Proceedings of the 15th International Symposium
Modern Trends in Livestock Production
October 29 –31, 2025, Belgrade, Serbia

VIEW AT SUSTAINABILITY IN DAIRY SECTOR: CURRENT STATE AND PERSPECTIVES

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https://doi.org/10.5937/AnimTrend25060S

Abstract: Milk and dairy products are nutritionally rich foods, providing energy and high-quality proteins along with a number of essential micronutrients. In this way, the dairy sector supports the existence of people in food chains around the world. Human activities affect the Earth's climate because they cause the release of huge amounts of greenhouse gases, which are retained in the Earth's atmosphere along with the gases that are naturally present in it. Food and drink are considered to be responsible for 20 to 30% of the impact on the environment, in which meat and dairy products are the most important. Research and methodologies are mostly focused on the emission of greenhouse gases (GHG), but numerous other impacts on the environment must also be taken into account, such as impacts on land and water through various types of pollution. In addition, the consumption of scarce water reserves and energy resources is also taken into account. Therefore, a sustainable approach to food and beverage production has no alternative. The dairy sector faces challenges to which it responds with numerous organized and synchronized actions and projects in order to successfully restructure and fit into the overall human activities to reduce pollution. Sustainability itself has 3 dimensions, ecological, economic and social. The aim of this paper is to present the current situation of sustainability in the dairy sector in the world and numerous activities undertaken by various actors in the dairy sector, from farm entities and dairy companies to various associations and umbrella organizations such as the International Dairy Federation, the European Dairy Association as well as non-specific dairy-strictly unrelated bodies. All activities are carried out in coordination and under the auspices of the United Nations and its organizations, primarily the Food and Agriculture Organization.

Key words: milk, dairy products, sustainability, pollution, gas emissions

Introduction

Milk and dairy products - a food that we are sure we know well. However, can we consider this to be true? This is a frequent question from consumers, but also from food experts (Rogelj, 1998). On the other hand, today we are witnessing fierce criticism and pressure on the production and processing of milk as a food sector that significantly contributes to environmental pollution and the production of greenhouse gases. Let's consider these two, seemingly different aspects, yet very related.

It is a proven and tested fact that milk is a food that provides the young organism with all the necessary ingredients in the right quantity, in the right proportion and in the right form that the body best absorbs (Sarić and Brenjo, 2022). It is also necessary for the normal functioning of the adult organism, so it is an important food during the entire life period and therefore occupies a special status among all types of food (Sarić, 2018). Milk and dairy products are a good source of high-quality protein, numerous micronutrients and natural bioactive components (Barać and Sarić, 2023).

Sustainability is a term that has a very broad meaning. The modern concept of sustainable development includes a balance between human activities and social, economic and environmental factors (Grujić and Andrejaš, 2013). The 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015, provides a common blueprint for peace and prosperity for people and the planet, now and in the future. The 17 goals of sustainable development are at the center (sustainable development goals - SDG) (UN, 2015). The European Green Deal is aimed at sustainable and inclusive growth in which there will be no net greenhouse gas emissions in 2050. It is the main strategic development document for the European Union (EU) in the period up to 2030 (Boromisa, 2020). The Green Plan is an integral part of the Commission's strategy for the implementation of the United Nations Program until 2030 and the goals of sustainable development (European Comission - EC, 2019). In 2020, the European Parliament debated about EGD (European Green Deal) and decided to support it, partly because of the circumstances at the time (Covid-19) to set 2050 as the target year for net carbon neutral EU (Fetting, 2020). Of course, the focus is on the entire food chain (from Farm to Fork) so European Comission (EC) adopted „Farm to Fork“ strategy (European Green Deal) which provides the main strategic directions for the development of food chains in order for Europe to become the "first climate-neutral continent" by 2050 (EC, 2020). In the EC report (2025) the progress of EU members in achieving national goals in the implementation of CAP strategic plans (2023-2027) for the period 2023-2024 is stated. Scientists of the Intergovernmental Panel on Climate Changes (IPCC) have warned that global warming of 1.5 °C (predicted in the period 2030-2052) will have serious and even irreversible consequences on our environment and societies (IPCC, 2018). According to Crippa et al. (2023) total GHG emissions in 2022 reached 53.8 Gt CO_2-eq, and the share of the food production sector is about ¼ of total GHG emissions. It was found that food and drink, including tobacco and narcotics, are responsible for 20-30% of the environmental effects of total consumption, and in the case of eutrophication, even over 50%. Meat and meat products contribute the most to this. The estimated contribution of these products to global warming is in the range of 4 to 12% for all products. This includes the entire production and distribution chain „from farm to fork“. The second most important product group is dairy products, while other food products have a lesser effect (EC, 2006). Globally, animal protein production is associated with a total of 6.2 Gt CO_2-eq emissions, which accounts for approximately 12% of the estimated 50 to 52 Gt CO_2-eq total anthropogenic emissions in 2015 (FAO, 2022a). According to IPCC report (2022) the sector of agriculture, forestry and other land uses (AFOLU) in the period 2010-2019 carried 13-21% of the total anthropogenic GHG emissions. At the same time, food systems account for 23-42% of global GHG emissions. In the same report, a diet rich in vegetable proteins and poorer in meat and dairy is recommended. The highest GHG intensity is shown by ruminant meat. Cattle from dairy systems have a lower intensity of emissions than those from meat farming (8-23 and 17-94 kg CO_2-eq/100g of protein resp.).

Current State in Dairy Sector

Dairy Sector is verry huge and probably the most comprehensive among all food chain systems. World milk production is forecast to grow by 1.5% to just under 981 million tonnes in 2024 (estimation for 2024, FAO, 2024a). Growth is expected to be driven by significant volume increases in Asia, with increases in Europe, South America, Oceania, Central America and the Caribbean. For the period 2024-2033, global milk production is projected to grow at a rate of 1.6% per year over the next decade, supported by higher yields per animal than most other major agricultural commodities. Global per capita consumption of fresh dairy products is expected to grow by 1.0% per year over the next decade, primarily driven by higher per capita income growth (OECD/FAO, 2024). On average, the calculated per capita consumption of dairy products increased by 1.36% in 2023, i.e. from 117.5 kg in 2022 to 119.1 kg in milk equivalent (Van Herdeeǹ, 2024; OECD/FAO, 2024).

The dairy sector is quite well institutionally organized at the world and regional level, including the aspect of sustainability. In its studies and activities, the FAO (Food and Agriculture Organization) has activities through many projects in the sustainable dairy sector and through its reports with data from the entire food chain in the dairy sector with recommendations to governments and institutions with an important emphasis on sustainability (2010, 2022a, 2023, 2024a,b) as well as in cooperation with the OECD (Organization for Economic Co-operation and Development - forum and knowledge hub for data) (OECD/FAO, 2024). IFCN (International Fast-Checking Network) is a politically neutral, global dairy industry supply chain research and advisory network focusing on milk production, milk prices and other dairy topics (IFCN, 2024).

The International Dairy Federation (IDF), founded in 1903, is the leading source of scientific and technical expertise for all stakeholders in the dairy chain. With more than 1,200 highly qualified dairy experts in 39 member countries worldwide, IDF represents 74% of global milk production (https://fil-idf.org/about-us/). The EDA (European Dairy Association) publishes data on the EU dairy sector in its 2023-2024 report under the slogan "The future is in dairy – milk and dairy products are nutritional treasures, economic powerhouses and true leaders in environmental sustainability".

Dairy as sustainable food

Consumption of dairy products and milk is often included as important elements of a healthy and balanced diet (Pereira, 2014). It is an ideal food because it contains all the necessary ingredients, properly balanced and free of toxins, in a form that is easy to digest (Sarić, 2018; Fox and McSweeney, 1998). In cow's milk, water makes up about 7/8, and dry matter about 1/8 of milk. Cow's milk is dominant and makes up about 81% of world milk production (Sarić and Brenjo, 2022). Its composition consists of dry matter (12.50-13.00%), milk sugar (4.70-5.20%), fat (3.50-4.00%), proteins (3.10-3.50%) and minerals (0.80-0.95%) (Miletić, 1994; Bijeljac and Sarić, 2005). As incomes and population grow, it is expected that more dairy products will be consumed globally in the medium term (OECD/FAO, 2024). Biologically active components of milk protect newborns and adults from pathogens and various diseases (immunoglobulins, antibacterial peptides, antimicrobial proteins, oligosaccharides and lipids) (Barać and Sarić, 2003). Among other things, milk and dairy products are a good source of calcium, essential amino acids and zinc (Havranek and Antunac, 1993; Badshah et al., 2021). Fermented dairy products are particularly noteworthy, as they provide the human body with microorganisms that modulate the intestinal microflora (Okoniewski et al., 2023).

Plant-based alternatives to dairy products (e.g., soy, almond, rice, and oat beverages) are becoming more popular in many regions, especially in North America, Europe, and East Asia. Key drivers of expansion include health concerns and greater consumer awareness of the environmental impact of dairy production. The sustainability of popular substitutes, such as almond and soy beverages, is being questioned as more and more consumers consider other environmental issues besides greenhouse gas emissions, such as water consumption and deforestation (OECD/FAO, 2024). For comparison, milk and soy drink can be observed. The soy drink does not contain cholesterol, but it contains phytochemicals (isoflavones), so we can really talk about the health aspect (Keshun Liu, 1999). Despite the well-balanced protein structure of soy milk, which some claim is even better than cow's milk, it cannot be a real substitute for cow's milk. The protein utilization ratio (PER), a measure of protein quality relative to casein (cow's milk, standard of 2.5), in raw soybeans is quite low (Gupta, 1997). Soy milk does not contain lactose, the main carbohydrate in cow's milk. The natural carbohydrates in soybeans are sucrose, stachyose and raffinose. The latter two can cause bloating and stomach discomfort (APV, 1997; Gupta, 1997). Compared to cow's milk, soy milk is poorer in vitamins and minerals except iron and niacin. Soy milk contains only 1/5 of the calcium of cow's milk (Sarić et al., 2006; APV, 1997).

Table 1. Vitamin content in soymilk and cow's milk compared with recommended daily intake (Sarić et al., 2006. adapted to APV, 1997; Bylund, 1995; Schaafma, 2003)

Vitamins	Recommended Daily Intake (mg/day)	Soy drink (mg/litre)	Cow's Milk (mg/litre)
A	0,8	50 i.u.	0,2-2,0
B_1	1,2	0,6	0,4
B_2	1,8	0,5	1,7
B_{12}	0,005	0,0	0,004
Niacin	15,0	5,0	9,0 NE*
C	70,0	5,0	5,0-20,0
D	0,002	0,0	0,002

*Niacin Equivalent

Some studies confirm that malnutrition remains a major and continuing problem in developing countries. Namely, many poor people in countries with low personal incomes suffer from micronutrient deficiencies due to a diet based mainly on cereals. Diet with food products of animal origin is particularly suitable for combating malnutrition and a wide range of nutritional deficiencies (Randolph et al., 2007).

Smedman et al. (2010) made a comparison of carbon footprints in gCO_2-eq for 100g of different types of drinks, where it turned out that milk was the worst choice, and mineral water the most sustainable. It is clear that mankind cannot live on mineral water, so they concluded that the amount of CO_2-eq cannot be the only criterion. Based on the fact that humans need a certain amount of nutritional ingredients, they defined the so-called nutrient density and climate impact index - Nutrient Density to Climate Impact Index (NDCI) = nutritional density (kcal, proteins, vitamins, minerals)/GHG emission (CO_2-eq) (Table 2). From this point of view, dairy products are among the best sustainable food products (Smedman et al., 2010; de Jong, 2013).

Table 2. Carbon footprint in g CO_2-eq/100g, NDCI index and nutrient density of several types of beverages (adapted to Smedman et al., 2010)

Indicator	Milk	Soft drink	Orange juice	Beer	Red wine	Mineral water	Soy drink	Oat drink
GHG emissions	99	109	61	101	204	10	30	21
Nutrient density	53.8	0.0	17.2	0.0	1.2	0.0	7.6	1.5
NDCI index	0.54	0.00	0.28	0.00	0.01	0.00	0.25	0.07

An interesting approach is provided by the work published by Đekić et al. (2025). They applied the calculation of the carbon footprint for 13 types of cheese using the factor 1 kg CO_2-eq per kg of milk taking into account the amount of milk required for 1 kg of cheese (FAO, 2022a). They took into account the weight of the cheese as well as the nutritional values (proteins, fats, energy). The results differed and showed that the nutritional value of the product must be taken into account when assessing the carbon footprint of a food.

Environmental sustainability of dairy production

According to many opinions, sustainability encompasses three dimensions: economic, social and environmental. These dimensions are also referred to as profit, people and planet (the 'triple P') (Jongeneel and Slangen, 2013). The first ecological question is how to quantify environmental impacts.

Quantification and allocation of environmental impacts in dairy production

Environmental impacts in dairy production are those from the farm (farm-gate), including impacts on soil, water, air, biodiversity, landscape preservation, etc. (Hind, 2010).

Table 3. Total reported carbon footprints for the entire chain of milk production, processing and transport in kg CO_2-eq* (Sarić, 2024, adapted to Carlsson-Canyama et al., 2003; Sevenster and de Jong, 2008; IDF, 2009; Smedman et a., 2010; FAO, 2010; US Dairy, 2011; de Jong, 2013; van Asselt and Weeks, 2013; IPCC, 2007)

Total emissions of CO_2 - eq of dairying (production, processing and transport of milk)**	0,3-2,5 kg CO_2 -eq/kg milk (average 1,4)
Milk production (to the farm gate)	0,65-1,65 kg CO_2 – eq/kg milk (average 1,13); Share in total emissions of the entire milk production chain **~81%**
From farm gate to warehouse before transport to retail	0,155 kg CO_2 – eq/kg milk; Share in total emissions of the entire milk production chain **~14%**
Dairy processing	0,117 kg CO_2 – eq/kg milk; **5,7%;** 0,086 kg CO_2 – eq/kg milk; **7,6%**
Share of milk processing in emissions from farm gate to warehouse before transport to retail	**13-14%** (0,17 kg CO_2 – eq/kg milk)

* Only emissions from milk production that go into the further chain of milk from the exit from the farm are taken into account, and meat is further calculated in other or special carbon footprint assessment cycles
** Calculations were made on the basis of data from various literature sources, so the sum does not necessarily have to be 100% (note authors)

When there is talk about the further procedures of transport, processing and sale (post-farm-gate), it primarily means the impact on water, soil and air, environmental pollution through the generation of different types of waste, and the consumption of scarce reserves of natural resources (water, energy sources). The usual measure of quantifying the impact on the environment is the carbon footprint, the carbon dioxide equivalent (CO_2-eq) of emissions per product quantity, and the LCA (Life Cycle Assessment) technique. In the case of milk, many factors are unknown or vary from farm to farm and even from cow to cow (Rotz et al., 2010; de Jong, 2013).

The main strengths of LCA lie in its ability to provide a holistic assessment of production processes, in terms of resource use and environmental impact, as well as to take into account multiple parameters (ISO, 2006). IPCC issued Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), and the following year provided data on GHG quantities and the participation of dairy production in global anthropogenic emissions. The amount of milk produced in the world in 2007 was about 553 million tons (FAOSTAT, 2009). Greenhouse gas emissions from dairy farming, including emissions from deforestation and milk processing, have been calculated at 1,989 million tonnes CO_2-eq. Milk and meat production from dairy farming (including dairy cows, replacement calves, surplus calves and culls) plus dairy processing, packaging and transport contribute 4.1% of total anthropogenic greenhouse gas emissions estimated at 49 gigatonnes (IPCC, 2007). Milk production, processing and transport alone contribute 2.7% of total anthropogenic greenhouse gas emissions. The average global emissions per kg of milk and kg of meat from cull dairy cows and bulls and kg of meat from surplus calves were 2.4 kg CO_2-eq, 15.6 kg CO_2-eq and 20.21 kg CO_2-eq resp. In the same year, IDF (2010) published a guide to LCA methodology, which was later supplemented (IDF, 2015; IDF, 2022). Bengoa et al. (2014) also mention milk and dairy products in their guide to LCA methodology for food products. The system boundaries are set “from cradle to farm gate” and “from farm gate to retail”. The functional unit used to report GHG emissions was defined as 1 kg of CO_2-equivalents per kg of fat and protein corrected milk (FPCM), at the farm gate (Vellinga et al., 2013). FPCM is mainly used on the farm, as a basis for comparing farms, it ensures a fair comparison between farms with different breeds or feeding regimes. FPCM is based on standard milk with 4.0% fat and 3.3% true protein content. In processing, the recommended unit is 1 kg of product (IDF, 2015), but in practice a conversion factor is also used, i.e. conversion into kg of FPCM. Allocation factors are important, so on the farm allocation is made to the produced milk and meat from separated cows and male calves, while in processing it depends on the dairy product (e.g. milk and cream or cheese, whey and cream) (IDF, 2010). Of course, data on GHG emissions depend on production conditions and vary by region. India, as the largest milk producing country, has an emission rate of 1.98 kg CO_2-eq. per kg of FPCM. This is approximately 0.5 kg CO_2-eq. per kg of FPCM above the world average of 1.50 kg CO_2-eq per kg of FPCM. In contrast, the USA as the world's second largest milk producer has the lowest average GHG emissions per kg of FPCM among the 10 milk producing countries and the second lowest of all countries analyzed (Hagemann et al., 2012). According to FAO (2018), in 2015 there was a marked difference in the intensity of GHG emissions between different countries. The lowest emission intensity at the farm level was found in countries with a developed milk production sector and ranged between 1.3 and 1.4 kg CO_2-eq per kilogram of FPCM. In developing countries, the emission intensity ranged from 4.1 to 6.7 kg CO_{2}-eq per kilogram of FPCM. In the FAO study (2022), where it was assumed that the global emissions intensity of cow milk for the year 2020 was 1 kg CO_2-eq per kg of milk, Africa was marked as the region with the highest emission of kg CO_2-eq/kg of milk, and looking at the countries with the largest individual milk producers, they are Pakistan, India and Brazil. Life cycle assessment is a quantitative method used as a decision support tool. It provides insight into which parts of the production chain have a major impact on the environment and what kind of interdependencies exist between the different phases of the life cycle (Sevenster, 2013). LCA is not only a technique that monitors GHG emissions, but also other environmental factors such as land or water use and related effects. Thus, the IDF created a guide to Water Footprint Methodology for the Dairy Sector (2017) and Life cycle assessment guidelines for calculating carbon sequestration in cattle production systems (2022). LCA is an important tool in industry strategy and government policy making. Major dairy producers worldwide such as FrieslandCampina, Arla Foods and Fonterra evaluate many of their products and packaging using LCA (Sevenster, 2013).

Sustainable milk production on dairy cow farms

To organize sustainable milk production, farmers' focus should be on all three aspects of sustainability: (i) economic (through increasing milk production), (ii) ecological (through reductions in resource use, nutrient excretion and greenhouse gas emissions per unit of product) and (iii) social (ensuring social acceptability through maintaining good health and well-being of cattle, producing safe and high-quality food and caring for the local and wider community) (Capper and Cady, 2020; Džomba and Čengić-Džomba, 2012).

Milk production on farms, primarily through the production of animal feed and animal excreta, largely contributes to soil, air and water pollution (expansion of arable land, deforestation, reduction of biodiversity). In the production of animal feed, soil and water pollution occurs primarily as a result of the application of mineral fertilizers and pesticides, while undigested parts of food are introduced into the soil and water through animal excrement; nitrogen, phosphorus, microelements, but also various drugs (antibiotics, hormones...) and pathogens. In addition to pollution, water consumption in the chain of animal production is also significant. Highly productive cows need to be provided with 82 liters of water/day (14 to 171 L/day) (Monteiro et al., 2023) and any reduction in feeding has a negative impact on milk production. Nevertheless, this direct water consumption amounts to only about 3% of the total water consumption on the farm, while the largest share of water consumption comes from crop irrigation (Capper and Cady, 2020). Of the total ammonia emissions, which are a significant contributor to acid rain and ecosystem acidification, about 64% originate from animal production. The welfare and performance of animals in dairy production are directly affected by climate change, while the indirect impact relates, to a large extent, to the production and quality of animal feed (Baumgard et al., 2017). At the global level, the emission of greenhouse gases from animal production amounts to 14.5% or 7.5 Gt CO_2-eq (FAO GLEAM, 2022b), where about 30% of GHG is emitted from milk production. According to FAO (2022a), for 2015, the dominant source of GHG was cattle production, which accounted for 62% of the total emissions from the animal production sector, namely 42% (2.9 Gt CO_2-eq) from meat production and

20% (1.4 Gt CO_2-eq) from milk production. The contribution of other types of domestic animals to the total emissions of gases was significantly lower and ranged between 7 and 14%.

In milk production, GHG emissions are the result of various complex biological and chemical processes. Excluding animal feed as an indirect source of emissions, direct greenhouse gas emissions from animal production are linked to CH_4 emissions from enteric fermentation and manure and N_2O emissions from manure (manure management, manure applied to the soil and manure left on pastures) and in 2021 amounted to 4.2 Gt CO_2-eq or 54% of total emissions from agricultural production (from farms) (FAO, 2023). Enteric CH_4 and CH_4 from the manure of dairy cows and heifers have the largest share in the total CO_2-eq from dairy farms (Capper and Cady, 2020). Other emissions include carbon dioxide, which is mainly associated with energy use, production and transport of inputs, and land use and land use changes. When considering the share of individual greenhouse gases in the total emissions from the milk production sector, methane from enteric fermentation participates with 58.5%, CO_2 and N_2O from the production, processing and transport of animal feed with 29.4% and CH_4 and N_2O emissions from manure management with 9.5% (FAO, 2018). In the production of one kilogram of milk, 3.15 kg of CO_2-eq is emitted, and the largest part of the emission comes from biological processes and activities related to the farm (1.51 kg CO_2-eq), land use change (0.51 kg CO_2-eq), animal feed (0.24 kg CO_2-eq), retail (0.27 kg CO_2-eq), processing (0.15 kg CO_2-eq), packaging (0.10 kg CO_2-eq), transport (0.09 kg CO_2-eq) and other losses (0.27 kg CO_2-eq) (Poore and Nemecek, 2018). Methane emissions from enteric fermentation contribute to more than half of the total emissions in milk production, which puts this source of methane emissions in the first place from the point of view of mitigating emissions. In second place is manure management. Methane production is also affected by the amount of food consumed, as well as the chemical composition of the food. Increasing food consumption also increases methane production in the rumen (Ramin and Huhtanen, 2013). Increasing the productivity of animals reduces methane production expressed per product unit, but in most cases the absolute emission on a daily basis (g CH_4 /day) increases. This is precisely why, in addition to increasing productivity, it is important to increase the efficiency of feed conversion or reduce the number of animals in the herd (Cassandro et al., 2013).

Manure is a source of CH_4, N_2O and NH_3 emissions, and the amount of emitted gases depends on the method of manure management, environmental conditions and manure composition. It is estimated that the total annual production of methane from manure amounts to 17.5 million tons (FAO, 2023b). The amount of methane originating from manure is significantly lower compared to the emission of methane originating from rumen fermentation and depends primarily on the way animals are kept (Hristov et al., 2013).

To ensure ecologically sustainable milk production, proper management of nutrients on dairy farms, primarily nitrogen and phosphorus, is of crucial importance. For the most part, nutrients enter the farm through animal feed and fertilizers (nitrogen also through fixation by legumes and precipitation). Nutrients leave the farm in the form of products - milk, meat and plant products (Čengić-Džomba and Džomba, 2021).

Sustainable dairy processing

Milk processing in general can be energy and water intensive, depending on the end product and the process chosen. During its life cycle, milk is heated and cooled several times. At the farm, milk is cooled to a temperature of 4°C. After milk is received at the dairy, it is heated and cooled several times (depending on the type of end product into which the milk is processed, e.g. cheese, powder, yoghurt, etc.). After processing, the milk will leave the factory at temperatures between 4°C (e.g. fresh products) and 20°C (e.g. milk powder, products stable at ambient temperatures) (van Asselt and Weeks, 2013). FAO (2010) published an estimated greenhouse gas (GHG) emission of 0.155 kg CO_2-eq per kg of milk from the farm gate to the warehouse before it reaches the retail outlet; of this, 0.086 kg CO_2-eq. per kg of milk (or 86 kg per 1,000 kg of milk) is attributed to the processing of milk in the factory. These are average values for Europe and vary depending on the region and product. For example, fermented milk has a rather high emission of 0.304 kg CO_2-eq per kg of milk while cheese and whey have a lower rate of 0.126 kg CO_2-eq per kg of milk at the farm gate. When calculated on a finished product basis, the emission rate for cheese is higher, approximately 1.260 kg CO_2-eq per kg of cheese (based on 10 kg of milk for 1 kg of Gouda cheese) (van Asselt and Weeks, 2013).

Table 4. Total reported carbon footprints for dairy products in kg CO_2-eq/kg product for the entire production chain „from cradle to grave“ (Sarić, 2024, adapted to IDF, 2009)

Drinking milk	**Fermented milk**	**Cheese and whey**
1,2 kg CO_2 – eq/kg drinking milk	1,1 kg CO_2 – eq/kg fermented milk	8,8 kg CO_2 – eq/kg cheese

It is significant that processing contributes a fairly small share of the total amount of GHG. When comparing the contribution of emissions from processing to emissions at the farm level they are much lower (van Asselt, 2013). The share of the farm represents about 80% of GHG emissions in the total life cycle of 1 kg of milk. The milking participates with a negligible ~0.02 CO_2-eq per kg of milk. GHG emissions in milk processing mainly come from the use of energy. The share of transport is variable but generally not significant. The main effect from the stages of storage, sale and consumption comes from cooling devices. Also, significant amounts of energy are consumed in cleaning processes. The main contribution to energy and water consumption comes again from the farm. The same applies to eutrophication and acidification (IDF, 2009).

Energy consumption and GHG generation certainly depends on the type of dairy product. Dryers and steaming stations are big consumers of energy, as well as heat treatment devices. Cheese production consumes less energy but generates large amounts of whey. All dairy products consume significant amounts of energy and water for washing and cleaning processes. Water consumption and the amount of waste water depend on the type of plant. Depending on the type of installation and the cleaning system and its management, the total amount of water used in the process can reach several times the amount of processed milk. Consumption is usually 1.3-3.2 liters of water / kilogram of milk received, but it can reach 10 liters of water / kilogram of milk received. Regardless, it is possible to optimize this consumption to 0.8-1.0 liter of water / kilogram of milk by using modern equipment and proper management (UNEP, 2000). The highest consumption of water occurs during secondary operations, especially in cleaning and disinfection, where 25-40 percent of the total amount is consumed. Data on the amount of wastewater varies, but some common values are 1-5 lit./kg of milk, although higher values are also recorded (Integrated pollution and prevention control, 2006).

To improve sustainability, a combination of technological solutions that are technically, economically and environmentally acceptable are applied. Of course, the social aspect is important because any actions must be transparent and be voluntarily accepted by the entire company or factory staff. Various techniques are available, including those from the set offered by BREF (Best reference documents): techniques to increase energy efficiency, techniques to reduce water consumption, techniques to avoid the use of harmful substances, techniques to increase the use of resources, wastewater treatment techniques, techniques to reduce air emissions, techniques to reduce noise, new techniques in the FDM (food, drinks and milk) sector (Santonja et al., 2019).

Also, IDF has developed guides with innovative technologies in wastewater treatment (IDF, 2019). In addition, there are case studies and various other techniques that will help in innovative sustainable technological solutions. Which of the techniques will be applied depends on the company's policy. Other sets of measures and actions include those related to economic and social activities.

Economical and social sustainability of dairy production

Improving the economic and environmental sustainability of dairy production requires a holistic approach that integrates technological innovations, management practices, policy interventions, market mechanisms and collaborative partnerships (Brkić and Puvač, 2024). Precise planning (both on and off the farm) is gaining importance, especially when considering and adopting circular economy strategies (Bhat et al., 2022). The dairy sector provides people with a means of livelihood, status, income and employment. Policies can play an important role in improving the profitability of the dairy sector. Since dairying is usually a commercial activity, the economic aspect is worth studying in its own right (Joengeneel and Slangen, 2013). A common description of economic sustainability is the ability of a system, company or sector to survive in the long term. It refers to the ability of a system, company or sector to maintain its structural and functional capacities after a disturbance or shock. Such a shock may be due to changes in physical conditions (e.g. weather shock), market conditions (e.g. price declines and increased price volatility) or policy changes (Perrings, 1998).

Over time, the EU dairy sector has experienced some changes in its policy framework, the most significant being the abolition of the milk quota system in April 2015. Following the abolition of milk quotas in 2015, EU milk production increased in five Member States. Market-based incentive payments provided by milk processors could help improve the carbon footprint of dairy products. CAP support payments and risk management tools are important to better cope with high price volatility in margins. Milk production in disadvantaged regions faces particular constraints, justifying a targeted policy approach (Jongeneel et al., 2023). The EU Green Deal "Farm to fork strategy" (EC, 2020) is a new comprehensive approach to the way Europeans value food sustainability. Creating a favorable food environment that makes it easier to choose a healthy and sustainable diet will benefit the health and quality of life of consumers and reduce healthcare costs for society.

The progress report on the EU28 CAP objectives for 2023-2024 outlines progress towards sustainability. The measures include: supporting farmers operating in difficult conditions (e.g. mountainous areas), managing these risks (adverse weather conditions, extreme events), improving carbon sequestration and storage in soils and biomass, reducing greenhouse gas (GHG) emissions associated with livestock farming, supporting young farmers, improving animal welfare and combating antimicrobial resistance (EC, 2025).

Small milk processors are important especially for developing countries and rural areas. The development of value-added products, a direct marketing approach improves short food supply chains and relationships between producers and consumers. Family participation, high standards of animal welfare improve the circular economy (Miočinović et al., 2024). In developing countries, besides providing nutritional ingredients to the population, cattle provide dairy products for the market that bring income to the household and are often a sign of social status (Murphy and Allen, 2003; Kitalyi et al., 2005; Randolph et al., 2007).

Activities on improving sustainability in dairy sector

The dairy community responds to the challenges of sustainable development with numerous activities. Following this, the Dairy Sustainability Framework (DSF) was founded in 2013, a non-profit organization that covers about 30% of global milk production (https://www.dairysustainabilityframework.org/). The Global Dairy Platform (GDP) is a body established by the world's largest Dairy companies (https://globaldairyplatform.com/). In 2016, the IDF signed a Declaration together with the head of the FAO in Rotterdam stating that "the dairy community accepts sustainability challenges" and that it undertakes to take a full part in promoting sustainability in the dairy sector (https://fil-idf.org/dairys-global-impact/dairy-declaration-of-rotterdam-3/). In 2021, the dairy community launched the Pathways to Dairy Net Zero initiative (https://pathwaystodairynetzero.org/), which expressed its commitment to reduce GHG dairy emissions by 2030. More than 200 organizations representing about 40% of global milk production have signed this declaration and given their support (https://fil-idf.org/about-us/). GDP (2022) in its rather critical review of the IPCC report on climate change (2022) says that the authors (IPCC note author) "suggest that increasing sources of plant-based protein can directly reduce greenhouse gas footprints and improve animal welfare, land use and human health. However, the report does not consider the nutritional implications of a diet rich in plants and low in meat and dairy products, especially in countries where meat and dairy products are scarce or too expensive for many people“. EDA (2023-2024) declares in its report that it strongly supports the ambitions and goals of the European Agenda for the Environment and that it wants to build the future of the dairy industry. There are numerous examples of projects and concrete actions that are carried out in many regions in cooperation with the DSF, GDP and the International Fund for Agricultural Development (IFAD). Some examples are: case study - Supporting the development of the sustainability of the dairy sector for small dairy processors in India, in Rwanda in cooperation with Inyange Industries', in Kenya in cooperation with Palmhouse Dairies (DSF, 2023, 2021-2022, 2020-2021).

Even in the first decade of this century, dairy companies clearly emphasized their sustainability goals. Here are some examples: "halve the ecological footprint of our products and sources and that 100% of agricultural raw materials are sustainable" (Unilever, 2011); "CO_2 neutral 2020 and global number one partnership criteria" (Danone, 2010), "in 2020 40% of energy used on dairy farms from renewable sources, 30% reduction in water consumption, 50% recycled packaging material" (Dairy UK, 2008) (de Jong, 2013).

Today, dairy companies publish their annual sustainable reports or these are part of general annual reports. In its sustainability reports for 2023 and 2024, the world's leading company Lactalis, regarding climate actions, set one of the goals "to reduce the group's greenhouse gas emissions by at least 50% by the end of 2033 (reference year 2019) (Lactalis, 2023, 2024). Nestlé, in its reports for the year, sets the main goals for climate change: "Nestlé aims to reduce greenhouse gas emissions gases (GHG) by 20% by 2025 and 50% by 2030 compared to 2018 levels, on the way to net zero by 2050 at the latest." (Nestlé, 2023, 2024). Royal FrieslandCampina N.V. also in its annual report for 2024, gives results in the field of sustainability (e.g. GHG emissions reduced by 1.4% in production and transport and by 9.8% in milk production on farms compared to 2023) (Royal Friesland Campina, 2024). The American cooperative Dairy Farmers of America states in the report for 2024 that the DFA is a science-based GHG reduction point of 30% by 2030 (https://issuu.com/dairyfarmersofamerica/docs/sust23007_ssr_fnl_issuu). The Chinese company Mengniu states in its 2024 report that "Mengniu's Ningxia factory has been successfully certified as a 'Lighthouse Factory' (solar-powered), which makes it the first dairy plant in China and the first liquid milk factory in the world to receive this prestigious title (China Mengniu Dairy Company Limited, 2023, 2024). Finally, two positive examples related to dairies in Bosnia and Herzegovina can be highlighted. The first is the biogas plant on the "Spreča" dairy farm near Kalesija in Bosnia and Herzegovina, which supplies milk to dairy Milko's d.o.o. Sarajevo. (https://rtvtk.ba/farma-spreca-u-kalesiji-prva-farma-u-bosni-i-hercegovini-koja- proizvodi-struju-iz-biomase/). Another example is the dairy Lactalis BH/Inmer, which has been part of the Lactalis group since 2007. With its activities, the dairy follows the group's main directions (Carbon Net Zero until 2050). Inmer undertakes activities: continuous process of plant modernization, fight against deforestation, appropriate packaging, consumer awareness, animal care, education, audits, raising awareness. Concrete actions at the local level are the procurement and planting of seedlings for 11 schoolyards in Bosnia and Herzegovina. Surely this is not the end of the list and similar examples in the region can be found.

Conclusion

Dairy sustainability is a difficult question to answer. It is true that there is strong evidence that significant GHG emissions are attributed to animal production, including the production of milk and milk products. Things seem to be like that if they are viewed unilaterally. However, looking at things comprehensively, the situation is not so simple. Bearing in mind other aspects of the sustainability of the dairy sector, it plays an important role in many segments of sustainability: it is a necessary source of valuable nutrients, especially for the children's population, for the malnourished population in developing countries, a huge number of people derive their income from dairying. On the other hand, the dairy community, which is very organized, is aware of the label it likes and the situation humanity is in, so it takes all possible steps in its segment and at all levels to be an active participant in achieving Global Net Zero and to be a leader in its achievement. Dairy science and practice has already found and is finding new opportunities every day to reduce the emission of greenhouse gases, pollution, and for a better economic and social policy. Many studies are undertaken to help both decision makers and policy makers to make the right decisions and take the right moves. It is difficult to say what the future holds and the fate of the dairy sector will depend on many things, but at the moment it can be said that the sector is very conscious of taking actions to achieve all sustainability goals.

Acknowledgement
We thank the staff and especially the director of the Lactalis BH/Inmer factory for the provided material about the dairy.

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