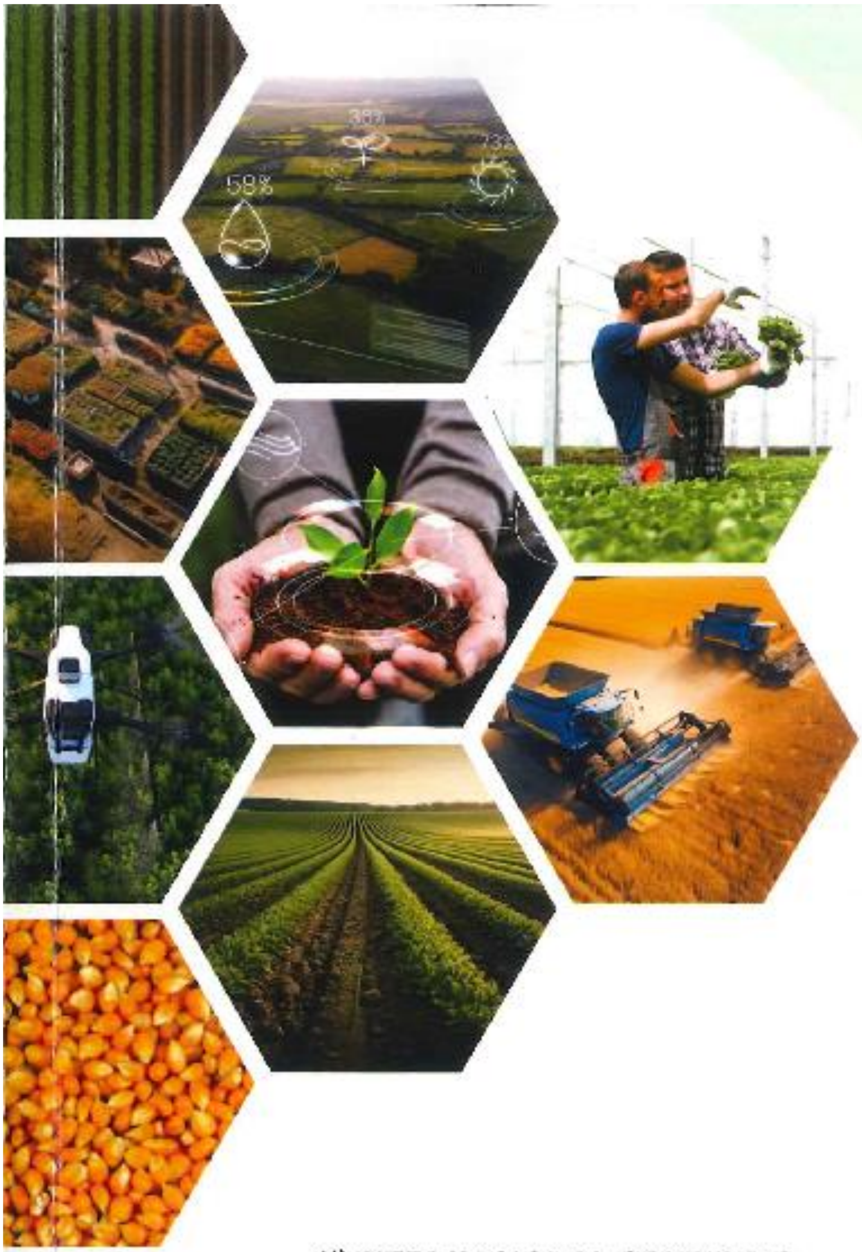

BOOK OF PROCEEDINGS

6th INTERNACIONAL SCIENTIFIC CONFERENCE

VILLAGE AND AGRICULTURE

29. SEPTEMBER AND 30. SEPTEMBER 2023.
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EFFECTS OF ENTERIC METHANE MITIGATION PRACTISE

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Abstract

The paper gives an overview of aspects of enteric methane emission, pointing out the importance of climate change mitigation practices. Enteric methane is formed as a by-product of the digestion of feed, primarily in ruminants by enteric fermentation. Ruminants emit methane created by enteric fermentation in the rumen, mostly by eructation. Nutritional interventions to mitigate enteric methane (ECH_4) have been thoroughly investigated and many innovative solutions are being tested and considered. To meet the increasing demand for meat and milk, the livestock industry has to increase its production, which is followed by increasing ECH_4 emissions. Continuous research and development are needed to develop ECH_4 mitigation strategies that are locally applicable. Climate change mitigation and adaptation policies play a crucial role in the political agendas of local authorities who have to support the development and implementation of innovative products or methods for ECH_4 mitigation. Addressing these challenges at local levels requires collaboration among many organizations and across different sectors, followed by cross-border and worldwide cooperation.

Keywords: enteric methane, ruminant nutrition, greenhouse gases, mitigation

Introduction

Air pollution depends on many natural and human factors, and the variation of pollutants and weather changes modify the concentration of pollutants in time and space (Battista et al., 2017). To meet the increasing demand for meat and milk, the livestock industry has to increase its production, and without improving its efficiency, raised livestock, especially ruminant animals, will worsen the environmental damage, mainly from enteric CH4 emission (Wang *et al*., 2023). Diary organizations worldwide announced greenhouse gas neutrality goals. Mitigation of enteric methane emissions is necessary to achieve these goals. Many innovative solutions are being tested and considered. Global challenges, such as enteric methane mitigation and its contribution to climate change, cannot be solved by one organization. Addressing these challenges requires collaboration among many organizations and across different sectors, followed by cross-border and worldwide cooperation.

Global climate change is affecting temperature, precipitation, and water availability, which directly affects agriculture and livestock productivity (Souza *et al*., 2023). Therefore, the expected decline in dry matter intake (DMI) and animal productivity and changes in water intake caused by heat stress may also affect the environmental costs of production in cattle. With the current interest in reducing CH_4 emissions in ruminant production systems to limit global warming (Arndt *et al*., 2022), models that predict CH_4 emissions have become an important tool to evaluate mitigation strategies (Niu *et al*., 2018), when other technologies are not available to measure individual enteric CH4 emissions, (Souza *et al*., 2023). The agricultural sector is faced with challenges related to global warming and climate change, which affect human and animal food security. Due to climate change, periods of drought might be longer and occur more frequently, which challenges roughage production and requires changed feeding of dairy cattle by increasing the grain content of the diet, (Ivetić *et al*., 2023; Olijhoek *et al.,* 2022). Also, the feeding behavior of cattle could be managed more effectively, (Ivetić *et al.,* 2008, Ivetić *et al.,* 2007). Land plays a key role in the global cycles of GHG (i.e., carbon dioxide (CO2), methane (CH_4), and nitrogen oxide (N_2O), and land use change can lead to the release of such gases into the atmosphere or the removal of them from the atmosphere, (Huang *et al.,* 2023). One of the most common forms of land use change is agricultural land conversion where agricultural lands are converted for other uses. Huang *et al*., (2023) reported that increasing agricultural land conversion to more than 8 % of available land led to increasing GHG emissions during the economic development process.

Livestock enteric CH_4 mitigation is an old feed energy efficiency problem with new dimensions, (Hristov et al., 2022). Governments and the public are interested in finding solutions to climate change, and it is believed that mitigation of agricultural greenhouse gas (GHG) emissions is part of the solution (US Government, 2021). In the United States, agricultural activities are responsible for the generation of GHG such as CO_2, CH_4, and N_2O, with the latter 2 gases being of primary interest: agriculture contributed 39% (CH_4) and 80% (N_2O) of their total emissions in 2019, on a CO_2-equivalent basis (USEPA, 2021). Within agriculture, livestock is responsible for 94% of all CH_4 emissions in the United States (USEPA, 2021).

Continuous research and development are needed to develop enteric CH_4 mitigation strategies that are locally applicable, also information is needed to calculate the carbon footprints of interventions on a regional basis to evaluate the impact of mitigation strategies on net greenhouse gas emissions, (Beauchemin *et al*., 2022).

Enteric methane

Enteric methane is a major source of greenhouse gas emissions from milk and beef production systems that contribute to global warming, (Tricarico *et al.,* 2022). Enteric fermentation is the second largest source of methane emissions after natural gas and petroleum systems, and the second largest source of agricultural greenhouse gas emissions in the United States after nitrous oxide emissions from managed soils (US EPA, 2021), Figure 1.

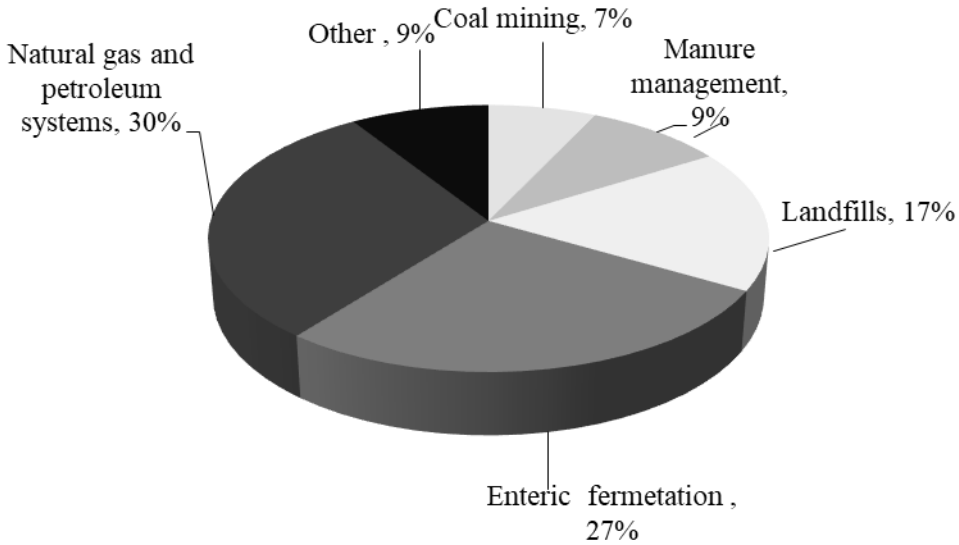

Figure 1. US methane emission by source, EPA 2020

Methane is estimated to have a global warming potential, global warming potential (GWP), 28–30 more than carbon dioxide over hundred years, by the United States Environmental Protection Agency (EPA, 2021, and Intergovernmental Panel on Climate Change - IPCC, Table 1. In Europe, 81% of agricultural methane emissions result from enteric fermentation, and 39% of those 81% are produced by dairy cows, (EEA, 2020).

Table 1. IPCC Sixth Assessment Report Global Warming Potentials,2021

Greenhouse Gas	100 Year Time Period			20 Year Time Period		
	AR4 2007	AR5 2014	AR6 2021	AR4 2007	AR5 2014	AR6 2021
CO_2	1	1	1	1	1	1
CH_4 fossil origin	25	28	29.8	72	84	82.5
CH_4 non fossil origin			27.2			80.8
N_2O	298	265	273	289	264	273

In the AR6 report, an additional GWP for methane has been included to differentiate between methane which originates from fossil fuel sources, and methane from non-fossil fuel sources, like agriculture.

Unlike other sources of greenhouse gas emissions, such as those from fossil fuel extraction and distribution that only contribute to atmospheric greenhouse gases, milk production systems are part of the biological carbon cycle and can function as a sink for greenhouse gases, thereby contributing to reverting climate change, (Le Quéré *et al.,* 2018). Because emitted methane is continuously removed from the atmosphere by hydroxyl oxidation, its atmospheric warming effects depend on the rate of emissions increase or decrease over the last 20 years rather than the total cumulative amount emitted over that period, (Allen *et al*., 2018). Tricarico *et al*., (2022), have the opinion that if mitigation of enteric methane production greater than 0.3% annually that is sustained over time (i.e., year-over-year) could be used to offset the atmospheric warming effects of carbon dioxide and nitrous oxide emissions from milk production systems. In this way, sustained mitigation of enteric methane production becomes a valuable tool for dairy value chains to meet their greenhouse gas reduction goals. Therefore, a significant reduction in methane emissions, particularly from agricultural activities, would rapidly mitigate climate change and is a powerful lever to meet the European Union's 2050 climate targets (Dupraz, 2021).

Gloux *et al,* (2023) highlight that the Intergovernmental Panel on Climate Change (IPCC) defines 3 different methods, to be applied to national inventories according to data availability:

- Tier 1 methods attribute default yearly enteric methane emissions factor per dairy cow. Tier 1 methods provide aggregate estimates, and are not adequate for monitoring changes over time and taking into account the variability of dairy farming practices;
- Tier 2 methods improve the accuracy of emission factors by including feed intake estimates of a representative diet and dairy cow;
- Tier 3 methods require a precise characterization of cows' diet to account for digestibility;

Aspects of the cost of implementing mitigation strategies have to be considered, for the adoption of mitigation strategies for livestock GHG emissions. Climate change mitigation and adaptation policies play a crucial role in the political agendas of local authorities who have to support the development and implementation of innovative products or methods for ECH_4 mitigation.

Mitigations methods

The amount of ECH_4 that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of ECH_4 (Ivetić *et al*., 2022a, Ivetić *et al*., 2022b, Ivetić *et al*., 2021) with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). World demand for animal-sourced foods and global warming concerns rise, safe and effective strategies for enteric methane mitigation in dairy cows are in high demand and De Ondarza *et al.,* (2023) created the dataset from data collected from scientific publications identified through searches of the scientific literature for the greenhouse mitigations effects. The bibliography used by Arndt *et al*. (2022), covers the period from 1963 to 2018, and De Ondarza *et al.* (2023), supplemented with literature searches to cover the period between 2019 and 2022. Information from 797 treatments was organized in rows and 162 columns containing variables, including experimental design, animal definition, methane measurement method, dietary nutrients, and treatment responses. Mitigation strategies were classified into 3 main categories: animal and feed management, diet formulation, and rumen manipulation, and up to 5 subcategories (Hristov *et al.*, 2022). This large dataset with descriptive data and treatment means from in vivo dairy cow enteric methane studies can be used by public and private researchers and advisors including nutritionists, environmentalists, and economists interested in cost-effective solutions to reduce global warming without compromising dairy farm sustainability. In France, the Eco-Methane organization brings together more than 600 farmers whose emissions reduction was estimated at 11% on average in 2017 (Bleu-Blanc-Coeur - BBC, 2022). Gloux *et al*. (2023), reported that BBC pays farmers according to their reduction of methane emissions in CO_2eq with a financial envelope made of donations from private actors (15€/tCO_2eq on average in 2017). The main strengths of the scheme lie in the strong scientific foundations of the method for quantifying emissions and the easy participation procedure for dairy farmers, (Gloux *et al.*, 2023). Near-infrared spectroscopy (NIRS) from cattle feces could be used as a phenotyping method to predict dry matter intake (DMI) as well as enteric methane emissions (ECH_4), (Andueza *et al.*, 2022).

Nutritional interventions to mitigate enteric CH_4 have been thoroughly investigated and, likely, strategies based on supplementation with plant extracts (such as a combination of Capsicum oleoresin and clove essential oils) may have a higher acceptance by livestock producers compared with, for example, the use of antibiotics, (Silvestre *et al.*, 2022). Several secondary plant compounds including tannins and saponins have been evaluated for their potential to decrease CH_4 production from ruminants (Kozłowska *et al.*, 2020; Jayanegara *et al*., 2012). Also, it is well known, that the addition of dietary fat can reduce methane emissions, (Olijhoek *et al*., 2022).

One of the proposed additives was essential oils (EO), classified as having an uncertain CH_4 mitigation potential with no long-term effects established (Hristov *et al.,* 2013), and Hegarty *et al*. (2021) concluded in their review that there is medium evidence of the potential of EO to mitigate CH_4 in vivo. Despite the limitations, a positive and strong argument for continuing the research with EO to mitigate CH_4 emission in livestock is supported by the fact that these compounds may have a higher acceptance by consumers compared with, for example, synthetic CH_4 inhibitors, (Silvestre *et al.*, 2023). Botanical preparations and EO are Generally Recognized as Safe (GRAS) compounds by the Food and Drug Administration (FDA; 2021). However, more research is needed to determine the long-term effects of EO supplementation, (Silvestre *et al.*, 2023).

For a given productivity level, introducing fodder with high sources of omega 3 content such as grass or linseed in the feed ration of dairy cows both improves the milk nutritional profile and reduces enteric methane emissions per liter in France, (Gloux *et al*., 2023).

Many studies have compared feeding maize silage versus grass or grass-clover (starch vs. NDF) diets to dairy cattle, to study the effect on rumen digestion kinetics and CH4 emission, (Brask-Pedersen *et al*., 2023). The quality and the composition of silage is important element of a ration daily for ruminant feeding, (Ivetić 2017, Ivetić *et al.*, 2018, Ivetić *et al*., 2013). It should be mentioned the application of alternative electron acceptors are organic (e.g., fumarate, malate) and inorganic (e.g., nitrate, sulfate) compounds that draw electrons away from methanogenesis and incorporate them into alternative pathways, (Beauchemin *et al.,* 2022).

The ruminant gut structure fosters extensive enteric fermentation of their diet, (Ivetić, 2017). Enteric CH4 emission from ruminants not only exacerbates the global greenhouse effect but also reduces feed energy efficiency for the animals and Wang *et al.,* (2023) explained that theoretically, redirecting [H] from methanogenesis to propionate formation to reduce CH_4 production could be a promising method for reducing greenhouse gas emission from ruminants, and may also increase animal productivity. Instead of directly inhibiting methanogenesis in the rumen, redirecting the flow of [H] towards alternative sinks could be a promising strategy. The complexity of the rumen poses challenges to reducing enteric CH_4 emission, but long-term comprehensive technologies may influence the evolution of the rumen and rebuild a microecosystem in a way that would favor the production of propionate to provide more sinks to dispose of H_2, (Wang *et a*l., 2023).

Macroalgae (seaweeds) have highly variable chemical composition, depending upon species, time of collection, and growth environment, and they can contain bioactive components that inhibit methanogenesis, (Beauchemin *et al.,* 2022). Seaweeds have been studied by Muizelaar *et al.* (2023) for their ability to reduce enteric methane emissions of ruminants when fed as a feed supplement. They reported that none of the seaweeds used in the experiment affected enteric gaseous emissions and that the inclusion rate might not have been sufficient for the specific metabolites in seaweeds to affect enteric methane production.

Methane inhibitors (3-NOP and bromochloromethane) had the largest CH_4 mitigation effect (Hristov e*t al.*, 2022) and did not affect DMI, fiber digestibility, milk production, or ADG. 3-Nitrooxypropanol is the most potent CH4 inhibitor currently available, exhibiting inhibition efficiencies of 20 % to 50 % across a range of doses, supplemental methods, diet compositions, and animal species, with no adverse impacts on diet digestion or animal performance (Hristov *et al*., 2015). Applied at 60 mg/kg feed DM via the TMR, 3-NOP decreased daily enteric CH4 emission by 26%, emission yield by 27%, and emission intensity (ECM basis) by 29%, (Melgar *et al.,* 2021). Chemical inhibitors can be easily combined with other mitigation strategies and their adoption requires them to pass safety tests for animals, consumers, and the environment, (Beauchemin *et al.,* 2022).

Two organizations based in the United States, the Foundation for Food and Agriculture Research and the Dairy Research Institute, have developed a collaborative program Greener Cattle Initiative to align resources and fund projects to identify, develop, and validate new and existing mitigation options for enteric methane emissions from dairy and beef cattle (Tricarico *et al*., 2022), shown in Figure 2.

Increased confidence in mitigation estimates is needed to develop socioeconomic innovation that encourages the adoption of mitigation options. The discovery of new enteric methane mitigation options, by itself, is not enough for the dairy sector to meet its environmental stewardship goals on climate change. Mitigation options need to be deployed by a substantial number of dairy farmers to achieve the desired results, (Tricarico et al., 2022). For example, animal feed and health companies that develop enteric methane inhibitors currently need to pursue regulatory pathways that were developed to establish functional claims for drugs, such as compounds to cure, prevent, treat, or mitigate disease conditions or that change bodily structures or functions (United States Food and Drug Administration, 2022). Antimethanogenic strategies may decrease total CH_4 production (absolute emissions, g/d), CH_4 yield (g/kg of DMI), or CH_4 intensity (g/kg of meat, milk, or wool produced), (Beauchemin *et al*., 2022).

The number of monitoring tools and experiences is progressively increasing also due to improvements in the standardization of methods and the proliferation of research and accounting experiments, which bring about an increase in awareness of political subjects and the general public, (Marchi *et al.*, 2023).

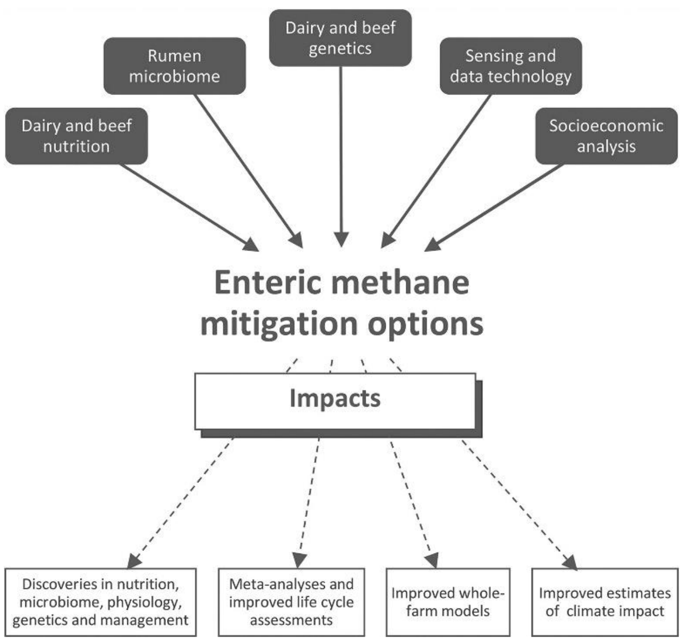

Figure 2. Areas of focus and expected impacts for research of enteric methane mitigation options for beef and dairy cattle, Tricarico *et al*., 2022

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Air pollution depends on many natural and human factors. The agricultural sector is faced with challenges related to global warming and climate change, which affect human and animal food security. Increased confidence in mitigation estimation and practice is needed to develop socioeconomic innovation that encourages the adoption of mitigation options. The discovery of new enteric methane mitigation options is not enough for the dairy sector to meet its environmental stewardship goals on climate change. Global challenges, such as enteric methane mitigation and its contribution to climate change, cannot be solved by one organization. Addressing these challenges requires collaboration among many organizations across different sectors, and is necessary to be followed by cross-border and worldwide cooperation.

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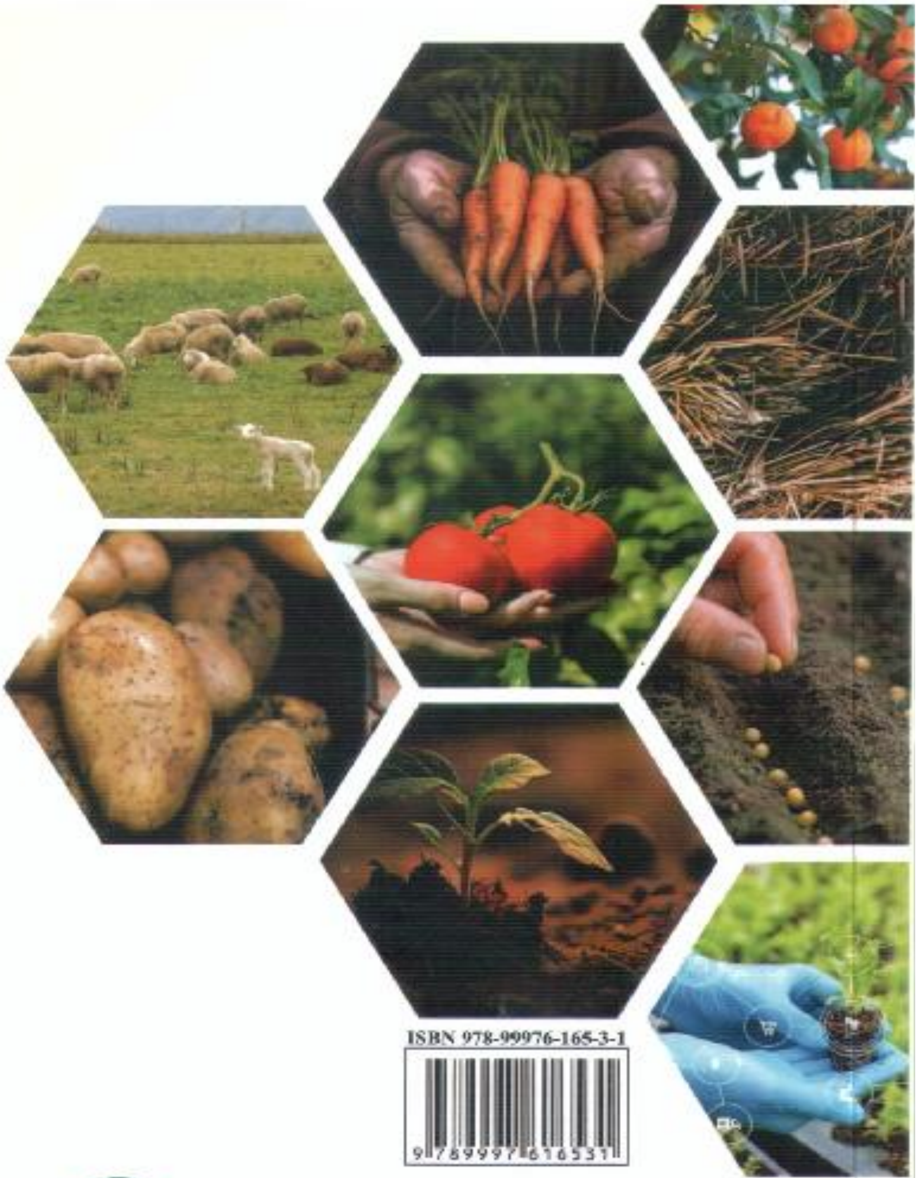

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