



## Editorial Global Dairy Sector: Trends, Prospects, and Challenges

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Currently, there is a strong need to find practical solutions towards meeting the expected efficiency and overcoming recurring sustainability challenges in the global dairy sector. Improving dairy production and its supply chain explicitly depends on adopting a sustainable 'state of the art' based approach. Carefully evaluating and understanding certain key sustainability indicators through a holistic approach is highly imperative. Appropriate design and application of novel green technologies, implementation of life cycle analysis, upgradation and optimization of the entire production line are some of the most important factors to be considered. It is vital that due considerations are given to the demands of the producers, consumers, and the dependent dairy industries. Nevertheless, in the future, concerns and challenges over the socio-economic–environmental security should not be ignored.

Rapid transitions are being witnessed in the global dairy sector, which has provided not only substantial commercial opportunities, but has also brought about several sustainability challenges. Some of the challenges include global population expansion, urbanization that has taken over the rural sectors, climate change effects, emerging diseases, and safety issues, in addition to the waste management strategies adopted (on- and offfarm). According to the Food and Agriculture Organization of the United Nations (FAO), Asia registered the highest volume increase in the global milk production output in 2020, with increased international trading of whole milk powder, whey, and cheese [1]. In the European Union (EU) alone, milk production growth is expected to decelerate to nearly 0.5% annually, and by 2031 reaching up to 162 million tonnes. In addition, organic milk production is expected to grow in the EU (reaching up to 8% in 2031), leading to economic gains, imparting environmental benefits, and overall animal welfare [2].

Of late, there has been mounting pressure from global consumers to reduce environmental stress from the dairy production sector, particularly when this is directly related to climate change. Nevertheless, a remarkable positive transition towards balanced production, reduced environmental impacts, and improvements witnessed in economic efficiency and social security have changed the components of sustainability in the dairy sector. Interesting information is available recommending the significance of reducing energy consumption in dairy industries and thereby providing crucial information on energy mitigation actions [3,4].

Hence, the need of the present day is to find practical solutions to the growing pressure towards meeting the expected efficiency and overcoming recurring sustainability challenges in the global dairy industries. Of course, gaining success in the dairy production and supply



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). chain sector explicitly depends on adopting a sustainable 'state of the art' based approach. Carefully evaluating and understanding certain key sustainability indicators with a holistic approach is highly imperative. Appropriate design and application of novel green technologies, implementation of life cycle analysis, up-gradation, and optimization of the entire production line are some of the key factors to be carefully measured and considered. Besides, it is vital that due consideration is given to the demands of the producers, consumers, and the dependent dairy industries. Nevertheless, concerns over the environment, social security, and economy of the region should not be ignored. Precise planning (both 'on and off' farm) assumes importance especially when circular economy strategies need to be considered and adopted. Furthermore, the roadmap to sustainable economies has been effectively provided via the 'European Green Deal' to ensure a sustainable economy by directing the climate/environmental challenges into opportunities.

With this as the background, this Special Issue (SI) 'Dairy Sector: Opportunities and Sustainability Challenges' focuses on identifying present opportunities, recent advances, and options to overcome future sustainability challenges in the global dairy sector. A 'Web of Science' search with keywords such as dairy industry, dairy metabolites, innovative technologies, sustainable production, valorization of wastes and by-products, circular economy, climate change, carbon footprint modelling, regulatory and legislative issues revealed a high increase in the scientific publications over the recent years in the dairy sector. This SI comprises 13 published articles focusing on various issues pertaining to the dairy sector that are discussed meticulously. Some interesting outcomes of the published articles are discussed in the preceding text.

The global dairy industry has always faced safety issues along the supply chain, and this has tremendously increased over recent years. As the dairy industry fulfills humans' basic necessities, safety failure factors affecting the supply chain can have tremendous impacts. This aspect has been explored by Hassan et al. [5]. In this study, a total of 25 failure factors were identified via literature reviews and by considering the opinion of experts from the dairy industry and academicians. In addition, interpretive structural modelling was applied to analyze mutual interaction among the barriers. Further, in this report, '*Matrice d'Impacts Croises Multiplication Appliques a un Classement*' technique (MICMAC technique) was adopted to identify the value of safety failure factors (SFFs), which was centered on the driving and dependence power. According to the researchers, results generated from this study will assist prime decision-makers in the dairy industries to precisely design supply chain activities and thereby efficiently manage certain identified barriers.

Furthermore, the global dairy sector is influenced directly by the consequences of global warming, and there is a significant release of greenhouse gas emissions witnessed. Ibidhi et al. [6] have reported on the importance of generating knowledge and a database on country-specific emission factors (EFs) in order to assess the national enteric methane emissions, which is expected to support mitigation action assessment. In a study reported from Latvia by Brizga et al. [7], environmental impacts of milking cows with diverse management practices are discussed. The researchers identified that land use differed more in the largest farms, which used nearly 2.25 times lesser land per kg of milk compared to the smallest farms. For the mid-sized farms, the potential of global warming, terrestrial acidification, marine eutrophication, and eco-toxicity was comparatively high. The researchers opined that if the presently used domestic farm-based protein feeds are replaced with imported high-protein soy-based feed, then the environmental impacts in dairy production can significantly increase (e.g., increased land use by 18% with global warming potential by 43%). Further, the researchers opined that the environment-based policy for handling the farms needs to sensibly contemplate the complete consequences of operation size on the environmental quality, and thus facilitate the 'best practice' for each farm type and driving for the systematic changes there-off. The constraints of the study and future research to enhance data quality, allocation methods, providing farm-size-specific information, breeding, storage of manure and handling are also being discussed in this article.

In order to assess the potential influence on the milk production, Ross et al. [8] evaluated the efficacy of commercial feed additives (SOP STAR COW), which had the ability to decrease the enteric emissions from dairy cow and cattle's performances. Results revealed both control and SOP-treated cows to exhibit identical outcomes for the amount (kg) of milk fat and milk protein produced in a day. Further, no changes in enteric emission or milk parameters were noticed between control and SOP-treated cows. The researchers opined that future work should focus on understanding the effects of long-term supplementation or high dose of 'SOP STAR COW' to regulate mitigation effects on methane emissions and increase in milk production can be ascertained. In another report, Ross et al. [9], by adopting various free-stall management techniques studied the means to lessen ammonia, greenhouse gas, and some air pollutants from lactating dairy cattle wastes. From the study, it was concluded that removal of dairy manure by 'scraping' holds a high prospective to enhance gaseous emissions such as ammonia and other greenhouse gases.

On another note, Byrne et al. [10] investigated the suitability of a heat pump waterheater system to reduce agricultural emissions in dairy farms in Ireland. The energy and cost-efficiency of heat pump system were compared with five other water heaters. Results of this investigation showed high efficiency, but the economic costs and complexity of the solar-gas system were found to be a major deterrent factor. The researchers concluded that the heat pump was cost-effective, competent, and a feasible option for dairy farmers who are aiming to reduce carbon footprint as well as energy bills.

In an interesting study from Brazil, Siqueira et al. [11] investigated the connection between organizational forms and adoption of the agri-environmental based practices by undertaking a case study of six archetypes of dairy farms. From the study, the researchers proposed a systemic approach and concluded that it is important to consider dairy farms as a heterogeneous organizational form (as human capital investment, resources, market, and other information access) in policy design to fast-track agro-ecological transitions.

The technical efficiency of the European dairy processing industries by adopting selected novel methods related to productivity and efficiency analysis was investigated by Čechura and Žáková Kroupová [12]. Accordingly, the input use efficiency was evaluated in ten selected European countries. Results of the study were constructed based on the 'Amadeus dataset', which indicated dairy products manufacturing companies to highly exploit the production possibilities during 2006-2018. It was also observed that the overall technical inefficiency (OTE) to be a result of 'short-term' shocks and unsystematic failures. In addition, in the European dairy processing industries, 'meta-frontier estimates' showed a specific degree of systematic failures like permanent managerial failures as well as structural problems.

In a noteworthy work from Italy, Masi et al. [13] used the 'cluster analysis technique' to recognize dairy farms (3 types) categorized based on the indicators of environment, social, and economic sustainability (dimensions of sustainability) with emergent structural relationships that were based on a structural characteristic of dairy farms. The classification rendered it feasible to portray 'state of art' of the Italian dairy sector and further helped to comprehend how diverse farms types can answer new European trajectories.

The expectations on specialty foods vs. conventional food products that can affect the overall well-being of consumers, and how small-scale artisan producers use this information towards designing better customer experiences are reported by Percival Carter and Welcomer [14]. The study revealed causal mediation analysis in expectations to mediate the link between product types and the utility of product information. The researchers concluded by stating that as consumers' choices evolve, small-scale producers should adopt various approaches to manage their products, thus helping them towards identifying unique opportunities for differentiation and to increase the profitability.

Further on, an interesting and novel perspective to measure the effects of production diseases on economic sustainability in dairy farms is reported by Hoischen-Taubner et al. [15]. The researchers opined that changing the perception of production diseases via reflecting it

as an indemnity damage and a risk to the farms' economic viability can further change the processes involved to minimize the production diseases.

On another note, this Special Issue has two interesting review articles focusing on the global review of monitoring, modeling, and analyses of water demand in dairy farming by Shine et al. [16] and on measuring variables leading to a seeming incongruity between anti-methanogenic potential of tannins and their perceived effects in ruminants byVerma et al [17]. In the review by Shine et al. [16], monitoring of water consumption in dairy farms has been documented. The review has components exploring dairy water consumption, prediction modelling, and analysis, followed by discussions highlighting some of the normal trends through dairy water literature. The authors have concluded by indicating that globally more studies are required that can focus on the consumption of water within the milking parlor. The researchers have also opined that to guarantee best practices, improving the perception of dairy water consumption via statistical analyses as well as empirical modelling can yield increased prediction confidence and improved appeal of empirical models as a substitute for 'physical metering'.

Verma et al. [17] have reviewed the variability of anti-methanogenic potential of forages and attempted to ascertain the reasons for inconsistencies in results. They have discussed options for optimization to produce comparable and reproducible results. These researchers have proposed a link between plant metabolome, physiology, and their anti-methanogenic potential that can be duly considered for improving the sustainable intensi-fication of livestock. The review is concluded by stating that a comparison of condensed tannins (CT) fingerprints between different species can be of use to understand various factors defining their anti-methanogenic potential, thereby offering an important background to assess interactions between plant constituents and rumen microflora, thus promoting ruminant health.

## The Future:

The global climate changes we are facing in recent decades and the transformations witnessed have prompted experts, politicians, and the public to question who are the main culprits and what actions need to be taken to mitigate these effects. The swift expansion in intensive farming systems has held the consideration of experts, who hypothesized large contributions to climate change by the livestock system, raising a question on sustainability among these farming techniques, specifically related to the negative impacts on the environment and animal welfare. These factors have led to enhanced social costs compared to costs of private systems, imparting negative effects on the entire society. This holds true when the livestock farming sector is of focus, wherein a larger number of inputs are used in the intensive farming systems, as well as when an enormous amount of wastes are being generated. Today, the basic requirement is to endure the social acceptability of these procedures and offer the dependent sector to be much more competent and be environmentally sustainable to overcome challenges of the future. In this perspective, the interests at stake are wide and not all 'Nations' are taking steps to improve the production performance of the supply chain with a view to sustainability. The new European trajectory like that of the 'Farm-to-Fork' strategy, places sustainability objectives of the sector in line with the demands of the planet. Indeed, in recent years, the entire sector is undergoing rapid transitions with novel sustainable production methods being developed. A factual classification of dairy farms covering all aspects of production systems can offer an outline of factors that can be demonstrative of the farm types from a structural point and at the level of intensity in the production system, which are envisaged to be useful for secondary evaluation, mainly with regard to farm sustainability performance. Further, sustainability assessment should be carefully monitored and calibrated based on the farm's structural asset such as farming area, number of animals raised, age and education of farmers as well as on the production methods employed (e.g., organic).

Moreover, accelerating the use of environmental sustainability practices in dairy systems is also of much importance. The demand for environmental sustainability practices has increased in a variety of economic sectors worldwide. In animal production, in which the environment (soil, water, atmosphere, and temperature, among others) is one of the main factors of production, such demands are even more necessary and of urgency. Small changes in the production environment can result in important negative impacts on animal

production as well as on the environment and society as a whole. Although environmental sustainability practices have been adopted in many dairy production systems, such practices should be increased in the coming years. Acceleration of the adoption of environmental sustainability practices is generally promoted by two major axes. First, through laws that regulate and oversee such practices and, second, through the generation of market incentives. Between these two axes, the generation of laws and oversight mechanisms may present more weaknesses, especially considering delays in the definition of laws and the difficulty, and high costs of monitoring compliance to governmental requirements. Thus, there is a tendency that acceleration of the adoption of sustainability practices in dairy systems be driven by market mechanisms, particularly those that result in milk valorization. For instance, farmers who adopt a set of more environmentally sustainable production practices could be paid more per liter of milk. Valorization of milk produced in systems with reduced environmental impact generally results from stable commercial relations, mainly via the establishment of purchase and sale contracts with clear clauses that can be verified by the different parties involved. Such a scenario is not observed in some countries that rank among the world's largest milk producers. Studies that analyze the characteristics of different forms of organization and identify market niches that may value milk produced by systems with reduced environmental impact are also important. Furthermore, identification of constraints or incentives to adopt environmental sustainability practices from the perspective of farmers may contribute to the creation of important public-private strategies for accelerating the use of environmental sustainability practices in dairy production.

Moreover, water demand in dairy farming will most likely increase in the coming years. Freshwater, encompassing only 3% of the global water supply, represents earth's most valuable natural resource [18]. However, the majority of the freshwater is entrenched in the glaciers, polar ice-caps, or in groundwater aquifers. A meager 0.4% of the earth's total freshwater is instantly available from rivers, lakes, or/and from [19]. Nearly 70% of the global freshwater is utilized by the agricultural sector, and hence this necessitates considerable perfection in water-use efficiency. Nevertheless, agricultural production depends not only on the availability of land, but also on the free accessibility to freshwater [20]. Further, the global water-footprint generated post-production of dairy products in the dairy sector is estimated to contribute nearly 7% of the total share, and this is expected to increase in future decades the world over, coupled with a predicted augmentation in the consumption of dairy-based products [20,21]. Even though green water forms the major category of water used in the stall- as well as pasture-based dairy farms, 'on-farm' blue water can also be more vulnerable to water shortage owing to its localized supply from rivers, lakes, or ground water aquifers, especially during periods of modest rainfall [16]. Therefore, the future direction of research related to water demand in dairy farming may trend towards identifying strategies to reduce blue water usage, which is composed of parlor and animal drinking water. In particular, strategies may focus on mitigating parlor water use as reducing drinking water may negatively impact milk production. Some of the factors like farm size, farming systems, milk pre-cooling, milking systems, and washing practices can have a profound influence on parlor water use. Strategies for reducing parlor water use may include the installation and use of a closed-loop milk pre-cooling system, wherein a buffer tank can store and supply water to the farm as and when required [22]. When water is essential for the pre-cooling of milk, this can flow via the plate cooler at the set water to milk ratio, and this flows back to the buffer tank, thus ensuring excess water use is minimal. Additionally, an effective blue water mitigation strategy should be identified and fixing of leaking water systems is a necessity. In New Zealand, 26% of 'stock' drinking water was discovered to be lost due to leakage [23]. Precise calculation on the blue water use in dairy farms is often seen as a limiting factor with the number of farms being included in water foot-printing studies. This might be due to high investment

and maintenance costs, and time constraints linked with metering types of equipment to monitor direct 'on-farm' water use. The majority of research investigations have focused on designing prediction models to simulate 'on-farm' water usage. The application of machine-learning algorithms has revealed improved total dairy water prediction accuracy by ~23%, which facilitates for 'coarse model' inputs exclusive of compromising on the accuracy [24]. Developing precise working models for 'on-farm' water consumption can definitely support an expansion in the dairy farm numbers and provide inputs for water foot-printing studies. This will offer an effective environment wherein non-linear impacts on dairy water use due to changed farm practices, equipment, or meteorological conditions can be quantified and be of practical use.

Finally, there is a need for more research to be undertaken, specifically in relation to the impact dairy farming has on the environment, society, and regional economies.

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