectiveness of the introduced emission reduction measures and to monitor emission trends due time.

There is decreasing dynamic in the number of dairy cows in Latvia but the milk yield per cow has increased in the past years. The same trend is observed also in Lithuania and Estonia. The decrease in dairy cattle numbers is slower in Latvia among Baltic States with the lowest increase in average milk yield per cow (Rizojeva-Silava et al., 2021). There is change also in herd sizes. Since 2000 on average herd size in Baltic countries has increased by 3 to 4 times but in Estonia increase is higher reaching 8 times. In Estonia share of farms with 5 cows is only 2% compared to other Baltic countries the share is 10 to 18% (Leola et al., 2021). This change in dairy cow farming is toward dairy sector to intensification. However, dairy intensification and concentration in large herds is recognized with many negative impacts to nature, including increased GHG emissions (Clay et al., 2020).

The inventory of agricultural GHG emissions reports emissions from dairy cows arising as methane (CH_4) from enteric fermentation and manure (stored, spread or via grazing) as well as nitrous oxide (N_2O) from stored manure. These emissions are strongly dependent on both livestock feeding and manure management system. The review of studies on dairy production in Europe shows that intensification of dairy sector often results in decreasing of GHG emissions, but emissions decrease per unit of milk production (Gerber et al., 2011; Gerssen-Gondelach et al., 2017). However, on a per cow basis, as animal productivity increases, GHG emissions increase with higher yields.

Accounting of GHG is now based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) which uses average cow productivity to determine emissions from the dairy sector. According to Latvia's National Inventory Report 1990–2022 (UNCC, 2023) dairy sector was responsible for 28% of total agriculture sector GHG emissions in 2021. The new methodology of 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) suggests to split calculations of GHG for low-yielding and high-yielding dairy cows. IPCC methodology updates will change the outcome of GHG emmisions estimation in more accurate and precise way, but deeper analysis of how new calculation approach will affect total GHG emissions in Latvian dairy sector must be done.

The aim of the study is to analyse the milk productivity of low-yielding and high-yielding dairy cows, evaluate the feeding of these groups and estimate GHG emissions changes after dairy cows' categorization according to IPCC guidelines 2019 Refinement.

MATERIALS AND METHODS

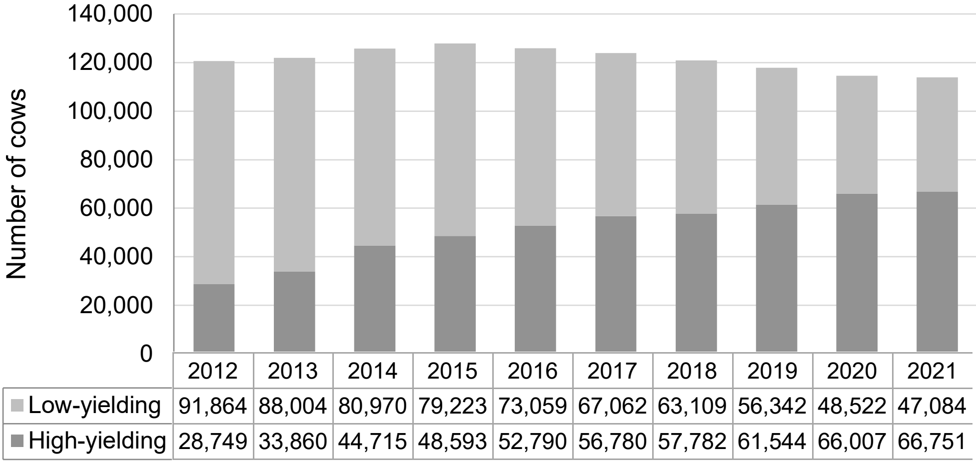
Every year Latvian Agricultural Data Centre (LDC) published cows' productivity data by breed and by the herd. For the study purposes, from the LDC web page data was collected about cows' milk productivity, which were lactated from 2012 until 2021 in the Latvian herds. The productivity of 11 breed groups is published by LDC. It could be defined three groups of breeds:

- Red breeds: LB – Latvian Brown, AN – Angler, DS – Danish Red, ZS – Swedish Red and White;

- Holsteins: HM – Holstein Black and White, HS – Holstein Red and White; Holsteins (X) - Holsteins in two generations;
- Other breeds: LZ – Latvian Blue, ŠV – Brown Swiss, SI – Simmental, XP – Cross Breed Dairy.

Dairy cows herds are defined into two productive groups: 1st group - highly productive commercialised dairy sector with average milk production above 7,140 kg head^{-1} yr^{-1} and 2nd group - low productivity systems are based on low-yielding dairy cows with average milk production below 7,140 kg head^{-1} yr^{-1}. Cows' milk productivity for each productivity group was calculated as a weighted average, that takes into account the number of cows in the herd and herd productivity.

The number of cows in the 1st and 2nd productive groups is presented in Fig. 1. The number of low-yielding dairy cows was decreased, and high yielding was increased during the presented time (Fig. 1). The ratio of high-yielding cows to low-yielding cows (calculated by dividing the number of high-yielding cows by low-yielding cows) was 0.31 in 2012 and 1.4 in 2021. At the same time, the total number of cows in Latvia increased from 2012 to 2018 and slowly decreased during the last three years.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
■ Low-yielding	91,864	88,004	80,970	79,223	73,059	67,062	63,109	56,342	48,522	47,084
■ High-yielding	28,749	33,860	44,715	48,593	52,790	56,780	57,782	61,544	66,007	66,751

Figure 1. The total number of high-yielding and low-yielding dairy cows.

Monitoring of cow feeding was carried out by determining feed rations in herds of high and low-productive groups of cows. The opinion of 24 animal feeding specialists of the Latvian Rural Consultation and Education Center (LLKC) were surveyed in all regions of Latvia. In order to analyse the chemical indicators of feed, feed samples were taken from all regions of Latvia. The feed samples for which were determined the chemical composition were hay, haylage, silage, total mixed feed (TMR), and concentrate. A total of 53 dairy farms feed samples were analysed. The following chemical analyses were determined: dry matter, crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), and digestibility of dry matter. The calculation of dry matter intake (DMI) was done according to Eq. (1) (McDonald et al., 2002).

$$DMI = 1.2 \cdot \frac{100}{NDF} \quad (1)$$

where *NDF* – neutral detergent fiber.

The feed chemical analyses were done by several methods: dry matter content was determined by ISO 6496: 1999; crude protein content was determined as total nitrogen content by the Kjeldahl method using coefficient 6.25 for calculation (ISO 5983-2:2009); ADF was determined using ISO 13906:2008, NDF was determined using ISO 16472:2006 methods, digestibility was determined using cellulose method. The chemical content of feed samples were determined in the Scientific laboratory of Agronomic analysis of Latvia.

GHG emissions calculation was done according to IPCC 2006 Guidelines and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) by Tier 2 methodology. The global warming potential (GWP) index 25 and 298 was ussed for CH_4 and N_2O, respectively.

RESULTS AND DISCUSSION

During the last decade, the cows' milk productivity in Latvia is increased and according to the LDC in 2021 the average milk productivity in standard lactation was 8,320 kg of milk yield, 4.02% of fat, and 3.36% of protein (Agricultural data centre, 2023). In 2020 in the EU countries the milk yield per cow was 7,509 kg on average with highest milk yield per cow (more than 10,000 kg per cow) in Estonia and Denmark (Eurostat, 2021).

Trends in milk productivity of high and low-yielding cows

After dairy cows' categorization high yield dairy cows' milk yield was in the range of 8,653 kg to 9,937 kg and low-yielding from 5,815 kg to 6,026 kg, and for both groups milk yield was increased (Fig. 2). Milk yield differences between productivity groups ranged between 2,838 kg in 2012 and 3,911 kg in 2021. Over the decade, an increase in milk yield is 14.8% and 2.4% for high and low-yielding cows, respectively. According to the FAO report 'Climate Change and the Global Dairy Cattle Sector' the average global milk yield per cow over a ten years period from 2005 to 2015 increased by 15% (FAO & GDP, 2018).

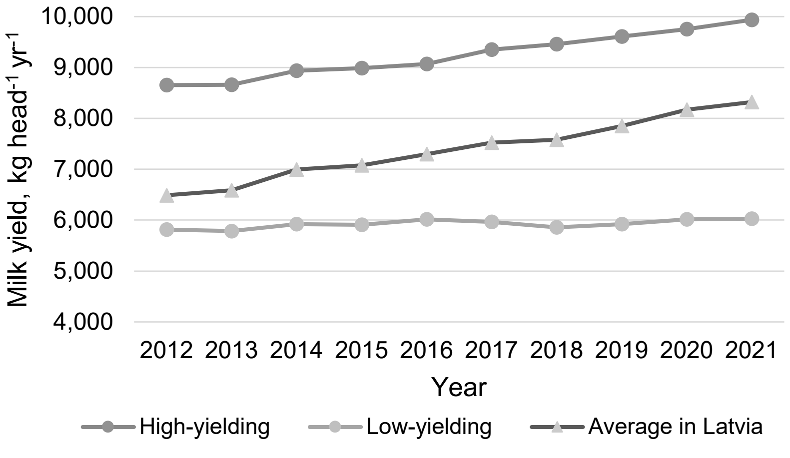


Figure 2. Average milk yield (kg lactation^{-1}) of dairy cows in Latvia and milk yield of high and low-yielding dairy cows.

As shown Slagboom et al. investigation (Slagboom et al., 2017) the farmers preferences for trait improvements for Danish red (DR) is reduce mastitis and improve milk production in the herds and it is resulted in high level in cow's milk productivity, where energy corrected milk yield is equal to 9,167 ± 160 kg. High-yielding cows' production levels in Latvia conditions are comparable to data in Slagboom et al. investigation (Slagboom et al., 2017).

Low-yielding cows' productivity in Latvia conditions are lower compare to the herds level of DR low-ranking cows with milk productivity for DR 7,809 kg ($n = 3,315$) and Danish Holstein (DH) 8460 kg of milk ($n = 34,434$) (Kargo et al., 2021).

By carrying out a large-scale study in the USA for the period from 2000 to 2020, it was concluded that the milk yield of dairy cows increased by 1.58% on average per year, reaching an average of over 10 t per cow, but the number of cows increased much more slowly, on average by 0.1% per year. It is noted that the increase in milk yield depends on the size of the herd; the smallest increase in the milk yield was obtained in herds of up to 200 dairy cows, an average of 0.59% (Njuki, 2022).

Thereby, fat content (Fig. 3) and protein content (Fig. 4) in cows' milk is more stable compared to the milk yield during the last decade. High-yielded dairy cows' fat content was in the range of 4.07% to 3.97% and low-yielding from 4.29% to 4.18% (Fig. 3), both traits are decreased during the analysed period, there is a tendency - a negative relationship that the fat content is related to the milk yield and decreased if milk yield increase. Fat content differences between productivity groups ranged between 0.22% in 2012 and 0.21% in 2021. Fat yield depends on milk productivity, thereby, the fat yield in the high-yielded dairy cows' group increased.

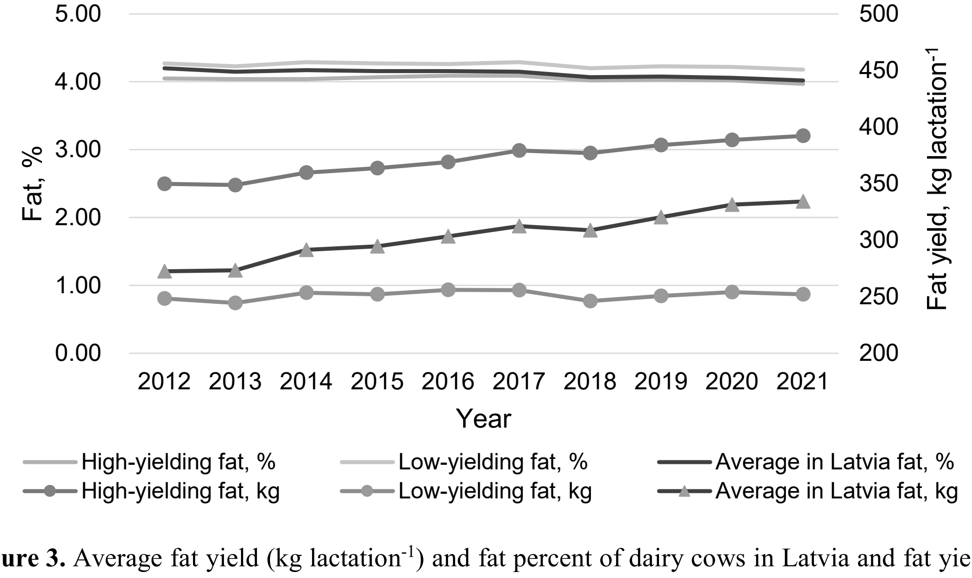


Figure 3. Average fat yield (kg lactation^{-1}) and fat percent of dairy cows in Latvia and fat yield and fat percent of high and low-yielding dairy cows.

The difference in protein content between high and low-yielding dairy cows was lower than 0.1% (Fig. 4). High-yielded dairy cows' protein content was in the range of 3.34% to 3.41% and low-yielding from 3.27% to 3.34%. Protein yield in the high yielded dairy cows' group increased and is higher compared to the low-yielding dairy cows' group.

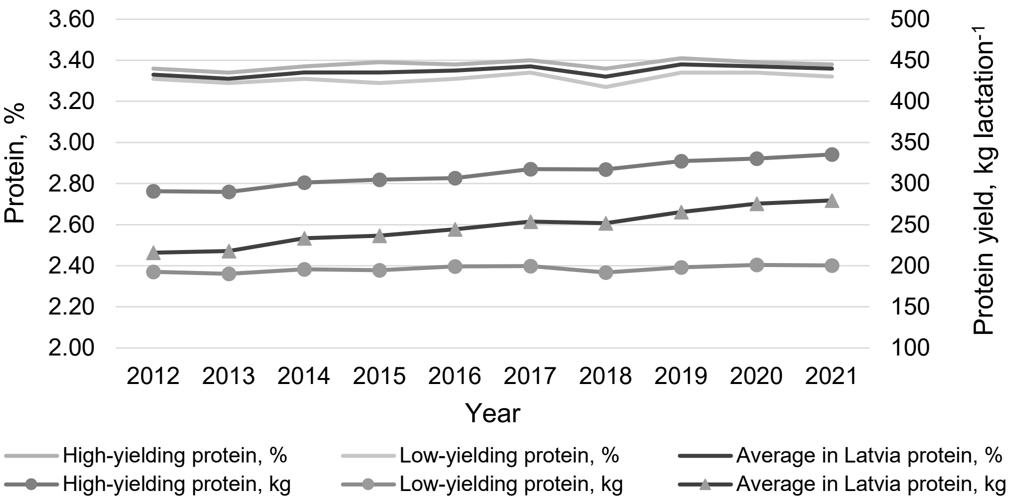


Figure 4. Average protein yield (kg lactation^{-1}) and protein percent of dairy cows in Latvia and protein yield and protein percent of high and low-yielding dairy cows.

Reduced fat and protein content in highly productive commercialised dairy sector has been linked to the selection cows for milk yield increasing, milk yield negatively correlated with the milk content traits (Strucken et al., 2012; Abdullahpour et al., 2013) and as shown our results difference in content traits are significant for high and low-yielding dairy cows. The correlations between fat and protein content is positive (Abdullahpour et al., 2013) thereby cows from the low productivity systems are characterised with higher level of fat and protein.

The cows' productivity increase can be explained through genetic selection and animal feeding improvement.

Productivity growth reasons

Cows' milk productivity improvement first of all is related to changes in cows' breed structure, then to cows' feeding strategy. For example, the proportion of Red and Holstein breeds' cows in 2012 was quite similar, however, nowadays the situation is changed and the proportion of Holsteins in Latvia is increased (Table 1). The obtained dynamics of changes in the number of cows by breed also correspond to the experience of other countries, for example, in the USA, since 2000, the proportion of purebred Holstein cows has decreased, but the proportion of crossbreeds cows has increased, which is resulted in the increase of the protein and fat content in the cows' milk (Njuki, 2022).

The highest milk yield during the analysed period was obtained from Holstein (7,042 kg in 2012 and 10,199 kg in 2021), than from Holstein breeds (X), other and Red breeds. Fat and protein content were least for Holstein breeds cows, than that of Red breeds. Cielava et al. (2017) analysed the lifetime productivity of Holstein Black and White (HM) and Latvian Brown (LB) cows and concluded that HM cows had higher milk productivity compared to the LB cows, which is also linked to the housing conditions. However, LB cows' milk contains a higher fat content than HM cows' milk (Paura et al., 2012).

Table 1. The number of lactation and average productivity of different breeds in standard lactation during the last decade

Group Year	No. of lactation	No. of lactation, %	Milk yield, kg lactation^{-1}	Fat, %	Protein, %
2012					
Red breeds	46,408	46.8	5,782	4.36	3.31
Holstein breeds	39,966	40.3	7,042	4.05	3.18
Other breeds	12,725	12.8	5,801	4.22	3.25
2015					
Red breeds	38,320	37.6	6,351	4.35	3.34
Holstein breeds	10,229	10.0	9,009	3.88	3.35
Holstein breeds (X)	42,083	41.3	7,396	4.03	3.21
Other breeds	11,276	11.1	6,500	4.19	3.28
2018					
Red breeds	25,885	27.4	6,638	4.35	3.36
Holsteins	11,055	11.7	9,677	3.86	3.33
Holsteins (X)	45,448	48.1	7,972	4.03	3.25
Other breeds	12,182	12.9	6,900	4.16	3.32
2021					
Red breeds	16,476	18.7	6,996	4.28	3.37
Holsteins	13,164	14.9	10,199	3.82	3.33
Holsteins (X)	48,280	54.7	8,578	4.00	3.29
Other breeds	10,271	11.6	7,104	4.17	3.34

Red breeds: LB – Latvian Brown, AN – Angler, DS – Danish Red, ZS – Swedish Red and White; Holsteins in 7 generations: HM – Holstein Black and White, HS – Holstein Red and White; Holsteins (X) - Holsteins in two generations; Other breeds: LZ – Latvian Blue, ŠV – Brown Swiss, SI – Simmental, XP – Cross Breed Dairy.

Our climatic conditions are very suitable for the cultivation of grass feed. It is also one of the cheapest types of feed, so production must be aimed at the maximum inclusion of grass feed in the ration. Although it is not always possible for a farmer to produce all the necessary feed on the farm, the owners try to at least provide the cows with self-produced grass feed. In conditions of intensive farming systems, care must be taken with excessive consumption of protein. Often, a bigger problem than protein deficiency is insufficient energy content in the ration, especially on farms where mostly clover and alfalfa are grown, or where protein-rich concentrates are purchased. In literature, researchers recommended reducing the crude protein content in the dry matter of the cow diet to 15–16% for higher productivity cows (> 30 kg of milk per day) during early lactation, to 14–15% for lower productivity cows (< 30 kg of milk per day) during early lactation, while the crude protein content in the dry matter of the cow diet during mid- and late lactation should not exceed 12–14% (Bittman et al., 2014).

In practice, the level of crude protein in cow diets is often higher than actually needed, as diet specialists sometimes include 5–15% more crude protein in the diets than necessary. The main indicators of the chemical composition of feed, which affect the emissions from the digestive tract of ruminants, are neutral detergent fiber (NDF) and acid detergent fiber (ADF), as well as crude protein and feed digestibility. The chemical composition of the feed is influenced by many factors: soil, soil fertilizers, botanical composition of feed, climate and rainfall, harvesting time, preparation process, vegetation phase of plants, storage. The chemical composition and quality of feed vary from season to season. Feed samples taken from farms in the autumn season of 2021 testify to this.

For example, crude protein ranged widely from 55% in hay to 58% in haylage. The results were better for completely mixed feed (TMR), where the differences were 26%. The average chemical content of the feed in the 2021 year is shown in Table 2.

Table 2. Chemical analyses of feed in dry matter

Indices	Hay (*n* = 33)	Silage (*n* = 33)	Haylage (*n* = 33)	Concentrate (*n* = 33)	TMR (*n* = 20)
Dry matter, %	84.23	32.45	44.86	87.90	39.45
Crude protein, %	8.15	13.61	10.14	19.99	17.79
Neutral detergent fiber (NDF), %	60.00	46.64	55.05	37.52	34.19
Acid detergent fiber (ADF), %	39.09	31.18	36.29	11.85	21.27
NEL, MJ kg	5.49	6.12	5.71	7.66	6.91
Digestibility of dry matter, %	58.75	64.39	60.60	79.67	72.33
DMI, %	2.04	2.61	2.26	3.20	3.60

Monitoring of cow feeding of high and low-productive cow groups shown that cow groups with high milk yield are kept in barns all year round and fed with mixed feed (TMR), where different grass feed consists of 65 to 70% of dry matter and about 30 to 35% concentrates and these are herds with more than 200–300 cows. Similar results we found in research before. If in herds were more than 200 cows, a completely mixed feed ration (TMR) was used with a high proportion of good quality corn, legume, grass silage, various protein and other additives, then in the feed ration concentrates was 31% in the early and 20% in middle stages of lactation (Degola, et al., 2016). The rations of l ow-productivity cows also consist of different types of grass feed, but their quality is often lower (Table 3). It refers to the amount of feed intake and milk yield.

Table 3. High and low productive cow group estimation of feeding

Estimated indices	High	Low
Average body weight, kg	650	550
Feeding confined: (stall, grazing pasture)	stall	Stall and grazing in summertime
Milk production per lactation, kg	9,186	6,394
Milk production per day, kg	30	21
Milk fat, %	3.95	4.21
Milk protein, %	3.34	3.34
Digestibility of feed, %	72	65
Crude protein DM, %	17.3	14.1
NDF in DM, %	34.2	49.2
DMI, %	3.6	2.5
DMI, kg day^{-1}	23	18
Dietary Net energy concentration of diet, MJ kg DM	7	6.5

The studies of LBTU (Latvia University of Life sciences and Technologies) scientists before on the situation in Latvia show that the average milk yield in a herd and individual animals depends not only on the amount of feed consumed, the physiological and health status of the animals, but also on the size of the farm. In Latvia, the least productive animals are located on farms with 1–9 milking cows (yield 18.3 kg d^{-1}), as the number of cows on farms increases, the yield (on average up to 41.3 kg of milk per day) from a cow gradually increases. As the milk yield increases, the average amount of dry feed intake in the farms also increases from 16.7 kg (in farms with 1–9 cows) to 28.8 kg in farms with more than 200 cows (Degola et al., 2016). The same results were found in the research of Kreišmane in 2021. Depending on the size of the herd, different feeds are consumed on dairy farms and the amount of feed consumed varies a lot of. In dairy farms where there are 1–10 cows, hay is used as the main feed. In the summer period, the juicy feed is pasture grass, as well as one to two types of haylage or silage, additionally feeding a small amount of self-produced or purchased grain feed. In medium-sized (10–300 dairy cows) dairy farms, a small amount of corn silage is sometimes fed, and the daily ration on average consists of rough forage, mainly different types of haylage and silage, and a small amount of hay (especially for cows at the end of lactation and in the dry period), as well as by additionally eating grain feed and purchased protein feed, such as rapeseed (Kreišmane et al., 2021). In farms with more than 300 cows, feeding TMR (totally mixed ration) to cows of all groups is becoming more common. In these farms, a slightly higher amount of forage dry matter is expected, however, the nutrients in these rations also exceed feeding standards. This situation occurs when dairy cows are fed TMR, where a ration reserve of 10–15% is provided. In such herds, there are also the most productive cows, which require a balanced feed ration according to the physiological and health status of the specific animals (Degola et al., 2016).

Emissions from dairy cows

Using the currently suggested methodology for national GHG emissions inventories from IPCC 2006 guidelines, it is possible to calculate that the total GHG emissions from Latvian dairy sector in 2021 reached 583.1 kt CO_2 eq. Total GHG emissions from the dairy cattle have decreased by 5.6% over the past 10 years. However, the fact that the number of dairy cows decreased by 20.3% in the period 2012–2021 should also be considered. Similar to other countries, milk yield increased in Latvia during this time period. Which compared to 2012, increased by 40.2%. However, as the productivity of cows increased during the analysed time period, there is a tendency of emissions increase from one dairy cow as well. During the period 2012–2021, GHG emissions from a dairy cow in Latvia increased by 18.4%. Emissions increased not only by higher gross energy intake, but also by the liquid manure management system share increase, which is characteristic for intensive dairy farming. On average, emissions from a cow increased by 2% every year over the time period. Emission per 1 kilogram of milk decreased more slowly by 16% during 2012–2021, the average rate of decrease was below of 2% per year (Fig. 5).

Life cycle assessment of cow milk production impact on the environment in Latvia done by Brizga showed that farms with herd size 10 to 50 cows have the highest environmental impact witch decreased with an increase in herd size due to higher milk yields (Brizga et al., 2021). However, our research shows that these negative impacts vary widely due to how and what these animals are fed. Low input dairy farming shows lower total emission outcome. Based on the observed results due to research it could be concluded that milk yield significantly ($P < 0.05$) explain the variance of GHG emissions. Farms with high milk yields often are specialized farms with higher inputs for feed. Farms with high milk yields also produce more liquid manure witch rise the total emission from manure management. Dairy cow diets have a significant impact on enteric emissions, however it could be observed that also emissions from manure management tends to be higher for intensive systems. Increasing milk yield requires more improved herd management through combinations of feed supply and quality and manure management as it lead to increased total levels of GHG emissions. However, increasing milk yield per cow is promising strategy for reducing emissions per unit of milk.

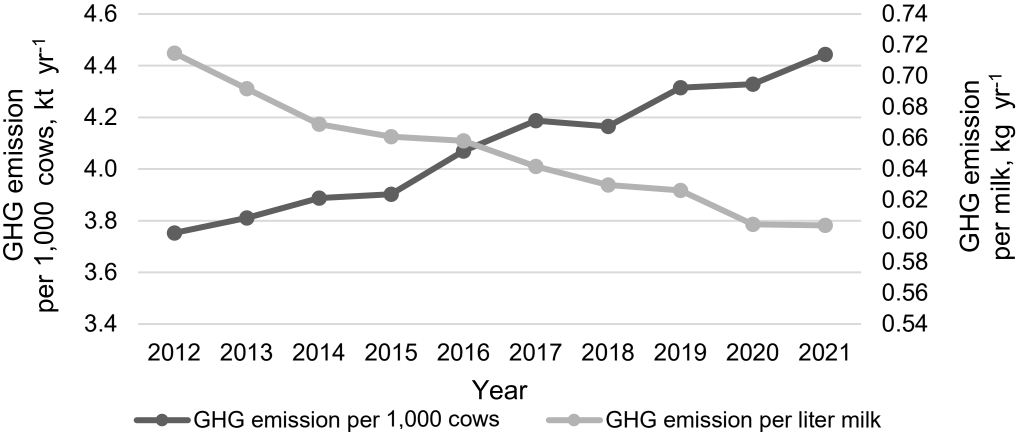


Figure 5. GHG emission per 1,000 cows and milk yield.

Although our research shows that absolute emissions in high-yielding herds will increase by using 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, where emissions should be calculated separately for high- yielding and lower-yielding cows. GHG emissions for high-yielding cows in Latvia reach 5.32 kt CO_2 eq per 1,000 cows, while in lower-yielding herds, GHG emissions do not exceed 3.81 kt per year. It should be noted that the proportion of liquid manure management increases and the proportion of pastures decreases in high-yielding production systems. However, emissions from enteric fermentation is lower in high-yielding herds, emissions from manure management are higher due to high proportion of slurry manure management use. Moving to the introduction of the 2019 Refinement in national inventory and planning measures to reduce GHG emissions, attention must be paid to this fact, because in 2021 the calculated emission according to the 2019 Refinement may increase to 629.9 kt CO_2 eq. year^{-1} (Fig. 6).

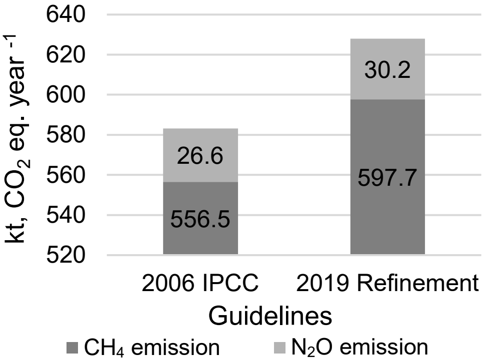


Figure 6. Calculated GHG emission from dairy cow herds in Latvia, 2021.

CONCLUSIONS

Increasing the productivity of dairy cows remain the important objective for many countries, including Latvia. The increase of average farm size and the decline of dairy cow's numbers are observed in latest years across the country that led to milk yield increase by 40.2% in 2021 compared to 2012.

The ratio of high-yielding cows to low-yielding cows was 0.31 in 2012 and 1.4 in 2021. Milk productivity improvement first of all is related to changes in cows' breed structure and then to cows' feeding strategy. The proportion of Red breeds decreasing, but Holstein breeds' cows increasing.

Reduction of GHG emissions from enteric fermentation of cows could be reached by determination of the chemical composition of the feed every year on each farm and preparation of accurate, balanced feed ration for dairy cows that is especially important for intensive farms with high-yielding dairy cows. However, high-yielding dairy cows will keep to produce higher emissions from manure management because of liquid manure management system that is essential for intensive farms.

Increasing milk yield per cow I general increase the total GHG emission outcome, however it could reduce GHG emissions measured per kg of milk yield. Results show that the intensity of decreasing of GHG emissions per kg of milk yield is lower than the intensity of increase of GHG emissions per cow regarding to increased milk yield. That shows importance to consider introduction of additional GHG emission measures in high-yielding dairy cow farms.

Total GHG emissions from dairy cattle increase by 8% when cows are divided into high and low-productive cow groups. In high productivity-systems total emissions from dairy cow can be by 28% higher comparing to low-productivity systems. Most important reason for that higher gross energy intake and utilization of slurry as manure management system.

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