Mitigating the Methane Output of Cattle Through Feed Additives

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Abstract

The atmosphere of the Earth is warming at an alarming and unprecedented rate. Methane (CH_4) is one of the most common and destructive greenhouse gasses that contribute to Earth's warming. CH_4 is a major contributor to the greenhouse effect, being 28 times more effective at trapping heat in the atmosphere than carbon dioxide (CO_2). The largest agricultural contributor of CH_4 emissions is cattle. This is due to a biological process carried out by cattle called enteric fermentation. A number of studies have shown that the implementation of algae into the diet of

cattle is a useful mitigation strategy as CH_4 emissions can be reduced 58-86%. The algae used in these studies is called *Asparagopsis taxiformis,* which is not found in Alaska. However, researchers theorize that other species of southeast Alaskan kelps could have similar effects. Sea kelps are prominent in Alaska and are ideal for implementing into cattle feed as well as providing other benefits to fighting climate change. In addition to greatly reducing agricultural methane outputs, sea kelp farms absorb significant amounts of CO_2, helping to mitigate ocean acidification. Southeast Alaska already has a growing interest in sea kelp farms and possesses the ideal climate for growth of sea kelp. Commercial sea kelp farms would be an immense economic boost for Alaska alongside their notable environmental benefits. Implementing Alaskan sea kelp into the diets of cattle would significantly reduce methane emissions, helping to mitigate the damaging effects of climate change.

Introduction

A continuous challenge towards efforts to combat climate change is the emission of greenhouse gases, specifically methane (CH_4). The globe's temperature is rising, and CH_4 is one of the main contributors (EPA, 2019).One of the largest global anthropogenic contributors to CH_4 emissions is cattle (Jones et al., 2021). As the number one source of agriculture-related greenhouse gas emissions, it is vital that their CH_4 outputs be reduced. The CH_4 emissions of cattle can be reduced by altering their diet. The majority of methane output from cattle is caused by enteric fermentation, and by changing their diet, the fermentation can be inhibited. *Asparagopsis taxiformis*, a species of red algae, can be used as a feed additive that has the potential to significantly lower the CH_4 emissions from cattle.

Although *A. taxiformis* is not available in Alaska, various types of sea kelp may similarly reduce the output of CH_4 from cattle, and is grown throughout the Pacific Northwest Coast. In Southeast Alaska, sea kelp farms are already producing a significant amount of seaweed. The industry is projected to grow rapidly, which would massively boost the economy for Southeast Alaska. Throughout this paper, the main topics to be discussed are CH_4's role in climate change, cattle, and enteric fermentation, *A. taxiformis*, sea kelp, and how to integrate this into our local ecosystem.

Climate Change

The Earth's climate is changing at an unprecedented rate, from both anthropogenic and natural sources (NASA, 2021). Climate change is largely caused by the greenhouse effect. The greenhouse effect is warming that occurs as a result of the atmosphere trapping heat that is radiating from the Earth towards space (NASA, 2021). There are various gases that contribute to this effect including, water vapor (H_20), nitrous oxide (N_20), carbon dioxide (CO_2), and CH_4 (NASA, 2021).

One of the most destructive greenhouse gases is CH_4. CH_4 makes up approximately 10% of the global greenhouse gas emissions (EPA, 2019). The fact that CH_4 makes up so much of the greenhouse gas emissions is dangerous because, unlike CO_2, CH_4 is not as easily extracted from the atmosphere through biological processes such as photosynthesis. While CH_4's atmospheric concentration is less than that of CO_2, CH_4 is 28 times more effective at trapping infrared heat over 100 years (IEA, 2021). CH_4 is a potent greenhouse gas that has an atmospheric residence time of approximately 12 years (UC Davis, 2021). CH_4 acts as a blanket to trap heat, causing the atmosphere to warm and bringing about many detrimental impacts on the Earth.

The damaging impacts of global warming on the atmosphere include, global temperature rise, rising sea level, and a loss of habitat (UN, 2021). As shown in Figure 1, the planet's average atmospheric temperature has risen about 1.4 degrees Celsius (ºC) since 1880 (NOAA, 2021). The rise in atmospheric temperature is destructive to the Earth because warmer temperatures change weather patterns and disrupt the usual balance of nature and other forms of life. Global warming causes sea levels to rise through thermal expansion. When the climate is warmer, the heat melts glaciers and ice sheets. Warmer temperatures in the Earth's atmosphere increase the sea level and decrease the amount of habitable land for a variety of species. Of those few who are able to migrate, many will be found in habitats they have never been seen in before due to shifting ranges in response to climate change (NASA, 2020). Climate change poses a risk to the survival of species on land and in the ocean. As temperatures continue to climb, forest fires and extreme weather conditions will occur at much more frequent rates (UN, 2021). *Figure 1. An anomaly graph showing the average surface temperature of the Earth since 1880 (NOAA, 2021).*

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CH_4 emissions come from various sources, such as permafrost, methane seeps, and ruminant digestion. CH_4 is not only produced by the decay of organic matter within the thawing permafrost soils, but can also be generated by natural gases trapped below the permafrost layer being released when the layer thaws (PNAS, 2021). 60 billion tons of CH_4 is buried beneath the Arctic Ocean, holding a large potential to impact the climate significantly (Yale, 2021). CH_4 is also produced by methane seeps, a point where CH_4 escapes from rock below the ocean. CH_4 is often stored in crystal lattices of water called hydrates. When those hydrates melt due to rising temperatures, the CH_4 is released into the atmosphere above. Furthermore, Cattle are the largest producers of CH_4 on the anthropogenic level, ruminant digestion accounts for 4% of global CH_4 emissions (UCDavis, 2019). Of that 4%, 2% of CH_4 emissions are attributed to cattle's enteric fermentation alone (UCDavis, 2019).

Cattle and Enteric Fermentation

As of April 2021, the worldwide population of cattle was estimated to be over one billion (Statista, 2021). Cattle are the number one agricultural source of greenhouse gases in the world, with a single cow capable of producing over 220 pounds of CH_4 each year (Quinton, 2019). In the United States, cattle alone are the top source of anthropogenic CH_4 emissions (Jones et al., 2021). The mass amount of CH_4 that is emitted from these cows is resulting in damage to the overall health of the Earth's biosphere by contributing to global climate change. To combat this issue at the source, the biological process of enteric fermentation must be addressed.

Figure 2. A visual of the biological process of enteric fermentation (FAO, 2021).

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Asparagopsis taxiformis

Table1. A compilation of data regarding the effects of A. taxiformis on cattle CH_4 outputs when integrated into feed at varying levels (Roque & Kebreab, 2021).

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Figure 3. An image of the red algae Asparagopsis taxiformis (Penn State, 2019).

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When integrated into cow feed, the percentage of *A. taxiformis* must be kept to a minimum as cows are relatively picky eaters and will not consume the feed if too much of the algae is present (Kebreab, 2018). When only 1% algae is added into a cow's diet, CH_4 reduction of up to 60% has been shown (Kebreab, 2019). This allows for more cows to be fed the algae without requiring large quantities, making this a practical and cost-effective mitigation strategy. According to these studies, in addition to decreased CH_4 outputs, milk production has either remained steady or has increased with the introduction of *A. taxiformis* to cow feed. In order to implement this mitigation strategy on a large scale, cattle owners must have access to a mass amount of the red algae. *A. taxiformis* is native to subtropical areas such as Australia and the Hawaiian Islands (Smith, 2019). This makes it unrealistic to grow algae like *A. taxiformis* in Alaska, but there are other species of seaweed that are capable of growth in colder climates and may show promise when implemented into the diet of cattle.

Global Atmospheric Benefits

A. taxiformis, the species of seaweed that has been found to cut methane production in livestock drastically, could be vital to total greenhouse gas emissions if utilized correctly. Red seaweed is the only seaweed that successfully mitigates CH_4 emissions, due to other types of seaweeds including brown and green seaweeds not having the same chemical. Most red seaweeds could have a similar effect but *A. taxiformis* is known to be the best at isolating CH_4 out of all known types yet it is not as prominent in the wild.

Livestock accounts for approximately 36% of CH_4 emissions caused by humans. Integrating *A. taxiformis* to their daily diet in controllable amounts would be extremely beneficial to the Earth's atmosphere. It can halt 58-86% of the methane being produced in the cattle's stomach which will prove a dampener on the negative effects of CH_4 being released (Duarte et al., 2017). As a result, nullifying this effect will be important and beneficial to the overall temperature of the Earth's atmosphere.

Figure 4. A diagram of the outcome of mitigating methane emissions
CCA Coalition (2020)
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There are also economic benefits to the reduction of CH_4 expenditure. If the collective effort manages to reduce CH_4 emissions in half by the year 2030, the U.S. will have saved approximately $470 billion globally (CCA Coalition, 2020). Humans can maintain economic stabilization while being cost-effective and spending less on atmospheric damaging processes.

Seaweed farming is an extremely cost effective method and may have many benefits. Most seaweed farms use a red seaweed known as *A. Taxiformis* and distribute harvests to cattle farms to then implement it into their feed. The market for this seaweed and these farms is not exceptionally widespread, and the demand is currently not high regardless, it is a promising industry that may very well be applicable locally.

Local Options

There are numerous red kelps in Alaska that may have similar effects to *A. Taxiformis,* but there is little information on specific types. According to Chief Scientist and Research director, Tiffany Stephens, at SeaGrove Kelp, many red kelps would likely have similar effects and could be used to mitigate CH_4 emissions. Unfortunately there is little research and exposure due to the newness of the industry in Alaska so funding is minimal.
Bromines are the chemical property used to cease the production of CH_4 and scientists can smell the bromines in them. Some red seaweeds species such as *Polysiphonia*, *Pterosiphonia* and *Odonthalia* could be potential seaweeds that work similar to *A. Taxiformis* but have yet to be tested in Alaska. The potential for a full-scale industry locally is substantial, and if research is put into *A. Taxiformis*, it could provide tremendous results and benefits.

Implementing Kelp

Kelp has the potential to be one of the most versatile natural resources to grow on planet earth (Yu, 2018). Implementing kelp into a cow's diet can lower CH_4 emissions by up to 82% (Kebreab, 2021). Reducing CH_4 emissions is the most beneficial step towards promoting the well-being of our planet. By starting seaweed farms in Southeast Alaska, CH_4 emissions have the potential to be reduced immensely, leading to a healthier climate. In Alaska, for several years, there have been commercial harvests of natural beds of seaweeds, mostly for the herring spawn-on-kelp market but also for other products such as plant fertilizer supplements and various bull kelp, *Nereocystis luetkeana,* products for human consumption (Stekoll, 2019). Alginophytes (i.e. alginate-yielding seaweeds) are mainly harvested from wild populations, although some of the raw material that is used in the alginate industry comes from the cultivation of the kelp, *Saccharina japonica,* (Peteiro, 2018). Some species of kelp can grow up to 3 feet per day. Therefore, by using zero fertilizer or pesticides, Alaska can safely operate kelp farms. Despite the current factors hampering the ability to easily create a large seaweed farm empire, the possibility of shedding light on this industry on a much larger scale is there. This opportunity can be a motivator to other states and countries on why utilizing this beneficial and profitable industry is a good idea.

Kelp Farms
The interest in kelp farming has been on Alaskans' mind since the state's first commercial harvest in 2017. Seagrove Kelp, a company located just off of Prince of Wales Island in Southeast Alaska. The main thing when starting a farm such as SeaGrove Kelp is finding a proper location. Despite the multitude of open and untouched areas there are for these farms, there are still a lot of boundaries such as political barriers, economic zones, transportation routes, and untouchable land. Seaweed farms are regulated to not be larger than ⅓ of the bay they are located in. Alaska has also set up a process for the permitting of aquatic farms jointly administered by the Alaska Department of Fish and Game (ADFG) and the Alaska Department of Natural Resources (ADFG, 2019). In 2015, there were 54 permitted aquatic farms, a few of which were permitted for seaweed (Pring-Ham & Politano 2016).

Benefits of Kelp Farming in Southeast Alaska
General kelp farms are used to combat ocean acidification through carbon sequestration (Graham, 2021). Carbon sequestration is when kelp brings in enough CO_2 to help to raise the pH of the water, establishing a healthy environment for shellfish growth. Shellfish growth in Alaska is beneficial to our economy. With kelp farms being built all over Alaska there are more ways than just shellfish growth that keeps the economy and environment booming. Many examples of the environmental significance of kelp farming have to do with cultivation. Kelp cultivation has been widely encouraged to control eutrophication and algal blooms. Results indicate that kelp cultivation slightly increases dissolved oxygen and pH, but reduces dissolved inorganic nitrogen and phosphorus (Jiang, 2020).

Conclusion
Heavy methane emissions are a significant challenge to efforts against climate change, but they can be mitigated. By implementing *A. taxiformis* or sea kelp into the diets of cattle, methane outputs can be significantly reduced. While Alaska does not have *A. taxiformis*, it does have sea kelp with similar effects. To support the increased demand of sea kelp, the numbers of sea kelp farms would have to surge. Aside from their impact by reducing the methane emission of cattle, sea kelp farms also mitigate climate change by absorbing large amounts of carbon dioxide and reducing temperatures. Southeast Alaska, which has an ideal climate to support sea kelp farms, would experience a massive economic boom as a result of this. There is already a growing interest in kelp farms in Southeast Alaska, and increased demand for sea kelp would only amplify it. The benefits of implementing sea kelp as a mitigation measure for methane emissions are substantial for the entire planet, and even more so for Alaska.

Acknowledgements
The Saber-Toothed Salmon would like to thank all of our generous sponsors that helped make this season possible. Thank you to SEALASKA, CCTHITA, Ketchikan Tlingit & Haida, Ketchikan Dry Goods, New York Cafe, Ketchikan Indian Community, Ketchikan PeaceHealth, Island to Island Veterinary Clinic, OceansAlaska, SeaGrove Kelp, F/V Savage, Dicks Autobody, and Tomi Marsh. We would also like to thank Julie Landwehr, Laura Sherrill, Tyler Merle, Caity Pearson, Anne Coss, Riley and Bridget Boss, Alyssa and Mike Lorain, Dan Ortiz, Frankie

Urquhart, Margaret Reich, Jason House, Molly Horne, Katie Lamn, Emma Hopkins, Gracen Loveless, and Tiffany Stephens for assisting with the revisions of our paper.

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