Innovative Use of Texas Agricultural Waste to Reduce Enteric Methane Emissions

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Team/university logo:

RuEFORM

An NC STATE startup

Company Overview

RuEFORM proposes a solution to enteric emissions from ruminant animals (beef, dairy, sheep, goats, and buffaloes): a novel feed additive (FA) that decreases methane (CH_4) production and emission intensity during enteric fermentation in the rumen (forestomach) during feed and forage digestion. The FA will minimize CH_4 emissions per kilogram of milk and meat produced by cattle and boost feed efficiency. The startup hopes to solve a global problem as well as a local one in Texas using agricultural waste.

Our Leadership Team:

The enthusiasm and competence of five Biological and Agricultural Engineering students is the driving force behind the success of RuEFORM. Here are the founders and team members of RuEFORM:

- ***Piyush Patil*** is a Ph.D. Candidate working on sustainable management of animal waste with experience working on biomethane potential analysis and other bioprocesses. This experience will be critical for the start-up to evaluate treatment alternatives.
- ***Carly Graves*** is a graduate researcher working with biochar as a poultry litter amendment to reduce odors and emissions in broiler houses. Experience with air quality will be critical for marketing the need for the product in terms of CH_4 emissions. Hands-on experience in industry at Novozymes will contribute to the large-scale production and processing of our FA.
- ***Victoria Augoustides*** is an undergraduate researcher utilizing biochar to filter hog effluent flushed from barn to lagoon. Familiar with principles of adsorption as well as experience working with starting a start-up will add value to the company.
- ***Rosie Maloney*** is an undergraduate student with a passion and interest for Veterinary Medicine in addition to Biological Engineering. Familiarity with the animal industry will provide knowledge on marketing and animal gut interactions.
- ***Paige Seibert*** *is an* undergraduate student with experience working in a carbon sequestration lab as well as hands-on experience on a dairy farm. This experience will provide a consumer perspective to better market to the target audience.

Our Mission:

At RuEFORM, we serve those who raise and care for ruminants, empowering them to address global challenges and providing tools to actively reshape animal agriculture.

Why We Are Here:

The world's population is expected to reach 9.7 billion by 2050, increasing demand for animal protein [1]. Specifically, the global milk and meat demand from ruminants (cattle, sheep, goats, and buffaloes) is expected by 2050 to increase by 60-80% from levels in 2010 [1]. Cattle production, a major source of revenue in the US, contributes to global warming and climate change by emitting greenhouse

gasses. An increased demand for cattle is expected to result in a 30% increase in global animal agriculture emissions (from 6.7 to 9 gigatons of Carbon Dioxide emitted (GT CO_2e) of which roughly one third is attributed to enteric emissions from ruminants [2].

Texas, with its temperate climate and large land area, is the top beef producing state in the US with 4.6 million beef cows accounting for nearly half of all agricultural revenue [3]. Manure from cattle (beef and dairy) farms produces N_2O and CH_4 (Fig. 1). Enteric fermentation contributes 27% of total CH_4 emissions in the US. In 2020 alone, enteric emissions accounted for nearly one-third of total CO_2 emissions in the US, with beef cows accounting for over half and dairy cows accounting for one-fourth. Furthermore, enteric fermentation is also bad for production in that it reduces up to 12% of an animal's growth and feed energy utilization down to almost a 90% conversion efficiency [4]. Improving feed efficiency reduces feed costs, the largest expense of raising cattle. In addition to affecting the planet, metabolic inefficiencies result in harmful environmental effects that damage public perception of the cattle industry.

RuEFORM's FA seeks to reform the cattle industry for producers, and the environment by reducing CH_4 production and emission intensity in the rumen (forestomach) during feed and forage digestion. The FA will help reduce CH_4 emissions per kilogram of milk and meat produced by cattle and increase feed efficiency. Climate scientists predict a "point of no return" in climate change if global temperatures rise by 2°C. To remain below 2°C, we need to cut GHG emissions by 11 GT of CO_2e per year [2]. RuEFORM believes that by addressing enteric emissions we can make a proactive step towards reaching the 2°C while also helping producers meet the bottom line by providing feed cost savings and the potential for additional revenue generation.

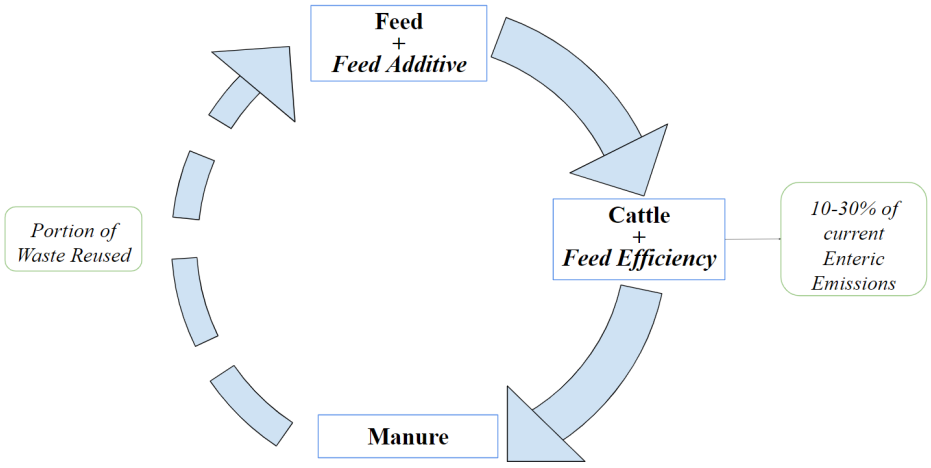

Figure 1. Gaseous emissions produced during cattle production

Carbon credits and increased feed energy utilization are the main financial incentives for cattle producers and integrators to reduce GHG emissions. As aforementioned, CH_4 production in the rumen reduces feed conversion. Improved rumen digestion could increase output and thus profits. Currently, anaerobic digestion provides a significant cash flow from carbon credits. Reduced enteric CH_4 emissions is transitioning towards this incentive. The California Air Resources Board announced an enteric emissions offset program for 2024. This movement wants to reward enteric emissions reductions at $50-65/MMT CO2e [5]. The proposed product can help producers earn extra income and offset FA costs.

Novelty and Innovation

RuEFORM proposes an original FA for ruminants made from Texas agricultural waste residues, targeting reduced enteric fermentation and subsequent CH_4 emissions. While there are no feed additive products on the market specifically targeting enteric CH_4 emissions, current R&D activities have explored products like 3-NOP (3-Nitrooxypropanol), biochar, and yeast. However, enteric emission reductions

ranged from 30-40% and further investigation of the impact of these additives on gut health, meat quality, and feed efficiency are still being evaluated. RuEFORM's FA is based on studies that began in 2012, where researchers discovered the surprising effectiveness of seaweed at reducing CH_4 emissions. The majority of studies utilized the macroalgae species, *Asparagopsis taxiformis* [6-8] and *Asparagopsis armata* [9]. These studies identified that bromoform was one of the key ingredients in the seaweed that resulted in up to a 98% CH_4 reduction. **Despite such amazing results, why has microalgae not been actively incorporated into beef and dairy cattle production? The answer is the high cost of production and processing at scale** [10].

RuEFORM poses a solution by safely incorporating bromoform into the diet of beef and dairy cattle without the high production costs. This is achieved by using biochar, a natural charcoal produced from the controlled burning of agricultural wastes, as a carrier for the active ingredient of interest (i.e. bromoform). Biochar has already been used as a FA for other applications like increasing animal weight gain, feed efficiency, and reducing pathogens and disease. RuEFORM's FA will be engineered to mimic bromoform doses naturally found in seaweed. The bromoform will desorb from biochar in the rumen without negative impacts on the rumen and stomach functionality or meat or milk quality. As compared to seaweed, biochar is much more readily available. Furthermore, biochar is stable, dry, and dense which allows for improved economical production, transportation, storage, and product shelf life, while retaining the required functions and achieving reductions in enteric CH_4 emissions.

We expect RuEFORM to advance the role of Agricultural and Biological Engineering in the sustainable development of global food systems. Methane emissions have been long identified as a major environmental concern in animal production. While there has been much talk in the community, there have not been any readily adopted or available FAs to reduce methane. We hope to improve the public association of animal production with livelihood rather than a detriment to the environment.

Engineering Design

The goal of the company is provide a tool to producers and integrators to improve profitability, animal welfare and environmental impacts. As aforementioned, bromoform (at concentrations 1.3-7.8 mg/g of seaweed) is the active ingredient that functions by disrupting methane producing enzymes in the rumen. Bromoform, when fed alone, may have negative side effects on animal health and/or the quality of the milk and meat due to absorption in the wrong areas of the digestive tract. Delivering this active ingredient to the rumen alone without seaweed is achieved with biochar, as it can be engineered to desorb in the physio-chemical conditions of the rumen. Biochar's large surface area makes it an exceptionally effective adsorbent and it is capable of interaction with a wide variety of chemical species including minerals, vitamins, and drugs [11]. Biochar is highly customizable depending on the engineering application. We plan to adsorb bromoform to the surface of the biochar to replicate concentrations naturally found in seaweed for effective enteric CH_4 reduction. The biochar can be derived from dairy bedding material, agricultural residues like peanut shells, rice husk, corn stover, or woody biomass abundant in the state of Texas.

The objective of proposed experiments is to determine the optimal dose of bromoform that needs to be fed to limit the generation of reductase enzymes that catalyze methane production. These experiments are planned to be carried out using rumen fluid, and digesting a combination of diets in an in *vitro* setting. Another set of experiments will be conducted to determine physical and chemical treatments (i.e. acidification or steam activation) to maximize bromoform adsorption on biochar (Fig. 2). Finally, the feed additive generated will be tested for desorption in the rumen fluid to ensure the required dose of bromoform is delivered in the rumen. Based on the experimental outcomes, a techno-economic evaluation will be carried out to determine the product's market value and process parameters that will maximize profitability.

Experiment 1: Langmuir isotherm for bromoform adsoption to biochar using titration methods

Experiment 2 : Dose response for in *vitro* methane production analysis with rumen fluid

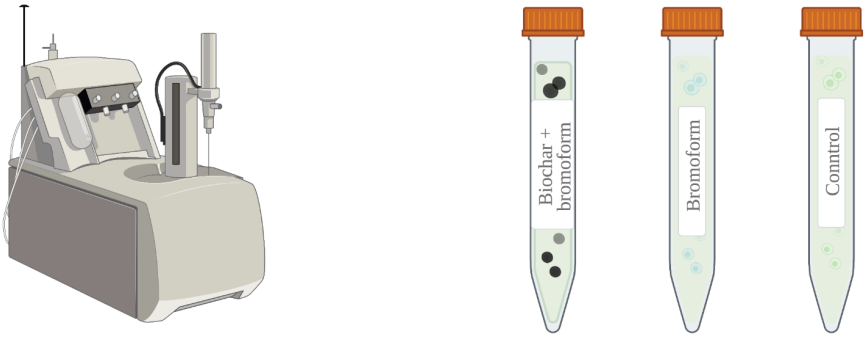

Figure 2. FA experimental setup to determine maximum bromoform adsorption to biochar (left) and methane mitigation of FA in rumen fluid (right)

Business Strategy

RuEFORM's target audience is ruminant animal producers, primarily beef and dairy cattle producers, irrespective of operation sizes. The High Plains region of Texas is one of the largest, most concentrated areas of cattle production in the U.S and a prime market for RuEFORM. The average Texas farmer/rancher is 59 years old [12], therefore some resistance to new products is likely. However, the business strategy for selling directly to farmers will likely be centered around increased feed efficiency and profitability. Additional markets include feed producers, animal operation integrators, as well as stakeholders interested in reducing environmental impacts by enteric emissions. To gain market acceptance, RuEFORM will also establish relationships with state agencies and extension personnel (specialists and agents) who can help advocate the FA benefits to their client base.

As previously mentioned, there is not a direct competitor in U.S. markets selling a FA targeting enteric CH_4 emissions. For that reason RuEFORM has the opportunity to reach the market quickly and occupy a major share. There is a start-up company, CH_4 Global, based out of Australia, who is marketing seaweed as a feed additive. This product is still in the initial development phase; other products that use 3-NOP as the active ingredient are also currently under investigation [13]. In the US the closest market competitor is FA Rumensin by Elenco US that claims to improve feed efficiency but no impact on enteric emissions. Our product is more competitive as it uses a waste resource for feed development, it enhances feed use efficiency and reduces environmental impacts. RuEFORM's business model is centered around:

- **Value Creation:** Manufacture the novel product to optimize use of active ingredients and biochar, while producing customized biochar in-house
- **Product Validation:** Conduct in-vivo and in-vitro (phase 2) trials in partnership with producers and public universities to verify product performance and make improvements.
- **Marketing:** Provide training to extension agents and stakeholder groups to ensure correct product use and performance evaluation. Conduct promotional events and outreach activities to increase product exposure.
- **Revenue generation and sale:** Revenue sources will include bulk sales to cattle feed mills to formulate a feed with the current additive, direct sale to individual ranchers and growers, contract with integrators for FA use in their formulations, and online sales at various ecommerce websites.

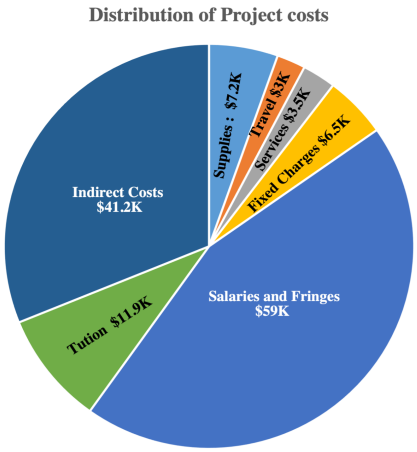

Figure 3. Startup project budget for research period

RuEFORM has already explored funding opportunities to help get the startup off the ground. These include, but are not limited to, the Foundation for Food and Agriculture Research (FFAR) Greener Cattle Initiative awarding $5 million over the next five years to support enteric CH_4 mitigation strategies, as well as the Global Methane Pledge dedicated to reducing CH_4 emissions 30% by 2030.

Social and Environmental Impacts

Texas ranked first in cattle production in the US, supplying almost 15% of the country's beef cattle and valued at over seven thousand million dollars [14]. Cattle have a significant environmental impact, contributing 65% of the livestock sector's emissions [4]. RuEFORM aims to reduce the negative effects of Texas's agriculture by reducing the emissions produced by beef and dairy cattle. As CH_4 is 25 times as potent a GHG as carbon dioxide, enteric CH_4 emissions are a crucial area for innovation [15]. Reducing GHG emissions will improve the environment state of Texas, the US, and the world. Additionally, by reducing this source of GHGs, Texas (specifically the animal agriculture industry of Texas) will improve its public environmental image by becoming part of the solution to climate change instead of further contributing to the problem. The biochar used in the product will also be sourced from local agricultural waste, further improving the efficiency of the process and Texas agriculture. Finally, the use of this product will likely improve feed efficiency. More of the energy ingested by cows can be put towards the cow's growth if it is not being used as much by the gut microbes. With the large agricultural industry in Texas, RuEFORM will be able to make a significant positive impact on the state.

RuEFORM highly values environmental sustainability. The product aims to reduce GHG emissions caused by methanogenic bacteria in ruminants, which also has the potential to improve feed efficiency. If cows can get more nutrients out of the same amount of feed (as less is being used up by microbes), less feed will be required to produce cows of the same size, further reducing the environmental footprint of the industry. Furthermore, as agricultural wastes (such as crop residues or manure) will be used as the biochar feedstock, RuEFORM contributes to the circular economy.

It is also important to take ethical and inclusion responsibilities into account in any company. RuEFORM will conduct trials in vivo before any product is used on live animals. Technology such as fistulated cows will allow access to the authentic rumen microbiota outside of the animal, so the optimal balance of ingredients in the product can be tested for efficacy in the reduction of CH_4 emissions and for a lack of unwanted byproducts. RuEFORM also values the creation of an affordable product. This technology should be accessible to anyone who wants it, whether a small, family farmer or a larger corporate farm.

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