Chapter

Impact of Emerging Agricultural Contaminants on Global Warming

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Abstract

There are many definitions of emerging contaminants (ECs). They are not usually new chemicals and could be substances that have stayed long in the environment with their presence and importance being recognized now. They may be chemicals or microorganisms which are not usually monitored in the environment but with known or suspected potential to cause ecological damage or adverse human effects. Some natural products and those transformed through biochemical processes from synthetic chemicals may be formed in the environment as ECs. Emerging Agricultural Contaminants are released to the environment or enter indirectly to the soil during the application of manure, fertilizers, biosolids or other solid waste materials. Once they enter the soil, they may be transported by leaching, runoff and drainage processes to water bodies. The extent of the transport is dependent on the persistence of the EC and on how it interacts with soil and air. These ECs contribute to global warming through the emissions of Greenhouse gases. The largest source of GHG emission from Agriculture is Nitrous oxide (N_2O) and it accounts for 38% of the total global emission through the process of nitrification and denitrification, anthropogenic activities (use of nitrogen fertilizer, production of nitrogen-fixing crops and forages, retention of crop residues, application of managed livestock manure) which are either through direct additions and/or through indirect additions (atmospheric deposition of applied nitrogen). The natural digestive processes in ruminants otherwise known as enteric fermentation account for the key source of methane production under livestock production hence the second largest source of total agricultural emission with 34% global share and rice cultivation being the third with 11%. The three important greenhouse gases (Methane, Carbon dioxide and Nitrous oxide) are not harmful in naturally occurring quantities for their atmospheric presence helps in sustaining life on the planet when they trap heat energy near the surface of the earth. Concentration of greenhouse gases from both the natural and human factors have been increasing and contributing to Global Warming and Climate Change. Increase in greenhouse gases may cause tremendous changes to our civilization positively or negatively but the total impact is uncertain. Climate change comes as a result of a warming planet which can affect the weather adversely in many ways. So, as climate changes, extreme weather activities release severe threats on human society. Indicators of global warming include sea surface temperature, temperature over land, snow cover on hills, temperature over land and humidity. It is expected that climate change may cause more floods, storms, droughts, heatwaves and other extreme weathers activities. IPCC estimated that temp may rise from 2 to 6°C within 2021. Mitigation of greenhouse effect could

be achieved through Biochemical methods on enteric fermentation, development of good environmental policies even Methanotrophs also aid in recycling the atmospheric Methane.

Keywords: emerging contaminants, pesticides, fertilizers, livestock, manure, global warming

1. Introduction

Global warming: The temperature of the earth since 1950 has been increasing above average temperature. This can also be referred to as climate change. Both climate change and Global warming refer to increase in average global temperature. Climate change involves a change in climate measured using statistical properties such as mean surface temperature which can range from months to millions of years. One of the facets of climate change is global warming as it has been described as an average increase in global surface temperature. The causes of Global warming are both from natural and human events. One of the natural factors is Greenhouse effect. This effect is a blanketing one by which greenhouse gases keep the surface of the earth warm [1]. The human influenced greenhouse gases (CO_2, CH_4, and N_2O) are also essential in climate change [2]. The energy that gets to the earth is absorbed by earth's surface and later re-radiated back as heat energy towards the space. Greenhouse gases equally and importantly trap this re-radiated energy within the atmosphere hence increase the temperature of earth's surface [3].

Climate change occurs as a result of high concentration of greenhouse gases (GHG) like carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), sulfur dioxide (SO_2) etc. [4]. The increase in high GHG emissions are associated with economic activity especially as related to industry, energy, transport and methods of land use (Agricultural production and deforestation [5]. Greenhouse gases are still building up in the atmosphere and prompting shifts across the globe in the climate.

Agriculture is a well-known source of global emission of greenhouse gases. Rearing of livestock and application of fertilizers and other related land clearing affects the levels of both GHG in the atmosphere and the possibilities of carbon sequestration and storage. Agricultural pollutants are the contaminants that are released into the environment as a by-product from growing and raising of food crops and livestock. However, these pollutants are biotic and abiotic by-products of farming practices (pesticides, fertilizers and livestock manure) that result in degradation or contamination of the environment and ecosystem hence leading to injury in humans and their economic interests. There has been an increasing concern over the emerging and growing increase in emission of Greenhouse gases such as CH_4, CO_2 and N_2O, etc. as they have detrimental impact on the environment leading to global warming which results in climate change and environmental degradation [6, 7].

1.1 Sources of emerging contaminants

Different routes of release of emerging contaminants can be summed-up into 3 major categories as follows:

1. Use of Livestock: This includes manure and flatulent gas (methane) being released directly from animals and their compost-releasing Methane gas into the atmosphere, artificial fertilizers, hormones used in livestock and all other veterinary composts.

2. Plant Protection Activities: These include mainly nanomaterials designed as "smart" chemicals or "smart" pesticides that have the ability for selective toxicities. Unfortunately, these nanomaterials enter the ecological system virtually undetected. Pesticides which include Rodenticides, Fungicides, bactericides, weed toxins, zootoxins which kill small animals like rodents, phycotoxins which inhibit the growth of algae, different personal and household use products, all that have the ability to produce other compounds that are consequently released directly or indirectly into the environment especially through air and wastewater as emerging contaminants.

3. Human Use Activities: These include chemicals such as new chemical compounds and pharmaceuticals synthesized by humans that are released directly and indirectly. These compounds usually pass into wastewater treatments to land resulting in sludge and biosolids, and or from irrigation to waste-water effluent. Pesticides which may be released as nanoparticles are also part of this group with increased absorption ability, increased solubilities, or increased toxicities.

2. Emerging contaminants from agrochemicals

Contaminants refer to biological, chemical, physical or radiological substances found in considerable concentrations that can adversely affect human beings through soil, food contamination and air. For a long time now Contaminants from Agricultural practices have been known to be as a result of human activities both man-made and natural. Their increasing effect on the ecological system including resultant Green-House effects poses a disturbing concern.

What are the emerging agricultural contaminants? Agricultural contaminants can generally be grouped into some major classifications, but a major source of concern for the environment is the emergence of animal waste and its release of Methane gas (CH4) into the atmosphere. Another growing source of concern is the emergence of pharmaceutical wastes as contaminants which manifests typically in run-off water in the agricultural watersheds. Although there are many definitions of what constitutes "emerging contaminants" it is of paramount importance to explain the word "emerging" attached to the contaminants as chemical compounds which have not been known to be in existence or have not been extensively studied. Again, emerging contaminants can be classified into chemical compounds which have been known previously but whose impacts on health and environment have not been fully comprehended. The definitions of emerging contaminants are numerous and vary from region to region of the world. They may be chemicals that have been shown to be threatening to the environment or public health through different routes without enough data to assess their risk levels. Those with potential health and environmental threat without regulatory standards also fall into emerging contaminants just as chemicals or substances that penetrate the environment through different routes but lack not only risk stratification, but inadequate detection capabilities. Although detecting emerging contaminants can be more challenging, they can penetrate the environment causing adverse biological and ecological effects [8]. The United States Geological Survey describes emerging contaminants as chemicals or microorganisms which are not usually monitored in the environment but with known or suspected potential to cause ecological damage or adverse human effects. New Synthetic chemicals or changes in use and disposal of existing ones can also be referred to as a means of creating emerging contaminants. Emerging contaminants in another way is defined as chemical substances or compounds that are characterized by a perceived challenge to human health or the environment lacking published health criteria. They may also be identified from sources that are unknown, new exposure to humans, or a new detection approach or technology [9]. Emerging contaminants (ECs) are not usually new chemicals. They could be substances or chemicals that have stayed long in the environment with their presence and importance being recognized now. There are many proposed and contradictory definitions of "Emerging Contaminants". Boxall [10] defines it as a contaminant from a chemical class that has not been studied extensively where either there is a concern from scientists, Regulators, NGOs or other Stakeholders that the contaminant class may be having an impact on human health or environment or where there is a concern that an existing environmental assessment paradigms are not appropriate for the contaminant class.

Recently, there has been a great concern on the environmental challenges caused by Emerging contaminants. These ECs emanate from by-products of a variety of materials such as paints and coatings, pharmaceuticals, personal care products, agrochemicals, veterinary medicines etc. Some natural products and those transformed through biochemical processes from synthetic chemicals may be formed in the environment as ECs.

2.1 Emerging contaminants from agricultural activities

Emerging Contaminants are released to the agricultural environment via different pathways. They may be released to the environment directly (veterinary medicines that are used in the treatment of animals at pasture) or enter indirectly to the soil during the application of manure, biosolids or other solid waste materials. Once they enter the soil, they may be transported by leaching, runoff and drainage processes to water bodies. The extent of the transport is dependent on the persistence of the EC and on how it interacts with soil and air.

2.1.1 Agricultural soils

The largest source of GHG emission from Agriculture is Nitrous oxide (N_2O) and it accounts for 38% of the total global emission. Through the process of nitrification and denitrification, it is produced naturally from soil. Agricultural activity which is anthropogenic may add nitrogen directly or indirectly to soils. The use of nitrogen fertilizer, production of nitrogen-fixing crops and forages, retention of crop residues, application of managed livestock manure, sewage sludge and cultivation of soils with high organic matter content are the direct additions. Through indirect additions are surface runoff and leaching of applied nitrogen into surface and ground water, volatilization and atmospheric deposition of applied nitrogen [11]. Other anthropogenic sources of GHG emissions from agriculture include manufacture of equipment, pesticides, fertilizers, on-farm use of fuels and the transport of agricultural products [12]. Emissions of GHG from agricultural soils (N_2O) and enteric fermentation and management of manure (CH_4) linked with livestock production contribute to the largest share in agricultural sector. So, from agricultural sector, sources of GHG emissions are accounted for as follows: Residue burning/forest cleaning (13%), Methane and Nitrous oxide from Management of manure (7%), Methane from Rice cultivation (11%), Nitrous oxide from fertilizers (37%) and Methane from Livestock (32%) [11]. These emissions are expected to increase in future due to high demand for agricultural products and enhanced nutrition [13]. The direct addition of both synthetic and organic nitrogen containing fertilizers will possibly be a key source of rise in emission of N_2O with the highest coming from developing countries that are seen using 36 million tons more than the developed nations [14].

2.1.2 Livestock

Emissions from Livestock constitute 9% of CO2 equivalent obtained from all human related activities and produces 65% of human-related nitrous oxide, and 37 percent of human induced methane, and 64% ammonia especially from manure. Considering agriculture sector, livestock account for nearly 80% of all emissions [15]. All these emissions from livestock make it a major target for mitigation options. Feed produced locally such as grass and other roughage, together with wastes that are rich in nutrient from farms and households when replaced with feed manufactured from feed mills containing some secondary plant metabolites able to reduce the emission of methane gas could lead to negative climate impact.

The natural digestive processes in ruminants otherwise known as enteric fermentation in sheep and cattle account for the key source of methane production under this category hence the second largest source of total agricultural emission with 34% global share and rice cultivation being the third with 11%. Other domesticated animals that also emit methane (methanogenesis) as a by- product of enteric fermentation include Horses, swine and poultry. The estimates of enteric methane from ruminants produced globally are about 80,000 Gg [16].

2.1.3 Management of manure

Handling, treatment and storage (Management of manure) of manure account for 7% of emissions from agriculture. Anaerobic breakdown of manure produces methane (methanogenesis) while aerobic handling of manure produces nitrous oxide (Nitrification) and then anaerobically (denitrification) hence often increased when the available nitrogen exceeds that of plant requirements [12]. Due to high demand expected for beef and dairy products globally especially from the developing world, methane emissions from enteric fermentation are expected to increase by 32% [11].

3. Impact of emerging agricultural contaminants on global warming

The three important greenhouse gases (Methane, Carbon dioxide and Nitrous oxide) are not harmful in naturally occurring quantities for their atmospheric presence helps in sustaining life on the planet when they trap heat energy near the surface of the earth. Concentration of greenhouse gases from both the natural and human factors have been increasing and contributing to Global Warming and Climate Change.

Increase in greenhouse gases may cause tremendous changes to our civilization positively or negatively but the total impact is uncertain. Climate change comes as a result of a warming planet which can affect the weather adversely in many ways. So, as climate changes, extreme weather activities release severe threats on human society. Indicators of global warming include ocean heat content, sea ice, sea level, sea surface temperature, temperature over ocean, temperature over land, tropospheric temperature, snow cover on hills, temperature over land and humidity. It is expected that climate change may cause more floods, storms, droughts, heatwaves and other extreme weathers activities. IPCC estimated that temp may rise from 2 to 6°C within 2021 [4].

Industrial Agriculture is one of the causes of climate change with the practices having impact on it. The currently practiced industrial agriculture with Agrochemicals and monocultures globally is a key contributor to climate change for it causes the emission of Green House Gases (GHG) via changes in land use and soil degradation or losses, via technologies in agriculture and from livestock [17].

According to Food and Agriculture Organization (FAO), Livestock production sector as the major emitter of all the greenhouse gases is responsible for about 18% on one fifth of human-induced greenhouse gas emissions [18]. For instance, in almost every step of egg, meat and milk production in agriculture, greenhouse gases that cause climate change are released into the atmosphere disturbing temperature, weather and health of ecosystem. Mitigating these problems will require changes in agricultural practices and livestock consumption.

Livestock Production as one of the Agricultural food-based industries has been described as leading or major contributor of the anthropogenic source of CH_4 and CO_2 greenhouse gases [19]. They contribute immensely to global warming, pollution and environmental degradation because of the large amount of greenhouse gases produced during the ruminal fermentation of feeds. For instance, anytime a cow burps or passes out gas, it puffs out a little methane which wafts into the atmosphere. Each of these puffs from the cow put together can result to a big effect on climate because methane as a potent greenhouse gas is about 25 times more powerful in trapping heat and increasing earth's global warming than Carbon dioxide on equal mass basis. The livestock sector therefore accounts for about 18% of CH_4 and 9% of CO_2 of all the greenhouse gases emissions [20] hence methane accounts for 50–60% of emitted gases during livestock production [21]. A lot of proposals have been focused on soil and plant production for the reduction of emission from agriculture leaving livestock production which accounts for major amounts of CH_4, N_2O, CO_2 and NH_3 emissions.

Several gases cause chemical reactions that can result in producing other greenhouse gases among other effects and some trap heat energy better than others. Considering the lifetime of greenhouse gases, some persist in the atmosphere for different durations of time and some contribute to global warming due to their long duration [22].

4. Mitigation

There are differences in Global Warming Potential (GWP) and lifetime of greenhouse gases in the atmosphere. One GWP has been assigned to CO_2 and the warming potential of other gases are based and expressed relative to CO_2 GWP [23]. For instance, 1 tonne of CH_4 has a warming effect of about 25 and 72 tons of CO_2 over 100- and 20 year periods respectively according to IPCC. Studies have shown that CH_4 is more potent than CO_2, so reducing CH_4 emission will show more immediate and significant impact on mitigating changes in climate than reducing CO_2 emissions [24] Another potent greenhouse gas is N_2O for it remains in the atmosphere for 114 years [25, 26]) and 298 times as potent as CO_2 over 100 years [27] (see **Table 1** below).

Increased Industrial agriculture is proposed to be a solution to the problems of climate change which is a contributor without its impact being addressed. In the

GHG	Atmospheric lifetime	GWP	GWP (100 years)
CO_2	Centuries to Millenia	1	1
CH_4	About 10 years	72	25
N_2O	114 years	289	298

Source: [27].

Table 1.
Global Warming Potential (GWP) and lifetime of greenhouse gases in the atmosphere.

negotiation for a new climate treaty that has been negotiated to follow the Kyoto protocol in 2012, agricultural practices have been proposed to be a means for climate change mitigation and partly for carbon trading [17].

Livestock farming in Agriculture is one of the largest sources of water contaminant and this contamination maybe the easiest route of emerging agricultural contamination in getting to humans and the eco-system. Animal dung production helps in releasing massive amount of Methane into the environment hence posing challenging situations as intensive farming serves in meeting global food challenges. Also, Algae and Fungi bloom intensifies methane release into the environment, thus having adverse effects on Green-house gases. To mitigate emerging contaminants the following can be employed:

1. Development of good environmental policies to mitigate unwarranted release of emerging contaminants such as standards for water policy, improved testing on pollution and emission, assessments on environmental impact of farms and irrigation systems.

2. Enhancing the intake of digestible forage will mitigate GHG emissions from rumen fermentation and stored manure (For example, to reduce enteric methane emission replace corn silage with grass silage in diet, apply dietary lipids, use legume over grass as it contains more fiber in addition to replacing inorganic fertilizer) [28].

3. Release of pollutants at the source of production should be reduced because of its easy entrance to vulnerable environment.

4. Reduction of the application of fertilizers and pesticides and introduction of natural pest-control methods should be encouraged.

5. Restoration of degraded pastureland by utilization of traditional approaches or techniques.

6. Methanotrophs otherwise known as the methane-eating bacteria found in the ecosystem where methane is produced ensures the conversion of methane into substances such as sugars before being released into the atmosphere. In this way, the methanotrophs help in recycling methane all over the globe.

7. Biochemical method of mitigation of Greenhouse gases: This is the employment of feed supplements that have the potential of reducing methane emission. The bulk of complex molecules contained in ruminant feeds are broken down during fermentation by microbes releasing energy and other chemical compounds [7]. Plant Natural Products (PNP) are engaged to aid in the challenges observed in livestock production where there is wastage of nutrient caused by excess excretion and poor or inefficient digestibility of feeds, emission of CO_2 and CH_4 that results to 2–12% loss of feed energy [29]. These PNPs include Saponins, terpenoids, tannins, flavonoids, phenols, glycosides, alkaloids and essential oils These challenges brought the attention of Biochemists, Nutritionists and Microbiologists to look into the PNP application [30], yeasts [31] and enzymes as additives to feed. This incorporation as additives is meant to modify fermentation kinetics in ruminants and manipulate microbial ecosystems. The primary purpose of these modifications is to improve the utilization of animal feed and digestibility of fibrous feeds, decrease degradability of protein [32], inhibit the proliferation of pathogenic bacteria in the gastrointestinal tract [33] enhance

performance of animals, reduce loss of dietary energy during fermentation in rumen and mitigate CH_4 and CO_2 productions. PNPs have been found to be natural and safer feed additives as they demonstrate vital role in mitigating methane and carbon dioxide productions without affecting fermentation in rumen during their production [6].

5. Conclusion

Emerging Agricultural Contaminants play both positive and negative roles in global warming which leads to the change in climate. The impact can be reduced through mitigation of the underlying causes such as the events that result in high emissions of the greenhouse gases. Climate change is serious and may likely worsen leading to land loss and unpredictable changes that will emanate from natural growing conditions.

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References

[1] Le Treut H., Somerville R, Cubasch U, et al. 2007. Historical overview of climate change. In: Solomon S, Qin D, Manning M, et al (eds.), Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 96).

[2] Forster P, Ramaswamy V, Artaxo P, et al. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon S, Qin D, Manning M, et al (eds.), Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 135-136, FAQ 2.1).

[3] Le Treut H., Somerville R, Cubasch U, et al. 2007. Historical overview of climate change. In: Solomon S, Qin D, Manning M, et al (eds.), Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 115 FAQ 1.3).

[4] Singh, B. R and Singh, O. (2012). Study of Impacts of Global Warming on Climate Change: Rise in Sea Level and Disaster Frequency. In Global Warming-Impacts and Future Perspective. Edited by Bharat Raj Singh Doi:10.5772/50464

[5] World Resources Institute (WRI) (2008) Climate Analysis Indicators Toolkit (CAIT) [January 2008, available online at: http://cait.wri.org/].

[6] Patra, A and Saxena,J (2010). ChemInform Abstract: A New Perspective on the Use of Plant Secondary Metabolites to Inhibit Methanogenesis in the Rumen Phytochemistry 71 (11-12):1198-222 DOI:10.1016/j.phytochem.2010.05.010

[7] IPCC (2007) Summary for policy makers. Climate Change 2007: Synthesis Report. Fourth Assessment Report of the Intergovernmental Panel for Climate Change. [Available online at http://www.ipcc.ch/pdf/assessment-report/ar4/ syr/ar4_syr_spm.pdf]

[8] Snow, DD; Bartelt-Hunt, SL; Saunders, SE and Cassada, DA. (2007) Detection, Occurrence, and Fate of Emerging Contaminants in Agricultural Environments Water. Environment Research Vol. 79, No. 10, Literature Reviews [CD-ROM content] (2007), pp. 1061-1084 (24 pages). Published By: Wiley. DOI: 10.2307/29763261 https://www.jstor.com/stable/29763261

[9] Murnyak, G,. Vandenberg, J., Yaroschak, J., Williams, L., Prabhakaran, K. and J. Hinz, J. (2009)"Emerging contaminants: presentations at the 2009 Toxicology and Risk Assessment Conference," Toxicology and Applied Pharmacology, vol. 254, no. 2, pp. 167-169, 2011.

[10] Boxall, A.B. A. (2012). New and Emerging Water Pollutants arising from Agriculture, in Water Quality and Agriculture: Meeting the Policy Challenge. (OECD report, 2012). Downloaded at *www.oecd.org/agriculture/water*

[11] U.S. Environmental Protection Agency. Frequently asked questions about global warming and climate change: back to basics, p. 3. http://www.epa.gov/climatechange/downloads/Climate_Basics.pdf.

[12] Rosegrant, M. W., Ewing, M., Yohe, G., Burton, I., Huq, S., Valmonte-Santos, R. (2008). Climate Change and Agriculture Threats and Opportunities pp 1-36 http://www.gtz.de/climate

[13] Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui, C. Courbois (1999) Livestock to 2020: The Next Food Revolution. Food, Agriculture, and Environment. Discussion Paper No.28, International Food Policy Research Institute, Washington D.C.

[14] Bumb, B. and C. Baanante (1996) World Trends in Fertilizer Use and Projections to 2020. 2020 Brief #38, International Food Policy Research Institute, Washington, D.C.

[15] Steinfeld H., Gerber P., Wassenaar T., Castel V., Rosales M. & de Haan C. (2006): Lifestock's long shadow. Environmental issues and options. FAO, Rome

[16] Ku-Vera Juan Carlos, Rafael Jiménez-Ocampo, Sara Stephanie Valencia-Salazar, María Denisse Montoya-Flores , Isabel Cristina Molina-Botero , Jacobo Arango , Carlos Alfredo Gómez-Bravo , Carlos Fernando Aguilar-Pérez and Francisco Javier Solorio-Sánchez. (2020) Role of Secondary Plant Metabolites on Enteric Methane Mitigation in Ruminants. Front. Vet. Sci., https://doi.org/10.3389/fvets.2020.00584

[17] Paul, H., Semino, S., Lorch, A., Anderson, B.H., Gura, S., Ernsting., A (2009). (2009) Agriculture and climate change: Real problems, false solutions Preliminary report by Grupo de Reflexion Rural, Biofuelwatch, EcoNexus and NOAH - Friends of the Earth Denmark pp 1-32 http://www.econexus.info/pdf/agriculture-climate-change-june-2009.pdf

[18] Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock‘s long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. xxi. 65 Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock‘s long

[19] Audsley, E and Wilkinson, M. (2014). What is the potential for reducing national greenhouse gas emissions from crop and livestock production systems? Journal of Cleaner Production 73:263-268 DOI: 10.1016/j.jclepro.2014.01.066

[20] FAO (Food and Agricultural Organization). (2013). Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities. Food and Agricultural Organization of the United Nations (FAO) Rome

[21] Mirzaei-Ag, Syed Alireza Sy, Hasan Fathi , Sohrab Rasouli, Mohammad Sadaghian, Mohamad Tarahomi. (2012). Garlic in Ruminants Feeding. Asian Journal of Biological Sciences 5(7):328-340. DOI: 10.3923/ajbs.2012.328.340

[22] McDonald, J. (2018) How Potent Is Methane? FactCheck.org® *A Project of The Annenberg Public Policy Center* , SCICHECK

[23] Paustian K, Antle JM, Sheehan J, and Paul EA. 2006. Agriculture‘s role in greenhouse gas mitigation. Pew Center on Global Climate Change, p. 3.

[24] Moore FC and MacCracken MC. 2009. Lifetime-leveraging: an approach to achieving international agreement and effective climate protection using mitigation of short-lived greenhouse gases. International Journal of Climate Change Strategies and Management 1(1):42-62, pp. 46-47, 49.

[25] Solomon S, Qin D, Manning M, et al. 2007. Technical summary. In: Solomon S, Qin D, Manning M, et al (eds.), Climate change

2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (New York, NY: Cambridge University Press, p. 33 Table TS.2). http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf.

[26] Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 82. http://www.fao.org/docrep/010/a0701e/a0701e00.HTM.

[27] Forster P, Ramaswamy V, Artaxo P, et al. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon S, Qin D, Manning M, et al (eds.), Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 212 Table 2.14).

[28] Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J. & Oosting, S. 2013. Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO2 emissions. Edited by Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar. FAO Animal Production and Health Paper No. 177. FAO, Rome, Italy.

[29] Hristov, A.N, Joonpyo Oh , Fabio Giallongo, Tyler W. Frederick, Michael T. Harper, Holley L. Weeks, Antonio F. Branco, Peter J. Moate, Matthew H. Deighton, S. Richard O. Williams, Maik Kindermann, and Stephane Duval (2015). An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production. PNAS, 112(34) 10663-10668. https://doi.org/10.1073/pnas.1504124112

[30] Elghandour M.Y., , Poonooru R. K., Salem, A.Z., Pandu, R., Iqbal, H., Alberto, B. and Duvvuru, Y. (2018). Plant Bioactives and Extracts as Feed Additives in Horse Nutrition. Journal of Equine Veterinary Science 69(2018): 66-77. DOI: 10.1016/j.jevs.2018.06.004

[31] Shurson, G.C. 2017. Review - Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. Anim. Feed Sci. Technol. 235:60-76.

[32] Salem Mohammed, Leonardo Souza Ahmed Serag, Fernie R. Alisdair, Ferag,A. Mohammed,Ezzat M. Shahira and Saleh Alseekh (2012) Metabolomics in the Context of Plant Natural Products Research: From Sample Preparation to Metabolite Analysis. Metabolites 10(1):37. DOI: 10.3390/metabo10010037

[33] Arowolo Muhammed and He Jianhua. (2018). Use of probiotics and botanical extracts to improve ruminant production in the tropics: A review. Animal Nutrition. 4(3): 241-249. Doi: 10.1016/j.aninu.2018.04.010