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Why Feed Seaweed? Tacit And Codified Knowledge Networks In The Dairy Industry

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ABSTRACT

While demand for dairy products increases globally, dairy cattle and other ruminants emit over a quarter of total methane emissions through enteric fermentation (Carrazco et al., 2020). A potent greenhouse, methane has eighty times the global warming potential of carbon dioxide over a 20-year period (Black et. al., 2021). Consumer demand for more environmentally friendly dairy products paired with state climate goals has the dairy industry seeking ways to reduce methane emissions. One proposed solution is to feed algae (e.g., seaweed, kelp) to cows, as some live animal trials have shown it can reduce methane emissions by 80% (Stefenoni et al., 2021). Many dairy farmers already feed algae to promote cow health (Antaya et al. 2019). In this thesis I discuss the use of algae as a feed supplement, drawing on interview and survey data collected from conventional and organic dairy farmers, dairy cattle nutritionists, and animal science researchers. I explore their beliefs about algae supplements through a theoretical framework of productivist and constructivist knowledge paradigms- namely tacit and codified knowledge. I investigate what farmers, nutritionists, and researchers know about algae-feed supplements, why they feed or recommend them, and what sources of information they rely on for trusted information about feed supplements. I find that dairy farmers feed algae for herd health reasons and for those who do not, they would need incentives to feed algae for methane reduction. Farmers primarily trust their nutritionist with feed decisions. Nutritionists and researchers obtain information pertaining to feed supplements from animal science journals, and trust data from reputable scientific experiments. This mixed methods study is part of a nationwide multidisciplinary research project investigating the feasibility of using algae feed supplements to reduce methane emissions and improve dairy productivity.

WHY FEED SEAWEED? TACIT AND CODIFIED KNOWLEDGE NETWORKS IN THE DAIRY INDUSTRY

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LIST OF ABBREVIATIONS

ASCO	Ascophyllum nodosum (a brown seaweed species, also known as rockweed)
C3	Coast-Cow-Consumer Project
CH4	Methane
JDS	Journal of Dairy Science
NIFA	National Institute of Food and Agriculture
NOP	National Organic Program
USDA	U.S. Department of Agriculture

CHAPTER I: INTRODUCTION & BACKGROUND

As climate change increasingly threatens global ecological sustainability and human livelihoods, additional attention is being directed to finding innovative mitigation strategies. While carbon dioxide emissions have been the primary focus of carbon reduction targets, methane emissions deserve more scrutiny. Methane has eighty times the global warming potential of carbon dioxide over a 20-year period (Black et. al., 2021) and accounts for about 11% of greenhouse gas emissions in the United States alone (Myhre et. al. 2013). The leading anthropogenic source of global methane is from cattle (Chang et al, 2019), specifically from enteric fermentation, or cow burps, and the methane emitted from cow's enteric fermentation is responsible for 28% of the United States' total methane emissions (Carrazco et al., 2020). Any effort to seriously curb methane emissions necessitates significant changes to livestock production.

Attempts to tackle livestock-derived methane emissions include improving the quality or types of feeds, carefully breeding for improved cattle genetics, manipulating the microbes of rumens, and making production more efficient (Pickering et al. 2015; Haque 2018; Matthews et. al. 2019; Beauchemin et al. 2022). Feed supplements that reduce methane emissions make up a significant number of scientific experiments and include ionophores, essential oils, tannins, saponins, and various microbial enzymes (Antaya et al. 2015; Beauchemin et al. 2022). One area of study is incorporating algae (e.g. macroalgae like kelp and seaweed, or microalgae like phytoplankton) into livestock feed, with some studies documenting dramatic suppression of enteric methane emissions in cattle. For instance, the red seaweed *Asparagopsis taxiformis* has been shown to reduce cattle's enteric methane emissions by up to 98% *in vitro* (Machado et al., 2014; Kinley et. al. 2020) and 80% *in vivo* (Roque et al. 2021; Stefenoni et al., 2021).

While studies of the anti-methanogenic properties of algae are relatively new, seaweeds have been used as livestock feed since antiquity (Allen et. al. 2001; Vijn et. al. 2020). Algal-based feed supplements have been included in livestock feed for decades and are widely available, most notably dried *Ascophyllum nodosum* (Antaya et al. 2019). Currently, there are numerous products on the market in North America identified as dried kelp meal which are made from *Ascophyllum nodosum*, a brown seaweed commonly known as rockweed. Much of this *Ascophyllum nodosum* is wild-harvested in Coastal Maine and Canada. Some companies have even achieved organic certification of *Ascophyllum nodosum* so it may be fed to organic livestock. These feed companies market their dried seaweed meal as a preventative health care input, touting the benefits of the many vitamins and micronutrients the seaweed provides. While *Ascophyllum nodosum* is perhaps the most studied seaweed for agricultural purposes (Allen et. al. 2001), researchers are only recently evaluating its anti-methanogenic potential (Antaya et al. 2019). Additional research is underway on the methane reduction potential of numerous other macroalgae species that can be cultivated in North American waters (Molina-Alcaide et al. 2017; Vijn et al. 2020, Min et al. 2021).

One such study is called “Coast-Cow-Consumer” (C3), a nationwide multidisciplinary study investigating algae species for feed supplements to reduce methane emissions and improve dairy productivity. The team includes over 50 researchers made up of algae scientists, animal scientists, extension specialists, sociologists, and economists from 10 institutions. The project is subdivided into teams: algal characteristics, milk yield and animal welfare, natural resource use, life cycle assessment, extension and education, database management, and last but not least the team I belong to, social and environmental implications. Our team is comprised of social scientists and economists from multiple universities and institutions. The algal characteristics

team screens macroalgae that grow in the Gulf of Maine, as well as microalgae species, for target characteristics; it can be cultivated not just wild-harvested, and it will have benefits to ruminants outside of just methane suppression. The goal of the project is to consider the overall goal of methane emissions reduction by feeding algae to cattle, while finding ways to strengthen rural coastal communities via algae production. Our individual team's goal is to conduct outreach in the dairy industry, by way of interviews and surveys, as well as market research and analysis, and have our findings inform the project at large. My work as a graduate research assistant on this project, supervised by Professor Rick Welsh, became my thesis project, with the additional theoretical framework of dairy farmer, nutritionist, and researcher knowledge production.

I. Background and Scope:

Here I define the scope of my thesis research, outlining who is included and who is not included as research subjects, where the study is geographically situated, and what aspects my research aims to investigate. I focus on the knowledge of specific actors in the Northeast dairy industry: farmers, animal nutritionists, and animal science researchers that inform the C3 project. It's important to provide background on the dairy industry as a whole to better understand the specific context within which these actors from the dairy industry exist.

The dairy industry is a significant sector of study due to the unique economic challenges dairy farmers confront in today's increasingly consolidated food system. The average American dairy farm has turned a profit only two times in the past 20 years, despite milk output increasing by over 30 percent, and despite huge growth in dairy export markets (Lakhani 2023). "Even before the pandemic dairy farmers across the nation were facing the challenges of volatile milk prices that have been dropping for decades, as well as increased competition from non-dairy milk products. This has led to a substantial loss of dairy herds, with the United States losing almost

40,000 dairy herds since 2003" (MENA report, 2021). The extreme consolidation of the dairy industry means that fewer and fewer dairies are able to stay economically viable unless they increase their size and produce more milk (Howard, 2016). In 1987, half of all dairy cows in the United States were on farms with herd sizes of 80 cows or less. By 2012, that midpoint herd size had increased to 900 cows (MacDonald, Cessna, and Mosheim 2016). Despite the attention on the expansion in herd size and the reduction in number of dairy farms overall, small dairies with fewer than 50 cows have persisted (Cross 2006). These smaller farms are able to stay in the game by finding niche markets for their milk, connecting to consumers willing to pay more for certain qualities like prioritizing grazing, selecting less common dairy cattle breeds, and obtaining environmental and/or health conscious third party certifications such as USDA Organic (Welsh and Lyson 1997; Dalton et al. 2006; Feng et al. 2018).

The geographic scope of my research takes place in the U.S. Northeast, and primarily New York State. Dairy is the largest sector of New York's agriculture industry, and the state is the third largest producer of milk in the U.S., and the largest producer of yogurt, cottage cheese, and sour cream (Valdez, 2020), even being called "the Silicon Valley of yogurt production" by the New York Secretary of State (Hamilton and Dudley, 2013). In the past 20 years, dairy farmers in New York State have struggled to keep up with declining milk prices and pandemic-related revenue losses have made it difficult for them to recover (MENA report, 2021). At the same time, corporations at the top of the industry are reporting growth in sales and revenue (Hamilton and Dudley 2013).

In addition to rapid consolidation, depressed milk prices, and pandemic revenue concerns, dairy farmers face concerns like increased environmental regulations involving nutrient management, inflated feed prices, increasing input costs, extreme heat stress, farm labor

shortages, and wage concerns (Hennessy and Feng 2018; Sirtori-Cortina and Elkin 2021; Elkin and Parija 2022; Galt 2023).

Newer pressures include climate targets imposed by states and industries. The United States has re-entered the Paris Agreement, committing to a reduction in emissions of 50-52% below 2005 levels in 2030, and net-zero emissions by 2050 (U.S. DOS 2021). Additionally, the United States was one of the key architects of the Global Methane Pledge, which set a goal of cutting methane emissions at least 30 percent by 2030 from 2020 levels and has been signed by over 110 countries, civil society organizations, and industry organizations (U.S. DOS 2022). Countries joining the Global Methane Pledge are encouraged to develop action plans for achieving their national goals (IEA 2022). The Biden Administration's "US Methane Emissions Reduction Action Plan" represents the federal government's strategy for achieving the Global Methane Pledge domestically (White House 2021). One aspect of the Action Plan focuses on the agricultural sector by employing incentive-based and voluntary efforts to reduce methane emissions. These endeavors include adopting alternative manure management systems, launching the Climate-Smart Partnership Initiative, promoting on-farm renewable energy from methane, and increased investments in agricultural methane measurement and innovations.

State governments are also taking action to reduce greenhouse gas emissions, with New York state adopting especially ambitious policies through the Climate Leadership and Community Protection Act (CLCPA). New York has set greenhouse gas reduction targets of 40% emissions from 1990 levels by 2030, 100% clean electricity by 2040, and no less than an 85% reduction in greenhouse gas emissions from 1990 levels by 2050 (NY Senate Bill S6599, 2019). Along with the CLCPA, New York state adopted a Scoping Plan for achieving these ambitious reductions, including actions related to reducing methane emissions from livestock. One such

action is “Advance Livestock Management Strategies,” which proposes research and incentives into feed additives for methane reduction: “*This strategy acknowledges that additional methane emission reduction may be realized from feed additives developed in the future and supports research to evaluate their potential. Research in combination with incentives may lead to substantial reductions in emissions*” (NYS Climate Action Council 2022).

Barriers to adoption of new technologies to suppress methane emissions may include accessibility and availability of the technology, safety to the animal and workers, cost, conflicting or redundant regulations, lack of technical support during adoption stages, and variations in production systems and values of producers (Beauchemin 2022). The C3 project intends to identify the barriers of highest concern to dairy farmers to discern where to focus research efforts, so that the greatest impact is achieved in lowering barriers.

Where do dairy nutritionists fit in to this? Most of the dairy nutritionists I met and spoke with for this research hail from land-grant universities, where they obtained masters or doctorate degrees in animal or dairy science. Land grant universities were established starting with the 1862 Morrill Act which allowed land to be sold by states to fund land-grant schools. This act also established the US Department of Agriculture (USDA). The Hatch Act of 1887 provided additional funding to land-grant schools to establish experiment stations, and the 1914 Smith-Lever Act established the county extension system (Hassanein, 1999). This was the beginning of scientific experiments and research into making dairy farming more efficient which consequently led to the consolidation of farms and milk processing facilities (Welsh 1995). This dramatic change in production style made dairy farms highly specialized, requiring new inputs and technologies. As farmers increased their reliance on outside inputs, they also increased their

reliance on outside advice – people who can recommend inputs and create complex feed rations for their cows.

There are many pieces of the dairy industry that influence its social, economic, cultural, and political landscape. This thesis does not analyze the entire industry, and particularly omits the role of consumers, retailers, distributors, milk buyers and cooperatives, input salespeople, the FDA, USDA, or the National Dairy Promotion and Research Board, Dairymen's Associations, and notably this research does not include the experiences and perspectives of farmworkers who feed, milk, and otherwise care directly for the animals. The scope of who is involved is limited by the questions I ask, which examine feed decisions on dairy farms. While the availability, safety, and price of feed supplements and feed commodities is largely determined by forces outside of the scope of my research, feed decisions and feed purchases are made by dairy farmers and their nutritionists.

II. Research questions:

1. What do dairy farmers, dairy nutritionists, and animal scientists know about algae-based feed supplements?
2. Why do farmers feed or not feed algae-based supplements, and why do nutritionists recommend or not recommend them?
3. Who or what sources do farmers, nutritionists, and researchers rely on for trusted information about algae-based feed supplements? Which forms of knowledge are drawn on for this trusted information?

III. Overview:

To address my research questions, I first present relevant literature in chapter two, in two parts: scientific literature on algae-based feed supplements and sociological literature on knowledge production. I highlight the existing gap of dairy nutritionist perspectives on algae-based feed supplements and explore this in relationship to our understanding of codified and tacit knowledge. In chapter three, I describe the methodology utilized in this research, outlining focus group interviews with dairy farmers, a survey of dairy nutritionists, and follow up individual interviews with nutritionists and researchers. Within each of these, I elucidate on the sample selection and characteristics, how the research was conducted, and how data was collected and analyzed. This chapter ends with a section on my positionality as a researcher and how it informed this project. In chapter four, I discuss the results of the focus groups, survey, and interviews. The chapter is grouped into three main areas of findings: (1) why farmers feed or don't feed seaweed and what farmers, nutritionists, and researchers know about algae-feed supplements (2) knowledge sources and who is trusted, and (3) biases and barriers in research. In chapter five, I summarize key findings, study limitations, implications for practice and policy, future research, and conclusions.

CHAPTER II: LITERATURE REVIEW

I: Algae as a Livestock Feed Ingredient

Livestock farmers in coastal regions of the world have fed seaweed to their animals since antiquity, collecting it or allowing the livestock to graze along the shoreline (Allen et. al. 2001; Makkar et al., 2016; Vijn et. al. 2020). There are also reports of it being preserved and fed to livestock during the winter in coastal regions, when other forage was not available (Evans and Critchley, 2014). To this day, there are farmers in Northern Scotland who graze their sheep almost entirely on seaweed, and the mutton is prized for its unique flavor (Henton, 2022). While the relationship of livestock and macroalgae in coastal areas is clear, feeding it to livestock outside of a coastal geographic context is relatively new. In the early 1970's, several businesses in coastal New England and Canada started wild-harvesting a brown seaweed called rockweed (*Ascophyllum nodosum*), drying, then powdering the product, and marketing it to livestock producers as a nutritional supplement called "dried kelp meal". This remains the primary macroalgae species fed to livestock in the United States and Canada today.

Research on the herd health and production benefits of algae began as early as the 1940's, when scientists fed giant kelp (*Macrocystis pyrifera*) to calves and cows at the University of Maryland. The article noted that "because of claims made and the fact that many dairymen have purchased kelp meal…it seemed practicable to conduct an investigation" (Berry and Turk, 1944). After feeding it at a 4% inclusion rate to a diverse and large number of dairy cows for two gestations, they concluded that feeding kelp to dairy cattle did not improve growth, reproduction, milk production, or feed efficiency. Notably, this study did not use *Ascophyllum nodosum*. Since then, it has been the most widely researched seaweed for agricultural applications (Senn 1987) and contains high concentrations of vitamins and minerals (Antaya et al. 2015; Makkar et al.

2016). *Ascophyllum nodosum* also contains bioactive compounds such as polysaccharides, antioxidants, peptides (Allen et al. 2001; Connan et al. 2004; Antaya et al. 2015;) and phlorotannins which have important antimicrobial and antidiabetic properties (Wang et al., 2009; Lee and Jeon, 2013; Belanche et al., 2016; Zhou et al., 2018; Brito, 2020).

In the early 2000s, researchers applied *Ascophyllum nodosum* extracts to pastures and found it reduced the toxicity of endophyte-infected fescue (Saker et al. 2001; Fike et al. 2001). Studies feeding *Ascophyllum nodosum* to livestock have reported improved resilience to heat and cold stress (Allen et al., 2001), increased immune function (Allen et al. 2001, Saker et al. 2001), weight gain (Turner et al., 2001), and reduced stress from transport in lambs (Archer et al. 2007), as well as improved production efficiency in dairy cows (Antaya et al., 2015; Antaya et al., 2019).

Other studies have not seen an effect on heat stress in dairy cows fed *Ascophyllym nodosum* (Pompeau et al. 2011) or animal performance (Antaya et al. 2015) but have noted that feeding it can reduce total dry matter intake (Heins et. al. 2015) or lead to higher iodine concentrations in milk (Castro et al. 2011; Antaya et al. 2015). Too high of iodine concentrations could pose a risk to humans, however American diets tend to be deficient in iodine. Therefore, supplementing cow's diets with *Ascophyllym nodosum* could increase iodine levels in humans that consume milk, and prevent deficiencies in pregnant women (Brito, 2020) providing a possible health claim for dairy marketing (Chaves Lopez et al. 2016). Although some brown seaweed species accumulate arsenic, transfer of arsenic to milk when feeding *Ascophyllym nodosum* is insignificant (Silva et al., 2022).

Ascophyllym nodosum is commonly used by organic dairy farmers as a livestock feed supplement (Hardie et al. 2014; Antaya et al., 2015; Sorge et al. 2016; Brito 2020; Snider et al.

2021), as they claim it improves body condition, decreases somatic cell count, eliminates reproductive issues, reduces pink eye infections, and assists with fly control. Organic farmers are not permitted to use many synthetic medications that conventional farmers would use to treat these issues, therefore feeding *Ascophyllym nodosum* may be used in place of antibiotics (Brito, 2020). Unfortunately, scientific studies have not been able to prove many of the benefits that farmers have experienced anecdotally. While many organic farmers have observed improvements in pink eye when feeding *Ascophyllym nodosum*, few studies have tested this, and the mechanism of action is not known. One experiment found no link between feeding *Ascophyllym nodosum* and reduced pink eye (Sorge et al. 2016). However, the study only used 6 cows, and many of the cows used had unusually high baseline levels of iodine. The study also used conventional confined cows, even though it is typically organic farmers that feed algae. Despite the lack of scientific support, some organic certifiers recommend supplementing with "kelp" (PCO Guidance, n.d.). Leading seaweed livestock supplement firms make marketing claims around the health and wellness of animals, some of which lack scientific evidence (Original data compiled by Ryan Fitzgerald).

Recently, the focus of research has shifted away from potential herd health benefits of algae supplements to focus on reducing carbon emissions. One branch of this research is how cultivating seaweed and kelp can capture carbon, removing it from the atmosphere (Krause-Jensen and Duarte, 2016). The other branch focuses on reducing the enteric methane emissions (burps) of livestock, preventing the release of greenhouse gases to the atmosphere in the first place. Efforts to tackle methane emissions include improving the quality or type of feed, carefully breeding for improved genetics, and manipulating the microbes of rumens (Pickering et

al. 2015; Haque 2018; Matthews et. al. 2019) and more recently, including macroalgae in the diet.

Over 40 red, brown, and green macroalgae species have been studied for their potential to reduce enteric methane emissions (Machado et al., 2014; Maia et al., 2016; Bikker et al., 2020; Sofyan et al., 2022). The level of enteric methane reduction achieved varies greatly among species (Min et al., 2021; Roque et al., 2021; Stefenoni et al., 2021; Glasson et al., 2022). Feeding the brown seaweed *Ascophyllum nodosum* has not been shown to reduce methane emissions (Belanche et al., 2016; Min et al., 2021). While some red macroalgae like *Chondrus crispus* and *Palmaria palmate* have little to no reported effect on methane reduction (Kinley et al., 2016), several experiments have shown that the red macroalgae *Asparagopsis taxiformis* has a huge impact; reducing cattle's enteric methane emissions by up to 98% *in vitro* (Machado et al., 2014; Kinley et. al. 2020) and 80% *in vivo* (Roque et al. 2021; Stefenoni et al., 2021; Sofyan et al. 2022). The mechanism of action that explains the success of this species over others in reducing methane emissions is due to its higher bromoform content. However, bromoform can be harmful to humans at certain levels, so longer term studies are needed to prove its safety (Vijn et al., 2020; Glasson et al. 2022). Additionally, a few studies noted a decreased dry matter intake (DMI) in dairy cows fed *Asparagopsis taxiformis* (Roque et al., 2019, Stefenoni et al., 2021) which could impact their performance. One of the primary obstacles for expanding feeding of *Asparagopsis taxiformis* is basic: it only grows in the wild, in tropical waters.

Even if studies show that seaweed species that reduce methane emissions are effective and safe to use long-term, that benefit alone may not be enough to encourage widespread adoption of the technology. The supplement would need to be cost effective for the producer, either through incentives or direct payments to farmers, or by having secondary benefits such as

increased milk production or reduced antibiotic use (Vijn et al., 2020). The next section of the literature review will discuss tensions between farmer knowledge and expert knowledge.

II: Tacit and Codified Knowledge

As expressed in the prior section, some farmers observe benefits from feeding seaweed-based supplements that cannot or have yet to be verified by modern scientific studies, such as the observation that feeding dried "kelp powder" (the brown seaweed *Ascophyllum nodosum*) helps get rid of pink eye in a herd. Farmers may state that they *know* that feeding kelp works, but they may be able to explain *how* or *why* it works. In scientific literature these types of statements are considered anecdotal evidence. Enteric methane emissions reduction is not something that can be easily observed by farmers, but it can be measured by scientists using specialized equipment. This scientific evidence is then communicated linearly via academic journal articles, trickling down eventually to the individual farmer through knowledge brokers such as extension agents (Wood et al. 2014; Noe et al. 2015). A key focus of this thesis is the relationship between farmer knowledge and scientific knowledge regarding algae-based feed supplements for livestock to reduce methane emissions and improve herd health.

In this section I discuss the objectivist, or productivist epistemological approaches inherent in the U.S. agricultural research system, in conversation with constructivist understandings of agricultural knowledge, and how a deeper understanding of these epistemic tensions can strengthen modern research projects. In this thesis, I refer to dairy farmers as "farmers" and animal scientists will be referred to as "researchers". The terms "advisor", "intermediary", and "knowledge broker" are used interchangeably to refer to dairy nutritionists, veterinarians, and extension agents. This section will also consider several terms referencing

farmer's knowledge, each of which carry a slightly different meaning, and will help contextualize the use of these concepts throughout the paper.

Where does the perceived dichotomy between farmer and expert knowledge begin? In western epistemology, we can begin by considering early philosophers such as Francis Bacon and Rene Descartes. Bacon believed that the natural world is made up of laws of nature, and that understanding these laws would allow one to dominate it. He felt that the only people who could establish a full and accurate understanding of nature was the scientist, whose detached logical reasoning resulted in unbiased studies. Similarly, Descartes understood nature as machine - if scientists could comprehend the rules governing nature, nature can be made orderly and controllable, or rational. He believed that knowledge is acquired through standardized research design and systematic measurement to test hypotheses, including replication of studies. Anecdotal evidence and variations due to local context were considered contaminating to the accuracy of the science (Hassenein, 1999 p. 16). Therefore, the ideal scientific studies could be completely generalizable to any location, and experiments must be detached from local contexts. In many respects, this is largely how scientific experiments are still conducted today. The positivist approach aspires to eliminate social and cultural factors present in the creation of knowledge, as perspectives and identities are viewed as errors or biases to avoid (Curry and Kirwan 2014). The farmer then is viewed as unscientific, and their observations are too localized and ungeneralizable (Noe et al. 2015).

In his book *The Tacit Dimension*, Michael Polanyi defines tacit knowledge, and contrasts this with codified or explicit knowledge. Explicit knowledge refers to standardized knowledge that can be easily shared and explained across various media and is seen as objective and rational. Knowledge exists independently from local context. Modern scientific information

would be considered codified or explicit knowledge. Tacit knowledge on the other hand is knowledge that comes from personal experience that is context dependent. Tacit knowledge is summarized as "we can know more than we can tell" (Polanyi, 1966). It is much harder to communicate tacit knowledge on a large scale, as it is best disseminated through shared experiences, conversations, and physical proximity (Morgan and Murdoch, 2000). In the context of farming, this means a farmer knows that something works without knowing exactly why it works. Storper discusses a "tug-of-war" between codified knowledge and tacit knowledge, noting this tension shapes the geographical distribution of knowledge (Storper, 1996).

Many academics in the 20th century have questioned this dichotomy and hierarchy between "unscientific" and "scientific" knowledge using various approaches and theories, arguing that science is created and not necessarily objective, also known as constructivism (Hassenein 1999; Curry and Kirwan 2015). Constructivist epistemologies value the presence of social forces, power dynamics, and cultural contexts within knowledge (Bourdieu 2000; Foucault 2001). They view positivist approaches to understanding the world as weaker and more imperfect than constructivist views, as constructivism maintains the complexity of problems, and values the links between variables (Curry and Kirwan 2014; Wood et al. 2014). In the late eighties and early nineties feminist frameworks of the sociology of science emerged, affirming the legitimacy of personal standpoint and experiences as sources of knowledge, some specifically noting the importance of on-farm gendered divisions of labor (Feldman and Welsh, 1995). Scholars developed terms inclusive of diverse standpoints, including working knowledge (Harper, 1987) and situated knowledge (Haraway, 1988).

Jack Kloppenburg also follows a constructivist, feminist lens, focusing on local knowledge. Local knowledge is similar to the theory of tacit knowledge, which Kloppenburg

defines as practical, sensuous, and personal skill that develops with careful attention to a specific location (Kloppenburg, 1991). He felt that "there are multiple ways of knowing the world" and that science does not have a monopoly on knowledge (Kloppenburg, 1991 p. 102). Kloppenburg's centering of local knowledge challenges the hierarchy of knowledge production in agriculture (Flora 1992; Šūmane 2018). Like with tacit knowledge, context is critical for the creation and reproduction of knowledge. Farmers' relationships with their land and animals develop slowly over time, from observing patterns season after season. Notably, local knowledge is adapted to place but is not created without interactions with other people; localized knowledge can be socialized through horizontal knowledge sharing networks, from farmer to farmer (Hassanein and Kloppenburg 1995). David Orr added the dimension of time into his qualification of scientific versus local knowledge. He noted that local or working knowledge is rooted in place and takes a long time to obtain, calling it Slow Knowledge (Orr, 1996). He contrasted this with quick fix technological approaches, or Fast Knowledge.

There is no singular definition of tacit knowledge. For the purposes of this thesis, I use the term to refer interchangeably to working, local, implicit, intuitive, and slow knowledge. This is a similar approach to other scholars such as Morgan and Murdoch (2000). Other scholars make distinctions between all of these terms. For example, Curry and Kirwan see local knowledge as context dependent but known and articulated, while tacit knowledge remains unstated. They also identify six separate types of tacit knowledge: customs, savoir faire, folklore, identify, roles, and discourse (Curry and Kirwan 2014). Lejeune (2011) notes that tacit knowledge cannot be formalized or codified, but that local knowledge can be.

How is tacit knowledge applied in agricultural contexts? Approaches to local, tacit knowledge in an agricultural context can be seen in the field of agroecology, which combines

indigenous or traditional knowledge about agriculture with applied ecology and agronomy. While agroecology acknowledges the importance of scientific research, it cautions against promoting technological fixes. Instead, agroecology follows a set of principles, which differ according to context. As agroecologists Rosset and Altieri explain, “It is not an agriculture of inputs but rather of processes” (Rosset and Altieri, 2017). The nucleus of knowledge in agroecology is the farmer, and farmer-to-farmer networks (Gleissman, 2015; Rosset and Altieri, 2017). Each farm is seen as its own agroecosystem in which humans are seen as part of the ecology. Solutions to on-farm problems are found in place, on-farm and from neighboring farms dealing with similar issues. Research in the field of agroecology includes the participation of farmers or is co-led by farmers (Rosset and Altieri, 2017). In other words, it is focused on grassroots networks of knowledge sharing instead of top-down, linear approaches to technology adoption.

In the field of sustainable agriculture, there are various frameworks and approaches to knowledge and practice. Green productionism is the use of “greener” inputs as a substitute for a conventional input to improve a problem, instead of changing the overall structural causes of a problem (Welsh, 1995; Noe et al. 2015). For example, monocultures make plants vulnerable to pests. Conventional agriculture uses pesticide applications to kill the pests, but this has negative environmental and health externalities. A green productionist approach would be to replace a conventional pesticide with a more benign input, as seen in modern organic farming. This does not address the cause of pest pressure, nor does it look to the farmer’s historical knowledge of place for complex answers. An agroecologist would use biodiversity to combat this, increasing natural predators for a pest and reducing the farm’s vulnerability to a pest. The United States’ agricultural system has shunned local and tacit knowledge production and encouraged the use of

one-size fits all agronomic solutions – seen as rational and scientific (Kloppenburg, 1991; Feldman and Welsh, 1995; Welsh, 1995). Cornelia Flora writes, “Farmers are becoming interchangeable, as knowledge of the local conditions is less relevant than following best management practices and package directions” (Flora 1992, pg. 93).

How did the idea that knowledge should be based on rational, scientific proof get codified into the agricultural system we have now? Starting in the late 19th century, a series of laws on the federal and state level laid the foundation for the three-pronged approach to agricultural science made up of teaching, research, and extension (Hassanein, 1999). Codified into law starting with the 1862 Morrill Act which allowed land to be sold by states to fund land-grant schools and establishing the US Department of Agriculture (USDA), followed by the 1887 Hatch Act giving more funding to land-grant schools to establish experiment stations, and the 1914 Smith-Lever Act which established the county extension system. “Thus, only a little more than a century ago, a system in which farmers relied primarily on themselves and their neighbors for the knowledge they needed was replaced, and agriculture became a subject of publicly supported, scientific education, investigation, and dissemination in the United States” (Hassenein, 1999 p. 12). Farmer’s tacit knowledge was replaced by external specialist adviser knowledge, codified by land-grant institutions (Curry and Kirwan 2014).

Recently, agricultural scholars are beginning to study actors in this knowledge chain other than scientists or farmers. This includes advisors, social scientists, extension specialists, nonprofits, agrarian civil society groups, conservation district technicians, and even websites and social media influencers (Rust et al, 2022). These intermediaries can act as translators, communicating new research to farmers and equally important, incorporating farmers’ concerns and observations into their work. These intermediaries, or “knowledge brokers” may be

especially important to enable an iterative process in which farmers and researchers continue to learn about each other's work, and innovations arising from such work (Rust et al. 2022). The research conducted by the C3 project's researchers adds to scholarship on intermediaries because instead of simply developing a new technology and asking dairy farmers to adopt it, they are studying a current agricultural practice and wanting to understand and measure it. The intermediaries on the project, in this case social scientists, animal scientists, and seaweed scientists are approaching dairy farmers and nutritionists and trying to understand why they use or do not use algae feed supplements. This research somewhat flips the script of the productivist way of conducting agricultural research but does not subvert power structures entirely. The social science team in the C3 project, which includes me, views surveys and interviews of farmers and advisors as a means for incorporating their voices into the research. However, these methods could also be construed by critics as extractive of farmer's tacit knowledge, built from years of experience, and attempts to scientifically "prove" that knowledge in order to legitimize it.

These lines are more blurred than they are defined. While it's easy to separate actors on this knowledge chain between farmer (tacit knowledge), intermediaries (knowledge brokers), and scientists (codified knowledge), the differences between these knowledge types are simplistic – scholars must look beyond the binary and in the overlapping areas of shared knowledge (Agrawal 1995). Scholarship on farmer knowledge shows that farmers around the world do not necessarily allow codified knowledge to go unchallenged, and they incorporate and choose from various and sometimes conflicting information sources – from their own tacit knowledge produced over time to codified, data heavy research papers (Fonte 2008; Ingram 2008; Kaup 2008; Lyon et al. 2011; Wood et al. 2014). Research has shown that farmers draw from every knowledge source they have available to conduct their work, and many farmers hold varying

identities which inform their experiences and access to information. Dairy farmers who obtain higher degrees such as PhDs in Animal Science are a great example of this. The productivist approach to understanding agriculture, reproduced in land-grant universities, is taught and internalized by farmers into their own understanding of what they know (Šūmane et al. 2018).

It is also important to examine the intermediary's standpoint as they may be coming from an academic-heavy background without applied farming experience, and their sources of funding (government, grant funded, etc.) could influence their communication and their perceived trustworthiness (Rust et. al 2022). Exchanges between farmers and intermediaries have inherent power imbalances, which also affects whether or not farmers perceive them as trustworthy (Ingram 2008). I must also acknowledge that research incorporating on-farm practices and technologies relies on the tacit knowledge of farmers, even while the structure of codified knowledge production undervalues it (Welsh 1995; Rodrigo 2010; Šūmane et al. 2018). Tacit knowledge can be co-opted by scientific research and codified without full appreciation for the time and effort that went into obtaining said tacit knowledge.

Much of the literature on tacit knowledge in agriculture focuses on sustainable and alternative agricultural networks (Hassanein 1999; Kloppenburg, Curry and Kirwan 2014). Morgan and Murdoch argue that conventional farmer's knowledge tends to be aligned with codified or explicit knowledge while organic farmers are more likely to be associated with tacit, local knowledge (Morgan and Murdoch, 2000). They associate the shift from tacit knowledge to codified knowledge with social and economic consequences from farmer's reliance on external sources of information rather than their inherent knowledge of their farm (Morgan and Murdoch, 2000). There are arguments that favor constructivist forms of knowledge in sustainable

agriculture specifically, centering the importance of social and economic contexts that differ from conventional agriculture (Adler 2002; Cleveland 2001)

It is insufficient to equate conventional agriculture with positivism and sustainable or alternative agriculture with constructivism. Tacit knowledge is present in conventional agriculture despite the influence of productivist epistemologies, and codified knowledge is very present in alternative farming networks as well. Kings and Ilbery (2010) found no relationship between sustainable farmers' practices and their adherence to constructivist or positivist knowledge. In their case studies, both organic and conventional practitioners employed a mix of positivist and constructivist knowledge, and never just one or the other. Examples of tacit knowledge are more readily seen in alternative agriculture systems, partially due to the gaps in research and funding that necessitate farmers rely on and share their tacit knowledge. Informal or tacit knowledge can compensate for gaps in codified knowledge, especially when public agricultural knowledge systems are weakened or underfunded (Šūmane et al. 2018).

Farmers are not a monolith and are not defined by their production systems. The huge variation in farming production styles, geographic locations, and individual experiences of farmers naturally indicates a diversity in thought for how to best solve farm problems. In the case of my research, there are organic and conventional dairy farmers in the northeast, and within those categories there is a large variance in herd size and reliance on industrial agricultural solutions. I take a co-constructivist view throughout this thesis, treating both scientists and farmers as experts (Noe et al. 2015), which is why I chose to avoid the term "expert" when referring to researchers. I also view farmers as scientists in their own right, so have avoided referring to codified knowledge simply as "scientific". My thesis builds on existing rural sociologist's scholarship on knowledge hierarchies in agriculture, both conventional and

sustainable, by identifying the tacit and codified forms of knowledge dairy farmers, nutritionists, and researchers rely on to make feed decisions, and how actors are linked through information sharing and systems of trust.

CHAPTER III: METHODOLOGY

Our interviews and surveys focused primarily on dairy farmers and dairy nutritionists in the Northeast United States. This geographic area was selected based on the scope of the universities and research partners involved in the Coast-Cow-Consumer (C3) project. As the C3 project continues, the researchers intend to widen their geographic scope nationwide. While year 1 and year 2 of the study were situated primarily in the Northeast, and thus may not apply to Western regions of the U.S., it's important to note that these states provide excellent case studies for research on algal-based livestock feed supplements. Maine is the locus of seaweed aquaculture on the East coast, and many algae products marketed to the livestock industry originate in Maine. New York, Vermont, and Maine also have vibrant dairy industries and research universities that provide initial and continued education for farmers, advisors, and animal scientists.

In this section I discuss the methods used by the social science team, including myself, in chronological order of their design and implementation. First, the social science team conducted focus group interviews of dairy farmers to gain background information and deeper insight into where the research project should focus. The focus groups elucidated the importance of dairy nutritionists, and so we developed and implemented a survey of dairy nutritionists at the 2022 Cornell Nutrition Conference in Syracuse, New York. Lastly, I conducted one-on-one interviews with dairy nutritionists and researchers to deepen the findings from the survey. I conclude this section with self-reflexive remarks on positionality.

I. Focus Group Interviews of Dairy Farmers

A focus group interview is an interview of a group of individuals that have something in common that is of interest to a social science researcher. The researcher takes on the role of

facilitator in the focus group, mediating discussions and keeping conversation going, if need be, but allowing for conversations to occur without too much intervention. Conversation amongst participants can create emergent properties, enriching datasets. Focus group methodology is often used by social scientists towards the beginning of large research projects in order to solicit feedback from target groups, and to incorporate that feedback into the research design. Ideally, this is an iterative process, highlighting possible blind spots in the research questions. Focus groups can save the researcher time and travel resources because it reduces the total number of interviews that must be scheduled and conducted. The group setting can also help make participants more comfortable and willing to share. Furthermore, it can remind individuals of details they might not otherwise recall and provide them opportunities to respond to one another (Adler and Clark, 2015).

The social science team determined that focus group interviews of dairy farmers would be the most helpful course of action to launch the social science research on the C3 project. As dairy farms are often geographically isolated from other farms, located in rural areas away from cities, and demand dairy farmer's undivided time and attention, in-person focus groups located in dairy regions would help encourage turnout.

Personnel from Maine and New York State cooperative Extension Services and UVM College of Agriculture helped identify conventional and organic dairy farmers in the Northeast United States to be interviewed. An incentive of $100 was paid to all interviewees and interviews lasted approximately one hour. Institutional Review Board approval for this study was granted by Syracuse University. Focus group interviews employed a structured interview guide (appendix I) leaving room for discussion amongst participants.

All interviews took place in-person, conducted by Professor Rick Welsh and graduate student Marie Claire Bryant, and were voice recorded with participant permission. When focus group participation was not possible due to the farmer's location or schedule, individual interviews were conducted by Rick or Marie Claire. In total, Rick and Marie Claire interviewed 27 farmers through 4 focus group interviews and 3 individual interviews. They conducted one conventional and one organic focus group interview each in Maine and New York. Additionally, they interviewed one organic farmer in New York and two organic farmers in Vermont.

Following the interviews, I transcribed the audio files of the recorded focus groups, removing participant names for anonymity. Using the qualitative research protocols outlined by Adler and Clark, (Adler and Clark, 2015), I analyzed the transcriptions using standard qualitative analysis methods of data reduction, data display, and conclusions drawing. I reduced the data by reviewing responses to interview questions and searching for common themes and patterns. Once categories emerged from the transcript data, I displayed the data through the process of cutting and pasting quotations from the subjects for each question asked. This display helped efficiently perceive, understand, and summarize the observations, experiences, and attitudes of the interviewed subject regarding the research topic, and thereby draw conclusions.

Table 1 summarizes the number of milk cows on participating farms using the lowest and highest number reported per group. The average herd size of the organic dairy farms is consistent with organic herd sizes across the Northeast, as organic dairy farms in the northeast average 53 cows compared to an average of 381 cows for farms in the West (USDA ERS, 2011). The conventional dairy farms participating in the New York focus group had larger herd sizes than the is typical for dairy farms in the state. According to the most recent U.S. Census of Agriculture, 283 farms report herd sizes over 500 milk cows, while 4,087 farms report herd sizes

less than 500. Most common are farms that have herd sizes between 20 and 100 cows (USDA NASS, 2017). While herd sizes in Maine trend smaller than in New York, the conventional farmers in the Maine focus group reported herd sizes that are larger than the average Maine dairy farm. Only 77 dairy farms in Maine report herd sizes larger than 100, while 373 dairy farms report herd sizes smaller than 100 (USDA NASS, 2017). One possible explanation for this is that participant farmers were identified by extension agents and researchers, who potentially are more likely to work with larger farms. In the future, it is imperative that surveys and interviews of conventional dairy farmers in the Northeast include farms with a more representative herd size.

Table 1 – Number of Milk Cows on Participant's Dairy Farms

	Organic farms in NY	Organic farms in ME	Organic farms in VT	Conventional farms in NY	Conventional farms in ME
Range in milk cow herd size	50-60	12-60	50-200	800-3,800	120-1,100

Table 2 displays the total number of participants in each focus group and their gender. In total, 22 men participated in focus groups, while only 5 women participated. Women were underrepresented in our study, as the USDA's 2019 Agricultural Resource Management Survey (ARMS) reports that 54% of dairy farms have at least one operator that is a woman (USDA ERS, 2020). Unfortunately, we do not have a state-by-state breakdown of the gender of dairy farmers, so it's not known how representative this sample is of the Northeast region. Future studies should also prioritize interviewing a more representative number of women.

Table 2 – Number of Participants by Focus Group and Gender

	NY Organic Focus group	ME Organic Focus group	NY Conv. Focus group	ME Conv. Focus group	NY and VT Individual interviews	**Total**
Male	4	7	3	5	2	22
Female	1	2	1	1	1	5
Total	5	9	4	6	3	27

II. Survey of Dairy Nutritionists:

The focus groups of dairy farmers indicated that many dairy farmers rely on their dairy nutritionist to make feed recommendations and decisions. There is very little, if any, existing scholarship focusing on dairy nutritionists in general but especially a gap in the literature exists with dairy nutritionists understandings of algae-based feed supplements. Serendipitously, I learned that the annual Cornell Nutrition Conference, which focuses heavily on dairy cattle nutrition research, would be held in Syracuse, New York. While focus group and individual interviews of nutritionists did not seem possible for the conference, a survey was deemed appropriate to yield important demographic information and quantitative data and identify blind spots or areas for future research.

It's important to note that this survey population was selected in large part due to convenience and to save resources, and therefore the population is not systematic or random. However, the Cornell Nutrition Conference is well attended, widely respected, and attracts attendees from around the world so the collected sample may be representative. However, as I discuss in the findings section, there may be certain kinds of nutritionists that attend this event, such as those who have PhDs in Animal Nutrition from Cornell University, as well as nutritionists from feed mills in the Northeast and Canada.

The survey (appendix II) was approved by the Syracuse University Institution Review Board and contained questions pertaining to algae feeds, how decisions are made, where they get information from, and demographic questions. The conference took place over the course of three days. One of the conference organizers provided a table outside of the lecture hall which included a banner identifying Rick Welsh, Ryan Fitzgerald, and myself as Syracuse University Food Studies affiliates, and several signs that said, “Please take our seaweed feeds survey”. We engaged with conference attendees as they walked by on their way to lectures and networking events and provided two options for taking the survey: an online Qualtrics survey or a paper version.

During our first day at the conference, we had a very low response rate. Attendees seemed weary to fill out a survey. A few people voiced that they thought we were selling something. This makes sense as many agricultural conferences are sponsored by feed supplement companies whose sales representatives do try and sell products to farmers. However, two researchers speaking at the conference explained who we were and what our survey was about and asked the audience to take the survey. Following these announcements, we received a much higher response rate.

In total, we received 100 complete survey responses, of which 85 indicated they assess or recommend feeds. Those that did not indicate they recommend or assess feeds were not asked further questions. Of the 85 that took the survey, only 68 specified their gender and 65 revealed their age. There were 42 male, 25 female, and one nonbinary respondent. The median age of respondents was 48.5 years old. This sample appeared representative of the population that attended the conference, based on visual observations.

III. Follow-up Interviews with Nutritionists:

Surveys provide excellent quantitative data and can be answered quickly by many people; however, answers to survey questions tend to be short and the option of anonymity means responses are not linked to respondents. Qualitative research adds richness to quantitative studies- enabling the investigator to describe a social setting more completely. I decided one-on-one interviews of a select number of survey respondents could add deeper insight to the survey results. The survey asked participants to indicate if they were open to being contacted for follow-up questions, and to share their contact information if so. Of the 85 respondents who indicated they recommend feed supplements, 26 provided emails and agreed to be contacted.

I eliminated participants from the interview pool if they did not meet the criteria of the desired sample population. In this case, many students indicated openness to being contacted for follow-up questions. However, my goal was to interview people with work experience recommending or analyzing algae supplements. This left 16 respondent names. They were each sent an email requesting a follow-up interview. Two emails were undeliverable, likely due to typos when respondents entered their email address in the survey. Five respondents agreed to be interviewed, but one of the five did not respond to scheduling requests.

In total, interviews were conducted with four respondents, two women and two men. Their job titles were rumen microbiome scientist employed by a startup to conduct commercial dairy trials, two ruminant nutritionists employed by feed supplement companies, and a dairy nutritionist employed by a feed mill. Interviews lasted between 45-60 minutes and followed a semi-structured interview guide (appendix III). The interview guide included questions about their experience with algae-feeds, their opinions on their efficacy and safety, questions pertaining to methane emissions, and questions about how they make decisions.

I conducted the interviews over Zoom videocalls and recorded the calls with participant's permission. The Zoom recording automatically produces a transcript that can be downloaded. I corrected the transcripts, as Zoom transcription is imperfect and sometimes transcribes the wrong words, especially when it comes to highly specific technical language (ex: *Asparagopsis taxiformis* > asparagus tax forms). I then scanned transcripts for emerging themes and grouped them into codes to be able to analyze the data as per Adler and Clark (2015, p. 421). We shared our survey results with the conference organizers and attendees who wished to receive a copy. A conference organizer mentioned an email listserv of nutritionist professionals existed, with hundreds of subscribers. In the future, surveys of nutritionists within the C3 project should take advantage of this listserv and others in order to reach beyond regional conferences.

IV. Interviews with Researchers:

While conducting the literature review, it became clear to me that there were more layers to the production of knowledge on this project, beyond the tacit knowledge of farmers or the codified knowledge of nutritionists. As I explained in the introduction, background, and literature review of this thesis, scientists involved in project implementation and design are not neutral in their understandings and beliefs. When it comes to scientific knowledge, it is often assumed that the scientist is objective. This is sometimes put in contrast to tacit knowledge, or in this case, knowledge based on anecdotal evidence and experience of farmers.

I wanted to interview researchers affiliated with the C3 project to better understand their perspectives on algae-based feed supplements, and because they are information rich cases. As with the nutritionist follow-up interviews, I reached out to researchers through email and asked if they would be willing to speak with me about algae-based feed supplements. I used a semi-structured interview guide (appendix IV) to keep the conversations on track as well as to allow

for follow-up questions as they arose. Interviews were conducted on Zoom and recorded with participant's permission. The Zoom recording produced a transcript automatically, that I downloaded and corrected. The interviews lasted between 30 and 45 minutes. In total, I interviewed three of these researchers, two women and one man. Their interviews were insightful and information rich, and they highlighted the importance of reflexive social science research within the project itself.

V. Positionality:

The SAGE Encyclopedia of Action Research defines positionality as "the stance or positioning of the researcher in relation to the social and political context of the study – the community, the organization, or the participant group. The position of the researcher affects every phase of the research process, from the way the question or problem is initially constructed, designed, and conducted to how others are invited to participate, the ways in which knowledge is constructed and acted on, and finally, the ways in which outcomes are disseminated and published" (Coghlan and Brydon-Miller 2014). An important distinction to make within one's positionality is one's insider or outsider role within the group being studied. An insider is a researcher who works for or with the participant community, while an outsider is viewed by participants as a non-member (Herr and Anderson 2005). Typical or traditional research positions, in which a researcher gathers data about their research subjects, would be considered an outsider role. An insider typically shares aspects of their identity with research subjects and is common in research with feminist methodologies and epistemologies.

Feminist epistemologies are particularly concerned with positionality and discuss the importance of the researcher's "degree of relatedness" to research subjects. This view of positionality is based on many characteristics of identity such as gender, age, race, class which

influence how the world is experienced. In the context of research, one's positionality may help or hinder research. These characteristics and experiences also inform implicit biases carried by an individual. Researchers can and should acknowledge the ways their identity and experience impacts interactions with research subjects, research design, analysis, and communication of findings. Feminist social science scholars challenge the positivist idea that research can be impartial and unbiased (Hastrup 1992; Harding 2010) and highlight the spectrum from outsider to insider position on a project. One can even be an "outsider-within" a group (Collins 1991). For example, if you are the "only" of anything (gender, race, class) in a group, you may feel like an outsider even though you are technically inside the group. These sub-positionalities are all important to consider when doing research.

Another aspect of positionality to include involves the aspect of change over time during the course of research. One's positionality can change a few or multiple times throughout a project depending on many factors including changes in the research subjects, changes in the identity and experiences of the researcher, as well as external factors like funding source changes and shifting needs and expectations of principal investigators (Ospina et al. 2008).

My positionality, my insider and outsider role, my identities and dimensions of relatedness, and the evolving and interactive nature of my research greatly impact how my thesis research was designed, conducted, and communicated. My identity as a white, cis-gender, woman in my thirties, and my status as a graduate student influence how survey and interview participants think of me, as well as what information they may feel comfortable sharing depending on each individual research subject's own identity, position, and implicit biases. Being a graduate student social science researcher allowed me access to the inside of "outside" spaces that I otherwise might not be privy to. Because I am not a dairy nutritionist and I do not hold a

masters or doctorate in animal science, I am an outsider in the context of the Cornell Nutrition Conference, as well as interviews with nutritionists and researchers. However, I also share dimensions of relatedness with nutritionists and researchers in that they all used to be graduate students as well and can relate to my position. The institution of Syracuse, the presence of my advisor Professor Rick Welsh, and the endorsements of highly respected animal scientists provided additional legitimacy to my research and granted me a seat at the table – or in this case, a folding table and three chairs on which to construct my display.

I also share, and do not share, many degrees of relatedness with dairy farmers. After obtaining my undergraduate degree, I moved to Massachusetts to farm. First on a rotational grazing operation and then a slew of seasonal mixed vegetable farms. Lastly, I spent three years on a small dairy farm where I milked cows and processed their fresh milk into cheese and yogurt. During this time, I learned a great deal about dairy cows and animal husbandry as well as milking systems, small farm economics, and in general how physically and emotionally difficult it is to work on a dairy farm. I experienced the headache of getting kicked by an ornery cow and the heartbreak of putting down sickly animals that we cared for like family members. Despite these hardships, these years cemented my love for farm animals and my respect for farmers. Dairy farming as a practice and lifestyle became embodied, it will always be part of me and a season of my life that I long for.

I spent the four years following dairy farming working at a state agricultural agency as an organic livestock certifier. In this role I communicated over email, phone, and in person with many dairy farmer clients and over time we built trust. This rapport made navigating difficult conversations possible, such as social and economic hardships. I also was exposed to more production styles and ways of dairy farming than just the one farm I worked for provided. These

experiences make navigating dairy industry spaces more relaxed, as I am able to use industry specific language to legitimize myself in conversations and assert that I belong in the space. This coded language builds trust and allows participants to feel more at ease. I can assure farmers that I somewhat understand their lifestyle and standpoints.

At the same time, I am also aware of the ways I do not fit in with these group identities. I am not from a farming background, or the northeast region. I did not attend a land-grant university or college, and I do not have a higher degree in animal science or a similar field. Visually, I present as a small woman and have often been experiences being underestimated in agriculture due to the assumptions about my potential physical strength or my knowledge on certain subjects. Furthermore, the conference attendees also trended male and middle aged, so as a young woman I had to take care to navigate my position. Conference attendees and interviewees were primarily white. My whiteness allowed me to move through spaces like this with ease, without my presence or belonging being questioned. So even within the survey itself I experienced insider and outsider status from moment to moment, from participant to participant, from farmer to nutritionist to researcher.

In conclusion, my methodology is made up of both quantitative and qualitative methods that may attempt to erase the standpoint of the researcher (me), but the standpoint still exists within the very questions I ask and ways I interpret and analyze the data collected. Scholars note the importance of self-reflexively turning the ethnographic gaze back upon ourselves in order to be accountable for our own analysis and understanding of our research (Harding, 2010; Mares, 2019). My background experiences and my current positionality are central to how I study the world and its phenomena, and this will be reflected throughout my work.

CHAPTER IV: RESULTS, ANALYSIS, & DISCUSSION

This chapter presents the findings from this research, which includes dairy farmer focus groups, a survey of dairy nutritionists, and individual interviews with nutritionists and animal scientists. In this research I seek to identify the motivations dairy farmers have to feed algae-based feed supplements, the sources of knowledge used in the dairy industry to make feed decisions, as well as potential barriers to implementing novel feed supplements. These findings include quantitative data and descriptive statistics, bolstered with qualitative interview data.

I. Why Feed Seaweed?

In this section, I present findings from focus group interviews of dairy farmers, the survey and follow-up interviews of nutritionists, and interviews with researchers discussing herd health claims, methane reduction claims, and sustainability and marketing justifications as these were the main themes that emerged from the data.

Firstly, farmers in focus groups stated that they feed algae-based feed supplements, typically dried *Ascophyllym nodosum*, for herd health benefits. This is in line with other scientific literature that used a survey methodology to ask farmers about their reasoning (Hardie et al. 2014; Antaya et al. 2015; Sorge et al. 2016; Silva et al. 2022). Farmers did not report feeding algae to reduce the enteric methane emissions of their cattle. In contrast, some farmers, as well as nutritionists and researchers, thought farmers might feed algae-based supplements for enteric methane emissions reduction to be part of sustainability conversations and marketing opportunities.

To better understand farmer's reasoning behind feeding *Ascophyllym nodosum*, we wanted to measure what they already know about the supplements. To obtain this baseline

knowledge, the focus group interview guide included a series of questions about common marketing claims – to which farmers indicated if they were aware, not aware, or unsure of the claim. Marketing claims may inform farmer's decision-making for incorporating them into their existing feeding regimens. The findings of claim-awareness are reflected below:

Table 3 - Claim awareness tally results

Attribute	Aware		Not Aware		Unsure	
	Organic	*Conv*	*Organic*	*Conv*	*Organic*	*Conv*
Increase Milk Yield	3		9	10	5	
Source of Vitamin C	3	4	11	6	3	
Source of Magnesium	6	2	5	8	6	
Source of Calcium	12	4	3	6	2	
Source of Zinc	6	1	8	9	3	
Enhance immune function	14	5	3	4		1
Increase weight gain	2		10	10	5	
Reduce weaning stress	2		15	10		
Improve fatty acid profile of milk	1	1	15	9	1	
Increase milk fat content		1	12	9	5	
Reduce somatic cell counts in milk	6		10	10	1	
Totals*	55 (29%)	18 (16%)	101 (54%)	91 (83%)	31 (17%)	1 (1%)

* reflects percent of total number of org. or conv. farmers times number of claims

Participants from organic dairy farms expressed more awareness of the above claims of algal feed supplements attributes than participants from the conventional dairy farms (table 3). Conventional farmers were more likely to say they were not aware of a given attribute claim, and organic farmers were more likely to admit they were unsure of a claim than conventional farmers. Organic farmers were most familiar with the claims that algae feeds were a source of calcium and could enhance immune function. Both conventional and organic farmers were mostly unaware of claims that algae supplements could increase weight, reduce weaning stress,

improve fatty acid profile of milk, increase milk fat content, and reduce somatic cell counts in milk.

As for the use of algae as a feed supplement in general, organic farmers were already aware of the use of algae in cattle feed and most of them had fed algae before in the form of dried kelp meals. Most of the conventional farmers interviewed were also aware of the existence of algae-based feed supplements, but a few were not aware of their use at all. In the focus group of conventional farmers in New York, a farmer noted, "*I don't even know if it's available. It's never been presented to me by a nutritionist saying we should feed this because of X or Y. Never discussed in that frame*."

Farmer's decisions about whether to feed algal-based feed supplements came down to perceived benefits to herd health, cow behavior, and lack of alternatives in organic farming, while the main barrier cited was cost. When asked why they choose to feed algae-based feed supplements, organic dairy farmers cited health benefits and described anecdotal evidence to support these claims which included treating pink eye, improving fertility, reducing placenta retention, lowering somatic cell counts, and ameliorating calf health. Several farmers in the organic Maine focus group attributed these improvements to the mineral composition of algae, one stating, *"It made perfect sense to me. Look at the label, there's 60 different elements on it. It's hard to go wrong with that,*" while another echoed, "*We've been feeding kelp for ages…We've always found we just liked the benefit of all the extra minerals it provides. I really think it's helping with a lot of things like pink eye*."

A reason unique to organic farmers for selecting algae-based feedstocks is navigating the constraints of organic certification's rules and regulations. Firstly, the algae must be certified organic to be fed to organic livestock, according to the National Organic Program's livestock

feed rule (7 CFR 205.237). An organic farmer in New York explained, "*Before we can feed this, we have to have it approved by our certifier*." Secondly, organic dairy farmers have fewer herd health options than conventional farmers. As many synthetic medications are not allowed in organic production, they tend to focus on preventative health measures – ensuring a balanced diet for their cows and providing enough micronutrients. Another organic farmer from New York stated plainly, "*We're looking for alternative methods to prevent or fix problems…we're restricted on some of the products that we can feed.*" Organic farmers in both focus groups and in individual interviews stated they often fed algae products to their milk cows for reproductive health reasons. A third farmer in the organic Maine focus group explained, *"[It] has a little extra iodine, it is supposed to help with cycling as far as getting cows bred. Yes, that's the biggest thing*," while a fourth farmer in the group elaborated, "*I mean, fertility is a big issue. We had retained placenta issues. And so, we would feed that in lieu of like, selenium shots or something. Feeding that on a consistent basis seemed to reduce the amount of retained placentas that we had*." Farmers rely on the product for lifesaving health care, as retained placenta can cause serious problems for a cow. A conventional farmer would likely use oxytocin or other medications to treat this issue.

While conventional farmers do not face the same limitations for feed and health care inputs as organic farmers, some conventional farmers do occasionally choose to feed algae supplements. Three reported feeding algae historically but stopped when it became prohibitively expensive. One from the conventional Maine focus group explained, "*We thought it was a natural source of bioavailable things like selenium and things like that. You know, I can't say it didn't work, but you know when the price went up, we kind of weened them off of it."* Another farmer in the same group agreed saying, *"We have [fed it], yeah. But when they doubled the*

price in one year, we didn't think it was really worth it." This finding indicates openness to incorporating algae into rations for health care reasons if it was affordable.

Turning to the survey results, of the 100 respondents, 87 indicated they recommend or analyze feed supplements for dairies and completed the survey. Of these participants, 82 had heard of algae-based feed supplements before but only 17 had ever recommended them to a client. The 65 who had never recommended an algae-based feed product reported their main reasons were because they did not know enough about them (41 respondents), that they are difficult to find (16), and that they are too expensive (13). One participant wrote "*there have not been enough studies on the long-term effects*" while another wrote that there was "*little data to support their use and economic viability*".

Using evidence from existing literature as well as marketing claims from algae-feed supplement companies, we collected a list of attribute claims. Instead of asking nutritionist participants if they were aware or not aware of each attribute claim regarding algae-based feeds, as we did in dairy focus groups, we asked them if they thought the claim had strong scientific support, some scientific support, or little to no scientific support. These findings are reflected in Table 4.

Table 4- Nutritionist Survey Results

Claim	Little/no scientific support	Some scientific support	Strong Scientific support	total
Treats pink-eye infections	39	9	1	49
Source of vitamins	15	34	8	57
Source of minerals	5	30	27	62
Source of Iodine	2	19	39	60
Reduces somatic cell count	37	12	4	53
Reduces methane emissions	6	31	27	64
Increases weight gain	36	19	2	57
Increases milk yield	38	16	5	59
Increases milk fat content	38	15	3	56
Improves milk fatty acid profile	36	18	3	57
Improves calf health	33	16	1	50
Helps with fly control	44	4	1	49
Helps cow fertility and reproductive issues	35	14	3	52
Enhances immune function	34	20	4	58

Respondents were more likely to say a claim had little to no scientific support, except for the claims that algae-based feeds are a good source of minerals, iodine, and that they reduce methane emissions. Notably, two papers were presented at the Cornell Nutrition Conference while we were conducting the survey that outlined the potential of some seaweed species to reduce enteric methane emissions, with special attention to high iodine concentrations as a concern. This likely influenced the responses to this question. Interestingly, respondents reported that there is little to no scientific support for algae-feed supplements treating pink-eye infections, helping with fly control, or helping with reproductive issues. These are the claims most reported by farmers for why they feed “kelp”. It is also important to note that not all participants answered this question and had varying levels of response levels to each claim. This may indicate that the respondent does not know enough to answer the question. The survey questions could be

strengthened in the future by adding a response option allowing them to indicate if they don't know. This would also allow for more cross-comparison with the focus group interview data.

In follow-up individual interviews with nutritionists and animal scientists, I asked why they thought farmers might purchase and use algae-based feed supplements. Steve, a nutritionist from Canada posited:

> *Some farmers are using it for reproduction, for the trace minerals and the iodine that it may bring along to help with reproductive issues. We have seen some data of it helping with heat stress as well. So, in the summer months we've used it to try to help dissipate heat stress on animals. Those would be the 2 big reasons. Maybe some use it for milk quality with the iodine and the trace mineral levels. Organic producers, maybe for health and breeding, you know, almost as a non-medicinal antibiotic-type product, right*?

While there are several published research studies showing a link between feeding seaweed and reducing heat stress (Fike et al. 2001; Antaya et al. 2015; Vijn et al 2020; Sofyan et al. 2022), there is not much existing, codified scientific literature to back up the reproductive benefits. The reasons Steve observes farmers feed algae are the same reasons we also heard farmers express in the focus group interviews. This indicates that Steve has a solid understanding of why his clients use seaweed, regardless of if he thinks they are valid claims. When questioned about whether he thought the health care reasons for feeding algae have scientific support, he quipped, "*We're not generally bringing fly by the seat of our pants type products. We're bringing products that we believe will work*". Heidi, a professor of animal science, focused on the available scientific literature, stating:

> *There's a lot of anecdotal evidence out there. Everything from pink eye to the immune system…there is some research out there, but I mean you know one paper here and there. I wouldn't say a substantive enough to be definitive on the on the*

> *actual scientific soundness of it. So, I would say anecdotal doesn't really equate to strong science backing for it*.

While Heidi may not see published research supporting claims made by farmers with anecdotal evidence, a professor of animal science at another university had a more optimistic take. When asked about farmer's reasons for feeding algae-based feed supplements, Theo responded:

> *I think there is some anecdotal evidence. Farmers anecdotally say, 'we have seen improvements in animal health in things from mastitis to fly control'. Considering seaweeds have all these different types of bioactive compounds (it's not well understood) I think it's possible. I think there are some indications that some of the seaweeds can benefit animal health*.

Both of these scientists run live animal feed trials and have extensively studied both conventional and organic dairy animals. While Heidi seemed to focus more on the literature, and does not equate anecdotal evidence with scientific evidence, she noted that the reasons farmers use algae that they reported in our focus group interviews shaped her own research design, investigating herd health benefits in addition to methane-emissions reduction.

Both farmers and nutritionists are aware that some seaweed species can reduce enteric methane emissions when fed to ruminants. Farmer's main stated reason for feeding algae-based feed supplements is for herd health benefits they observe, and not for methane reduction. However, nutritionists and researchers frequently mentioned methane reduction as a justification for feeding seaweed. Interestingly, both farmers and animal scientists did not discuss methane emissions reduction as an altruistic motive, but framed methane reduction as a marketing opportunity; sustainability not for the sake of ecological sustainability per se, but as a means to achieve economic sustainability in the dairy sector.

In the focus groups, farmers were asked, “Have you heard that feeding algae feed supplements reduces methane emissions, and is this of interest to you?” Many were aware of recent studies that show feeding algae can reduce enteric methane emissions, although the conventional farmers expressed more skepticism than the organic farmers. Both conventional and organic farmers voiced interest in reducing methane emissions but clarified they would need to be compensated to make up for the increased cost of feeding algae supplements.

One form of compensation would be charging milk buyers and consumers more for milk from algae-fed cows, employing a marketing strategy. Conventional and organic farmers mentioned increased marketing opportunities as a reason they would feed algae for methane reduction. A conventional farmer in the Maine focus group explained, “*For me, this angle, especially just for like the direct marketing, being able to say you're doing something, like obviously doing something about it [methane emissions], but also being able to…put it on the label,*” while a conventional farmer from New York somewhat cynically noted, “*Everyone's trying to use this as like, ‘oh, well maybe Walmart will buy our cheese and we can say we are good economic stewards’. I think it's all just marketing*.” An organic farmer from Maine justified marketing ecosystem services:

> *That marketing and labeling becomes really important. How you differentiate your product from other milks on the marketplace that are being marketed as being healthier for the environment and your body and your children and all this…when you know almond milk is the most destructive thing they make. That marketing part has to be there too.*

An approach used by the government or milk buyers to encourage adoption of technologies is to compensate the farmer or subsidize the inputs. Conventional farmers agreed in focus groups that algal feed supplements would either need to be cheaper before they would be willing to feed

them, or they would need to be incentivized. However, there was hesitation among farmers about incentive programs. A few elucidated that previous attempts to incentivize environmentally friendly management practices failed because the programs that paid farmers to do so ended. One farmer in Maine explained, *"It was like cover crops. You know, everybody was doing it when we were getting paid 20 bucks an acre and then when that program went away, people didn't really focus on getting it done. Even though there's a benefit, it just…there's an expense*."

An increasingly popular approach to mitigating climate change is paying farmers to reduce their overall carbon emissions. When asked about models like carbon offset programs, farmers expressed concern about bureaucracy and not being reimbursed quickly enough. A conventional farmer in New York told us:

> *There's multiple different ones and they're somewhat complex and kinda hard to navigate…it's gotta be faster and simpler. So, the one that we're involved with now, we get an annual review…which was in June, and I just got it [the reimbursement] in March. So, the offset that was produced from June of 2020 to June of 2021 was approved in June 2021 for March of 2022. So that's too slow*.

That lag time in reimbursement can be make-or-break for farms operating on thin margins, and so the decision to participate in these programs may come down to how the programs are actually administrated.

Farmers also expressed concern that incentivizing feeding algae would ignore other climate-friendly practices they already employ. While both conventional and organic farmers voiced frustration with pointing the finger at dairy farms for greenhouse gas emissions, many organic farmers felt that their pasture-based systems are not to blame. Organic regulations require ruminant livestock obtain a minimum of 30% of their dry matter intake from pasture during the grazing season which must be at least 120 days long (7 CFR 205.237). Additionally,

some organic farmers add a separate grass-fed certification, which specifies more stringent pasture standards and prohibits grain from rations. Three of the farmers in the organic New York focus group reported obtaining this extra certification. Organic and grass-fed certified farms report feeding algae-based feed supplements in addition to grazing, so the two practices are not mutually exclusive. In fact, the Certified Grass-Fed standards list "kelp" as one of only seven supplements approved for use without restrictions, and note it serves a rumen health function (Organic Plus Trust, Inc, 2023).

An organic and grass-fed certified dairy farmer in New York expressed frustration regarding carbon offset programs targeted to dairy farms, stating "*we're obviously not perfect farmers but we don't really create some of the problems that you see somebody with a different operation creating. We're talking about carbon credits…well, how about us? We're all grass, sequestering carbon*." A farmer in the Maine organic focus group similarly observed:

> *I feel like there's more effective ways that we can reduce methane than going after cows and trying to make them the most efficient machines. Especially when most of us are grazing our cows anyway, we're not in a feed lot. You know, we have those carbons sinks, we're collecting our manure. We're highly regulated and managed both by the state as well as our certifiers. So, it's like, we do more than our part already.*

Conventional farmers stated they would need financial assistance to start feeding algae supplements and the organic farmers stated that such incentive programs should account for climate-friendly practices the farmer already employs. Our findings are consistent with previous research showing most farmers require incentives for providing additional ecosystem services (Ma et. al. 2012; Smith and Sullivan, 2014).

Surprisingly, nutritionists held a similar perspective. I had expected nutritionists and researchers to view methane reduction as the only worthy goal of feeding algae, as the survey

indicated nutritionists believe there is strong scientific backing for this claim. Only one interviewee expressed that farmers may feed it for altruistic reasons. Amanda, a researcher with a PhD in animal science working on animal nutrition in the Northeast, offered, "*Maybe part of it is the mental aspect of doing good by feeding something that's helping the environment at the same time*." Nutritionists and feed supplement researchers are not in the position of marketing dairy products and ensuring the economic viability of dairy farms – although nutritionists discuss feed costs with farmers and researchers often consider feed supplement costs in studies – so it was interesting to hear them express that farmers would feed it for economic justifications. Mariah, a cattle nutritionist in the Midwest, conducted research on algae and methane reduction in grad school in which they found evidence for methane emissions reduction. She stated, "*I would say right now the reason that somebody would feed it is just to include themselves in the sustainability conversation and say, 'I'm part of the help, not part of the problem*'", which is a very similar sentiment that conventional farmers expressed in the focus group interviews. Interestingly, Mariah only works with conventional cattle farmers, and does not have experience with organic clients.

Jess is a rumen microbiome scientist working for a feed supplement startup in California and collaborated with other researchers working with algae during her PhD studies. When I asked her why she thought some people feed algae to dairy cows, she responded without hesitation "Yeah, to reduce enteric methane emissions." She was not familiar with other health benefits farmers experience when they feed algae to cows but did express concern about deleterious effects on health such as possible impacts to the rumen wall lining. She added:

> *My understanding or feeling is that [feeding algae] is not driven from their desire to be more sustainable because they already view themselves as very sustainable, based*

> *off other reports, but they have some financial incentives. I know certain banks or co-ops or processors are starting to require or subsidize those things*.

This is in line with perspectives of organic and grass-based farmers from the focus groups, who believe they already implement sustainable agriculture practices, and may already feed seaweed, but would feed a novel species of algae to reduce methane if it is incentivized.

Some co-ops and processors offer incentives to farmers for various ecological practices. For example, in September of 2022, the USDA announced a $25 million award to Organic Valley Coop for their "carbon insetting" program. Carbon insetting refers to direct payments to farmers for implementing on-farm practices that reduce greenhouse gas emissions. This includes feed supplements that reduce methane emissions, as well as practices that sequester carbon like improved pasture management and agroforestry (Organic Valley, 2022). I spoke by phone with a sustainability employee at Organic Valley who explained that if farmers have done any of these practices in the last five years, with supporting documentation, they are eligible for carbon insetting payments. She specified that the program is voluntary at this time. Interestingly, she noted that 43% of Organic Valley's dairy farmers are Amish or plain folk, and due to their beliefs "*will not take money from the government".* Based on this information, future studies should attempt to contact Amish and plain folk dairy farmers about their perceptions on algae-based feed supplements. Acknowledging that there is a wide variety of production systems under the umbrellas of conventional and organic will yield important results about farmer's barriers to implementing new feed technologies.

Steve, a Canadian dairy nutritionist, observed similar sustainability goals and carbon reduction initiatives in the dairy industry on his side of the border and explained how these goals affect dairy farmers:

> *Reducing methane is starting to become a topic with my clients mostly because producers are starting to be inundated with it. It's not a big topic for them yet. It's mostly when they're reading popular press, and the Dairy Farmers of Canada have set a goal for net-zero for 2050. So, they're hearing about it through that right? How are we as producers going to meet this goal that our marketing boards have set for us*?

While individual farmers may want to be included in the sustainability conversation or be perceived as more ecological, the fact that milk is not sold directly to consumers means that the cooperatives and marketing boards are brokering the image of the farmer to consumers. It does appear to boil down to an economic decision. Theo, a researcher and animal scientist at an American University in New England summed it up:

> *There are these conversations with methane, and I think some [algae species] seem to be very efficient in reducing methane, so then I guess it would be important to take a look at the tradeoffs between some of these mitigation strategies on methane. But at the same time, whether or not these animals are still producing the amount of milk that farmers are being paid for*.

II. Knowledge Sources: Who is trusted?

A central goal of this research was to gain an understanding of how knowledge is communicated within the dairy industry, and which knowledge farmers, nutritionists, and researchers view as legitimate. In this subsection I outline findings from farmer focus group interviews, the nutritionist survey, as well as individual interviews with nutritionists and researchers. In this research, I explore how tacit knowledge is valued in different groups. I theorized that farmers would value tacit knowledge as that is what they use day-to-day to operate their farms, while I theorized that nutritionists and researchers would view codified knowledge

sources as more legitimate due to their relative distance or alienation from the on-farm setting, as well as their place in academia and science.

a. Sources of Tacit Knowledge on the Farm:

It was surprising to me that farmers did not describe their own tacit knowledge when asked directly where they get trusted information about feed supplements, even though we know from the above section that farmers observe improvements to herd health when feeding "dried kelp", and that those improvements are measured by farmer's observations. However, farmers did refer to the cow's as a source of information when asked if they have observed changes in cattle after feeding algae. The cow's own behavior was cited as reason to feed algae. An organic farmer in Vermont explained in an individual interview:

> *Sometimes they lick salt blocks all day long and sometimes they ignore them. I think that the cows have some ability, maybe more than humans do, to selectively pick what they need to balance their diet… And clearly the cows, we have learned over the years, they tend to eat those kinds of things because there's something in there they need, right?*

In New York, an organic farmer in an individual interview similarly observed, "*If they crave that kelp, they'll eat a whole bag of it. If they don't want it, you couldn't force it down. I'm assuming that their system is getting balanced inside and they no longer crave it. If there's a deficiency, they would go for it*." They are describing a deeply tacit knowledge that the cow herself has about what she needs to eat to be healthy.

This philosophy was not only voiced by farmers. Gary, a nutritionist stated, "*I'm old school enough where I try my best to listen to the cow first, not tell the cow what to do because my computer says so*." Gary explained he has worked as a dairy nutritionist for over 30 years at

various feed mills in New York State. Here, he is expressing dismay that the tacit knowledge of listening to a cow has now been pushed aside in favor of codified knowledge, held in a database. I asked him how he listens to the cow, and he described his method like this:

> *She can't speak English, but you learn her language fairly well. you know what her eyes look like. How does she carry her head? What are her hooves saying? Is she lame? Or on the way to lame? Things like that. How she eats, if she eats, how does she react to the people in her life? Does she go to them?*

Each of these steps will tell him so much about a cow and her health, and this knowledge is embodied. Gary is able to suggest and adjust rations according to these observations and has seen years of success doing it that way. It is notable that Gary and the two farmers quoted above observe that the cows are a source of tacit knowledge, without acknowledging that they are the ones observing and interpreting the cow's behavior. They use "data" from the cows, such as dietary preferences from day to day, to inform their decisions and understanding about which supplements to provide.

Other sources of tacit knowledge include fellow dairy farmers. This may mean neighbors, farmers using similar production systems in their area, farmers at conferences, and more and more, farmers on the internet. Theo, a researcher, when asked where he thinks farmers get trusted information about feed supplements responded quickly, saying, "*It'll be from farmer-to-farmer meetings and things like that…online you can find a bunch of stuff…and at regional conferences*." Heidi, another researcher noted, "*They rubber neck and look at their neighbors and see what their neighbors are doing and talk to their neighbors*."

Mariah, a cattle nutritionist, discussed where farmers get their information and described tacit knowledge sources while simultaneously implying codified knowledge is more legitimate, saying:

> *I think it's based on what they think they've seen in their herd first, and then they start listening to what other people have seen…I think it's improving with farmers having greater education. More and more are holding higher degrees, so they know how to look at research. They know how to interpret data, and really look at trends. Our dairy industry is way smarter than it used to be.*

This statement, that the industry (farmers) is smarter than it used to be because farmers are holding higher degrees reflects a historic bias or assumption that farmers will farm "better" if they get higher degrees. A study of dairy farmers in New York state found that those who obtained higher degrees from land-grant universities were more likely to use pesticides on their farm than farmers with less formal education (Welsh 1995). While some would see the use of pesticides as the embrace of technology, and perhaps "better", pesticides have many negative environmental, economic, and health externalities. The farmer has thus replaced their tacit knowledge of their farm and how to manage pests with instructions on a pesticide bottle. Farmers who choose not to adopt new technologies, or are hesitant to do so, are viewed as "laggards" while early adopters are lauded (Cruise and Lyson 1991; Welsh 1995 p. 90).

This implicit bias that sees farmers with higher degrees as smarter than those without degrees trickles down to farmer's own perception of themselves. It was my intention to interview dairy farmers for my thesis research, as I believe farmer's voices should always be included in research about the dairy industry. I thought the challenge in interviewing farmers would be finding time in their schedules, traveling to their farms in wintery conditions, or having them respond to emails at all. I did receive responses from farmers to emails I sent them requesting interviews, but the real challenge was that they did not believe they were worth interviewing. They did not view their own tacit knowledge as worthy of a scientific study, despite my explanation that I wanted to hear about their experiences and observations feeding algae. One

farmer responded*, "Kelp is a component of a free-choice salt mineral mix that the dry cows and heifers get during the grazing season…I don't believe I have enough information to be of value to you."* Another farmer responded:

> *The thing that keeps popping up in my mind about your question is - I'm not sure we have anything to say. We've been feeding kelp for so long, that there is nothing to compare it to - as in before we fed kelp - if that makes any sense? Think, if you will, about taking supplements for yourself. Every day you take Vitamin C, let's say. Then someone wants to spend time asking you about your Vitamin C supplementation, and how it affects you, what do you say?*

Not knowing if it makes a difference is still valuable information to have, and understanding why they feed kelp in the first place would have been a fruitful discussion.

b. Knowledge Brokers

A crucial finding from the focus group interviews of farmers is that both conventional and organic farmers trust and rely on dairy nutritionists to source appropriate feeds and provide information about new or alternate feed sources. While a few organic farmers we spoke with use nutritionists as a resource for accessing information about new feeds, some conventional farmers stated they trust their nutritionists to such an extent that the farmer may not know every sub-ingredient in their total mixed rations, which are formulated by nutritionists. A conventional farmer in Maine acknowledged dried algae may have once been included in their cow's rations, but that they would not have been aware of it.

When we asked, "who do you turn to for trusted information about cattle nutrition?" one conventional dairy farmer from New York joked, "*Somebody that I can fire if they're wrong….a nutritionist who's on-farm and has a good background, good experience. He's supposed to have*

the next level understanding to bring in the right kind of experts and to bring them in to participate." Another farmer in the same group added, "*I would agree. So primarily a nutritionist, but we bring a lot of people in sometimes from groups that help us grow forages."* Conventional farmers in Maine made similar statements, noting they trust nutritionists from feed companies, feed salesmen, and cooperative extension agents. They primarily sought someone with the expertise to analyze feeds, balance their rations, and make rations for each group of cattle on their farms including heifers, dry cows, high producers, and low producers.

Several organic farmers in focus groups responded similarly to the conventional farmer groups. An organic farmer in Vermont noted, "*Well there are two [that I trust]. One of them is the representative of the feed company and the other is a staff veterinarian at Organic Valley*" while an organic farmer in Maine explained, "*Cooperative extension, they have staff nutritionists. The feed mill has good nutritionists too*." While many farmers stated that they trust nutritionists from feed mills, not all of the organic dairy farmers interviewed used a nutritionist at all. Some farms do not employ nutritionists because they have a low-input system and therefore have no need to balance rations. One grass-based farmer from the organic focus group in New York stated *"I don't have a nutritionist. I feed a basic mineral mix and that's it; hay and pasture*." The organic or conventional dichotomy may not correlate to whether nutritionists are used or not – as much as production style such as industrial or low-input. Theo, an animal scientist and researcher, stated:

> *I think they get information from suppliers that probably approach them, nutritionists that use some of this [algae] in the grain mixes. Online you can find a bunch of stuff, specifically with organic I know there are some publications that are targeting issues associated with management and nutrition. I think there's not much difference where they're getting this information from whether it is conventional or organic.*

Heidi, an animal scientist and researcher from a different university, expressed a similar observation that the usefulness of nutritionists depended more on the scale and production style of farms, and not necessarily if the farms were organic versus conventional. When asked where she thought farmers get trusted information about cattle nutrition, she explained:

> *Their nutritionist or their neighbor…Farms tend to use their nutritionist pretty heavily from the mill and those nutritionists will give a lot of information, especially about the products that they sell and carry. If a farmer has a low input system or doesn't use a nutritionist extensively, and there are lots of them, then they have to rely on others.*

This is where production system and style, as well as farm size, may play a large part in what kinds of knowledge are valued and used. A nutritionist can be seen as a technology, because they have large data collections available to them that an individual farmer does not have. A nutritionist costs a farmer money, and only makes sense economically at a certain scale. It also only makes practical sense when the farm is a certain size or uses Total Mixed Rations. Farms that have small herd sizes may have an easier time observing individual cows, and farms that rely on grass for rations or only feed premixed feeds have a lower need for a nutritionist.

While the value of a nutritionist was not dependent on conventional or organic, but mostly whether or not they are low or high input farms, the value of veterinarians was more dependent on organic versus conventional status. We asked, "How about veterinarians? Are they useful sources of information around nutrition?" An organic farmer in New York stated "*I would say the vet but most around here don't know, maybe it's not necessarily the knowledge, but are not quite so into organic so I think they don't have the alternatives. They're not so educated with the alternatives*." This opinion was also stated by an organic farmer in Maine who quipped, "*Not*

really. They're not really pro-organic either. They'd rather we just switch to conventional methods. That's easier because they're used to doing it more." Another farmer in the Maine group chimed in, "*In their defense that's all the information they get in med school!*" Whereas the main struggle with turning to veterinarians for cattle nutrition advice is that they do not understand the organic regulations and may therefore suggest materials that are not approved by the certifier, veterinarians may also be viewed as under-educated about other production systems; a subtle indication that organic farmers value and trust specialists that are familiar with organic agriculture. This finding is in line with literature in which differences in trust between farmers and advisors are evident based on organic or conventional status. While conventional farmers are encouraged to have blind-trust in intermediaries (often representatives from feed or input supply companies), organic farmers must "construct studied trust relations" with other organic farmers and organic advisors in networks (Hassanein 1999; Morgan and Murdoch 2000).

Originally, I intended to interview and survey more dairy farmers about their experiences and observations with algae-based feeds as a follow-up to the focus groups. It is typical in social science research design to view focus group interviews as valuable for providing background information and identifying informants and more participants through snowball sampling. Then, a social scientist may have deeper individual interviews to investigate themes that emerged in the focus groups. However, an emergent theme from these focus groups was that dairy farmers rely on nutritionists for feed decisions. This finding shifted the direction of the research significantly. While a handful of dairy nutritionists had previously been consulted through background interviews, the purpose was to gain information about what to ask farmers and how to navigate the supply chain. To turn the lens back onto the nutritionists, or to "study up" (Nader 2018) became central to the design of this research, as well as reflexively flipping the lens to

researchers that design animal feed trials and publish in respected academic journals. Understanding how the producers of codified knowledge view farmers and intermediaries and how those groups view each other is valuable for knowing not only how information should be communicated depending on the group, but *who* should be doing the communicating.

In conclusion, farmers obtain important information about feed supplements from their own tacit knowledge, via observing their cow's behavior, as well as networking with other farmers about what works well for them. They also rely heavily on intermediaries like extension agents, and especially nutritionists. While farmer's tacit knowledge comes from experiential learning over long periods of time, situated in a specific farm, emerging research and new technologies are still of interest to farmers and so they rely on knowledge brokers to provide this information. Knowledge brokers are people who have access to codified knowledge and can communicate it well to farmers and ideally also communicate tacit knowledge back to the codified knowledge producers.

c. Codified Knowledge

A central question of this research as it shifted gears towards nutritionists, was who or what sources do they depend on for trusted information about cattle nutrition? I theorized that nutritionists would depend heavily on codified knowledge produced at research and land-grant universities, where many of them get their higher education.

Our first foray into answering this question was included in the survey of dairy nutritionists conducted at the Cornell Nutrition Conference. We asked, "Where do you get trusted information for recommending dairy feed supplements?" and provided a free form answer text box in lieu of multiple choice or having them rank options. Of the 85 respondents that indicated

they analyze or assess feed supplements, only 59 of them answered this question. Because it was a free form answer box, many people listed multiple sources of information. Similar responses were grouped into categories. The results are seen below:

Table 5 - (Nutritionist Information Sources)

Source:	Responses
Scientific Literature/Research/Journals	35*
Cornell University/Other Universities	12
Peers/Colleagues/Other Nutritionists	10
Companies and/or Suppliers	10
Conferences and Presentations	9
Journal of Dairy Science specifically	5*
American Dairy Science Association	2
Popular Press/Magazines	2
Food and Drug Administration (FDA)	1

*Journal of Dairy Science included in total for Journals

The most common answer was “peer reviewed journal”, “published research”, and “scientific literature”. These were grouped into one category, since they refer to the same final product: a peer reviewed piece of scientific literature, based on research, that gets published in a respected journal. Many respondents specifically listed the Journal of Dairy Science or “JDA” as it is known colloquially. The second most frequent answer was Cornell University or “other research universities”, with 12 responses. This is not surprising, as the conference was put on by Cornell University, and many attendants are either graduate students, faculty, staff, or alumni of Cornell.

Ten respondents noted they get trusted information from fellow nutritionists, such as their coworkers or other folks in the industry, while 10 respondents get their information from feed companies and input suppliers. Only nine respondents mentioned conferences, although we were all in attendance at a conference where emerging research was being communicated through presentations and networking opportunities. It is worth mentioning that JDS is the official journal of the American Dairy Science Association, which was also listed by two respondents.

The survey location was great for finding nutritionists, and it was convenient to sample there. However, the results are likely skewed towards nutritionists from Cornell, from other universities, and those with PhDs. Some nutritionists I spoke with at the conference mentioned other upcoming dairy nutrition conferences and noted that some of them focus more on academic research while others are more targeted to industry like feed suppliers. Future surveys within the C3 project should strive for a more representative group of nutritionists, especially those without the means to travel and attend conferences. The responses to this question show that dairy nutritionists who attend the Cornell Nutrition Conference highly value codified knowledge produced at Cornell and other universities, especially when published in JDS.

A second means of exploring "who or what sources do nutritionists depend on for trusted information about cattle nutrition" was approached through the question "Please indicate your level of agreement with the following statement. The effectiveness of a feed supplement is best determined by…" Respondents used a Likert scale to express their relative trust in dairy farmers, consultants/extension agents, and research scientists. Of 85 survey participants that identify as analyzing or assessing feeds, 72 responded to this question:

Table 6 - (The Effectiveness of a Feed Supplement is Best Determined By)

Source:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Dairy Farmer	3	9	20	31	9
Consultant/Extension	1	4	17	38	12
Research Scientist	3	0	6	37	26

In general, respondents agreed that dairy farmers, consultants, and researchers are good arbiters of a feed supplement's effectiveness. However, I wondered if there was any relationship between a nutritionist's place of work and how they would answer this question. For example, would a nutritionist who works for an extension agency be more likely to agree that extension agents are better than say, dairy farmers, at determining the effectiveness of a feed supplement? Would a professor employed by a university be more likely to trust researchers over consultants? We included demographic questions on the survey, including information about what type of organization they are employed by, since animal nutritionists can be employed by feed companies, extension agencies, consulting firms, and dairy farms. Of 85 survey participants, 82 responded as follows:

Table 7 – (Nutritionist's Place of Work)

Type of Organization	**No.**
Grain or Feed Co.	20
University or College	17
Other*	16
Consulting Firm	10
Veterinarian	9
Dairy Cooperative	6

Extension Service	2
Milk Processor	1
Dairy Farm	1

*most common response from other category was feed additive company or supplier

I explored the relationship between a nutritionist's place of work and how they answered who best determines the effectiveness of a feed supplement by performing a cross-tabulations analysis and found no significant results (not presented in tables). It might be interesting to offer this question in a future survey to nutritionists using a rank choice question instead of a Likert scale, as the question was seeking to answer who the best arbiter is. This would force the respondent to indicate their preferences in order. However, it is still valuable to see that many respondents value multiple sources of information about feed supplements. I decided this was an important question to include in follow-up individual interviews with nutritionists and researchers, as I hoped to gain more clarity within these opinions.

Individual follow up interviews were completed with four nutritionists: Jess, Mariah, Steve, and Gary, as well as three researchers in the field: Amanda, Heidi, and Theo. I asked them "Who or what are your most trusted sources of information for cattle nutrition?" All of them except for Jess, a rumen microbiome scientist at a seaweed startup, and Gary, a nutritionist at a feed mill, mentioned the Journal of Dairy Science (JDS) by name. Amanda stated, "*I'd say Journal of Dairy Science is my most visited site. And then I would say, for people, University of Guelph, Cornell University, Wisconsin…sources that that have really reputable reputations and strong research."* Mariah built on this response:

> *Obviously, Journal of Dairy Science is a very reputable source. Looking at literature is my first go-to. Secondly would be old professors and people still in the industry*

> *doing research. Lastly, producers and other nutritionists, seeing what people are actually using instead of just what is being researched*.

For these two nutritionists, both young women relatively new to their jobs, they turn to JDS because they trust its rigorous review process and they believe the information they provide to their clients must be sound. While Amanda included research universities in her list of reputable sources, Mariah mentioned producers and nutritionists, noting the importance of on-the-ground experience to informing her work. Theo, an experienced animal scientist with an international reach, explained:

> *For me, specifically, I got most of it [information] from scientific papers. Yeah, we have alerts from journals, specifically Journal of Dairy Science, which is an American based journal, but it's across the board so it's a worldwide audience that comes in and reads the papers and studies that are published there*.

Steve, a nutritionist from Canada, also referenced the journals' roots in the United States in conversation and noted, "*We use the Journal of Dairy Science. We rely on our suppliers to bring us information. We read some of the popular press and information from various universities be them Canadian or American. And conferences, we try to pick up information there as well."* There may be explicit differences between dairy farms in Canada and the United States due to policies around production levels, quota systems, and labor laws for example, but what doesn't change is the animal science research informing the world of new technologies and their merits. Heidi, another highly experienced animal scientist, explained the importance of critical thinking in interpreting the literature:

> *Journal of Dairy Science is a pretty big one for the United States in terms of the quality. I mean, it's the same with every journal where there's some articles that you really have to take with a grain of salt. But I mean we're trained in critical analysis*

> *so I can go criticize it, analyze the paper, and realize this part is totally confounded, but this part, I feel, is sound.*

Heidi here focuses on the scientist's role in interpreting data, and not just allowing the authors of research papers to do the interpretation for you. Several other interviewees described their research methods, and how they also comb through scientific literature to better understand issues. One theme that emerged was the role of data in their hierarchy of knowledge. When asked "what convinces you to recommend feed supplements?", Mariah responded, "*I would say data first, and then large-scale production afterwards. Being a graduate student at one point, I feel like I go to data first. I don't know if that's necessarily a good thing, but that's how I tend to operate*." For Mariah, data refers to both the results of a study in quantifiable numbers, as well as published research in general. Amanda noted the centrality of "good" data in her work:

> *I really enjoyed research, and I've always found myself drawn to literature to fact-check claims and to not just rely on anecdotal evidence. So, I think at least with the way that I like to think, I like to go back to literature and go back to the Journal of Dairy Science, or Journal of Animal Science and actually find numerous replicated studies that have shown similar results. For example, if in five studies there was a production response, but in six studies there was not, then I look at differences between them. So, I don't personally find it too challenging to sift through that stuff and present the client with facts and with good data.*

Like with Bronson's *Immaculate Conception of Data*, there is an idea that the "raw" data can reveal inherent truths about what is being studied, because "raw" data is somehow immune from human decisions (Bronson 2022). This is in contrast to the science studies perspective that the context of human decisions around doing science affect the end result, as it is humans who decide what gets measured, how it gets measured, and which

measurements are reported (Kloppenburg 1988; Hassanein 1999; Sismondo 2008; Welsh et al. 2010). While Amanda stated she wants to present clients with facts and good data, we are left wondering what makes data *good*, and which data is better than others? Brian Wynne argues that "established concepts of 'good science' lend politically privileged authority to particular scientific subcultures and exclude others and are not naturally given but culturally validated – and the reciprocal validation occurs too" (Wynne 1998). In this case, nutritionists and researchers hold animal science journals, and especially certain journals over others, in high regard – so what is published in Journal of Dairy Science for example, will be considered authoritatively "good data".

The belief that data is somehow separate from people produces the idea that data can always be trusted because it doesn't lie, while people may not always be trustworthy. As long as you know how to read the data you can unlock its true meaning (Bronson 2022). This view was echoed by Heidi:

> *I do trust the science. I don't always trust the nutritionists because they're looking at what the scientists are doing and interpreting it. And sometimes the interpretation is wrong. Or sometimes they've taken anecdotal evidence and kind of taken it as hard fact, or they've done small kinds of skewed trials on some of the farms that they work with, and I and I don't have a 100% faith.*

Heidi focuses on an important point: it matters who is doing the data interpretation, and that interpretation can spoil the whole study. However, she also views the data itself as true, as something she can have "faith" in, which ignores the fact that people, in all of their social, cultural, economic, and geographic context, shape the studies that generate the data. This sentiment was expressed by Jess, who explained: "*I haven't been in the field super long, but I've seen there's a big – I don't want to say all nutritionists because there's a wide range of*

backgrounds and priorities – but there's some nutritionists that are really data-driven and have really cool insights." The language of "data-driven" is a focus of social science scholars, who note that it implies that the data is doing the driving, and people are along for the ride (Bronson 2022). For the majority of the nutritionists and researchers I interviewed, it was equally important who was determining data's good-ness. Data-driven nutritionists are preferred over the unstated, undescribed nutritionist who presumably may not be as focused on data.

If the arbiters of data's good-ness are other animal scientists, what knowledge is being excluded? Can a study on dairy animals be considered valid without mention of the farmer, farmworkers, or their practices? These types of studies aim to generalize, to flatten the complex climate and ecosystems in which farms are situated. When complexity from ecosystems and human beings is viewed as contaminating, rather than enlightening, how can we expect the results to apply to real-life applications? Where does the tacit knowledge of farmers and nutritionists fit in? Bronson and other science studies scholars suggest a "data feminism" approach, which would "value rather than problematize the inherently local, regional, and geospatial nature of data" (D'Ignazio and Klein 2020; Bronson 2022, p. 152). It is people who decide which data are collected from all the data that could possibly be gathered, and those people do not exist in a vacuum. In this theory, transparency in methodology, in funding sources, and conflict of interests is key to establishing trust.

Another potential critique of research is that it can concentrate large agricultural datasets, many that farmers helped generate, behind paywalls with highly specialized scientific language that many farmers cannot access. Bronson found many farmers were willing to accept restricted access to this information "in part because they assume that 'raw' data are useless without the…expertise to manipulate them into meaning" (Bronson

2022, p. 4). This issue can be partially addressed through ensuring journals are open access, and that findings are written in clear language. Journal of Dairy Science is open access, all authors pay a fee to ensure that their work remains free to read and share. Ensuring the language used is accessible is another story.

If C3 project researchers conduct more interviews with dairy farmers, it would be valuable to ask about farmer's experiences with and perceptions of academic journals. Many farmers now have higher degrees in animal science and can interpret the data and findings easily. However, do farmers find the journals useful for their daily decision-making on the farm? For farmers that do not have higher degrees, or may not have access to paywalled articles, understanding their perspectives and opinions on academic journals could provide deeper insight in how best to communicate the C3 project's findings.

III. Biases and Barriers: What is measured and what is missed?

A third crucial theme emerged from the follow-up interviews nutritionists and researchers; that science and technology is seen as the way forward towards innovation and a better future, but that barriers exist in the form of biases in favor of or against certain kinds of studies or study subjects. I engaged in these conversations intending to investigate differences nutritionist and researchers perceive between conventional and organic dairy production. Based on the existing literature on the subject (Hassanein 1999; Morgan and Murdoch 2000) I theorized that they would think organic producers rely more on anecdotal evidence than conventional producers, and that conventional producers rely more on codified scientific evidence. However, interviewees responded with far more nuanced views, beyond the false dichotomy and I left the

interviews looking not at nutritionists, or farmers, but reflexively at my own research design and questions.

When I asked Theo, an animal science researcher, if he thought there were differences in where organic and conventional farmers get information about feed supplements, Theo stated, "*I think there's not much difference where they're getting this information from whether it is conventional or organic. I think it's about the same source, you know, from people in the industry, milk processors, or magazines online.*" When I asked Amanda, another animal science researcher, if she thought that organic farmers relied more on anecdotal evidence than conventional farmers, she answered, "*I don't know that that's specific to organic versus conventional, just to like the personality of the farmer and like their thought process in their beliefs*." It was Heidi's comments that flipped an important switch for me. As an experienced dairy cattle researcher, she brought up key points regarding the conventional and organic dichotomy being less important than whether a farm is low input or relies on precision agricultural technologies:

> *If you're talking about, say, a grass-fed organic system, there's very little in terms of feed mill inputs happening there. It's very much what you're growing on that farm is what's getting fed to the animal, and so you don't need to have a nutritionist come out to alter the precision feeding TMR on a regular basis, because what the grass is, the grass is. You care more about what your fertilizer looks like in your manure, and in talking to the soil lab, and things like that. So, I do think that that interplays a little bit in terms of how precision feeding is your system, how hands-on does your nutritionist have to be to make that work? The more hands-on the nutritionist is with your farm because of the type of feeding you're doing, the more you're going to just naturally talk to them and ask them 'Hey? I heard my neighbor does this', or 'I saw this on this new app', or something like that. But if you don't really use a nutritionist because there's not the need to or there's not the ability to, because of the type of diet*

> *that you're feeding on farm then you're not gonna reach out to a mill and say, like, 'Hey, I don't buy from you but I have these questions, because the next thing the nutritionist is trying to get you to buy stuff. So, I think it is a little bit of a function of what the system is in terms of how heavily they communicate with the nutritionists.*

While I had been examining biases in the perspectives and perceptions of nutritionists and researchers, my own inherent bias in this study emerged. Nutritionists are not utilized equally by all types of dairy farms. Their observations of low-input farms, or organic farms, may not be useful since those farms don't require nutritionists – the interaction between them is low and therefore knowledge about each other would be low. Grass-based farms do not need to hire someone to balance their rations or create complex rations for multiple groups of animals. If we are looking to nutritionists to help us understand farmers better, so that we can understand how farmers interact with algae-based feed supplements, we are likely missing out on a large swath of low-input farmers. However, the aim of the Coast-Cow-Consumer project is not necessarily to have all dairy farmers feed algae. It is ultimately to see if large commercial dairies would use a seaweed supplement to reduce methane emissions, as they are larger emitters of enteric methane. By targeting nutritionists for this information, we are by default filtering out farmers that do not use nutritionists, and those that do not purchase many off-farm feed inputs. The algae supplementation proposed by some animal scientists to reduce methane emissions will only be relevant to farms with feed supplements coming from off the farm. In a review of current enteric methane emissions reduction strategies published in the Journal of Dairy Science, Beauchemin et al. write, "Production systems with grazing ruminants with no supplementation represent a unique challenge for mitigation because delivery systems for dietary and rumen modification-based strategies are unavailable (Beauchemin 2022, p. 9315).

The carbon cost of harvesting, shipping, distributing, and feeding algae may or may not outweigh the benefits of reduced enteric methane reduction, but we should also consider farms more removed from carbon-intensive systems of agricultural production. In dairy production this means concentrating on grazing intensive systems and on-farm forage production.

While I did not detect biases nutritionists and researchers held towards farmers based on production system, their interviews revealed biases in measurement, in the design of the studies conducted on dairy animals: there is a bias towards studying larger, conventional farms that collect data with technology. Amanda explained:

> *If you go into Journal of Dairy Science, I've never actually done this, but I'm sure if you did tally up the amount of conventional research versus organic research. It's not going to be fifty-fifty. So maybe that's part of it, too. Is that there's just a lot more research that's been done on conventional versus organic. Part of that might be numbers. Usually, conventional farms are a lot larger than organic farms, and as someone who does research, you need statistical power. You need large numbers, and usually it's easier to achieve those sample sizes and to get projects done faster. Time is money, projects cost money, it's usually just more effective to do it on really large farms where you have a ton of animals, and usually those large farms aren't organic, at least in this area.*

Researchers wanting to work with farms that are easier to work with instead of studying a representative or wide variety of production systems is not a surprising finding, but it does undercut the idea that data is independent from cultural, political, economic, social decisions. It aligns with Enlightenment-era thinking that the subject of study must be standardized in order to be understandable and broadly applicable. When I asked Lisa more about the live animal trials she conducts with her company's microbial feed supplements she mentioned, "*We try to work with farms that have daily milk meters*", while Amanda explained that:

> *A lot of the smaller organic farms that I worked with didn't use EasyFeed or TMR Tracker, which are feed programs that a lot of larger firms use. So, unless you are taking super good records, it's nearly impossible to do nutrition trials and feeding trials on smaller organic herds, and they probably have one diet, whereas conventional farms have multiple groups. You can have a control group. You can have treatment groups. I think it just makes it a little bit more challenging on smaller farm settings but doesn't make it less important. I think it's a really important area, just harder to actually accomplish good solid research on smaller farms like that.*

While Amanda acknowledged the importance of studying smaller farms and organic farms, she also implied that because they lack consistent recordkeeping, and software that can easily compile the data researchers want to obtain, studying these farms would not result in "good solid research." Agricultural science's preference for studying large industrial style farms reinforces disadvantages among farmers.

Researchers and nutritionists also mentioned barriers to more live animal trials of algae-based feed supplements. One reason organic farmers' voices and experiences seem to be missing from the literature on algae-based feed supplements for methane reduction is because it is difficult to get studies approved for feeding algae to cattle in the first place. Mariah conducted *in vivo* studies of beef cattle eating an algae-based product and mentioned that another study ran into issues because:

> *It [the algae] wasn't either FDA approved or GRAS status so they were going to have to euthanize animals and not put them into the market. I know that there was kind of a hiccup between small-scale, where you only had 6 or so animals, to large scale because they wanted the status that they could still harvest those animals.*

The smaller farms were unable to participate in the study because they could not afford to take animals off the market due to the feed supplement.

Something I heard frequently when conducting the survey of dairy nutritionists, is that nutritionists want to see more published research showing the safety and efficacy of algae-based feed supplements before they recommend them to clients. Theo explained that to get a true picture of the long-term effects of feeding algae, *in vivo* studies need to be longer. He explained "*these long-term studies in the context of the life cycle of the cow need to go through at least two lactations. I think it's very costly…. if you want to measure in the long term [feed] intakes daily, individually for animals, that's when things get really expensive*." Currently, research on seaweeds show they are relatively safe for cows but may heighten concentrations of iodine in milk. Theo believes that in order to solidly affirm the safety of an algae-based supplement, long-term studies must be conducted.

Heidi, like Theo, designs and conducts *in vivo* experiments on dairy cattle. She highlighted not just the importance of longer studies, but the importance of taking things slowly, deliberately designing research experiments to ensure the safety of animals:

> *Sometimes we get cast in this light that we're unfeeling towards animals, or that we're animal machinists and think that they're just a tool. No, it's normally the opposite - we care so much. This is the reason we're doing this job. So, we tend to move forward very carefully and are regulated on top of our own ethics and morals…that's why you see a lot of* in vitro *work out… because there's no impact to an animal. I take rumen fluid, and then we test it. If I crash the system, then it's not going to hurt an animal because it's outside of an animal. But once you start saying, 'I'm going to put that diet in front of an animal', that's a different can of worms. And so, it's much slower. Not that we don't have to get there, but just being super careful about all that preliminary stuff before we move that far.*

Despite how scientific research and technological solutions operate in "fast knowledge" (Orr 1996) studies of animals require time. Animal scientists are calling for longer-term studies, and

for moving forward with care. At the same time, there is pressure to take immediate action on methane reduction to slow climate change and adopt methane reducing technologies quickly. Research design and approval on animals takes time. Subtle changes and improvements in animals, over long periods of time, over many lactation cycles and births, are things that dairy farmers and farmworkers witness that scientists may not see. This slow, tacit knowledge is precisely what is worth measuring. Technological innovations and farm size increase may reduce the time farmers spend with their animals, and increase their reliance on knowledge brokers and experts, as well as technological, “data-driven” solutions.

CHAPTER V: SUMMARY & CONCLUSION

In this final section of my thesis, I summarize the findings of my investigation into the knowledge networks underlying understandings about algae-based feed supplements. I include reflective and reflexive thoughts on the limitations of my research, implications and suggestions for future research on the topic, followed by my closing remarks.

I. Study limitations:

Naturally, a master's thesis is constrained by both time and resources which impacted the depth and breadth of my work. I had only two years to obtain my degree, and only began my thesis in earnest in the second year. The irony of reading about tacit knowledge and slow knowledge while trying to finish my thesis in a short amount of time is not lost on me. I would have liked to hold in-depth individual interviews with dairy farmers in the Northeast, especially which organic dairy farmers who are already feeding algae. I reached out to dairy farmers on several occasions, but they often responded saying they didn't think they'd be very helpful because they didn't "know" a lot. Despite my insistence, explaining that they would indeed be very helpful, and that I was not testing their scientific knowledge but rather aiming to learn from them about their observations and priorities, it did not work out. Perhaps this was a failure on my part to adequately communicate the research questions and goals for the project. However, other scholars have noted this phenomenon. In one study on local knowledge in sustainable agriculture, they found that a consequence of the dominance of productivist agriculture is that "farmers tend to give less weight to their own experimentation and knowledge" (Šūmane et al. 2018).

I also found this to be true for nutritionists. Over the course of the conference where the survey was conducted, nutritionists would insist that they had no value to add to my survey. After

much cajoling and explaining exactly what we were measuring, they tended to relent. Even researchers I interviewed expressed not knowing enough to speak with me. My positionality as a social scientist from a research-heavy university may have informed my identity to them, and assumptions about what information is valid. However, I think the reason for this is that productivist agriculture has defined what data is good data, and what data is contaminating. My curiosity for the "contaminating" social, cultural, and experiential factors informing farmers, nutritionists, and researchers, and its ensuing confusion from research subjects, shows how far we have to go until the wholeness of knowledge is truly included in science scholarship.

Another possible limitation to my research is the sample selection and sample size for interviews and surveys. None of the research I conducted was systematic or randomized, and therefore codified science would call it's validity into question. The survey should be iterated on and disseminated beyond the geographic and cost constraints associated with in-person conferences, to land-grant universities, extension services, feed mills, online networks, and email listservs for dairy nutritionists. Additionally, Amish and Plain Folk dairy farmers, as well as women dairy farmers, should be incorporated into the scope of research for the project. Widening the net for the survey as the C3 project expands out of the boundaries of the Northeast would continue to help inform the project's direction.

Lastly, as my research progressed, more and more themes about the role of technology and bias in research came forward. It would be interesting to survey farmers as well as nutritionists about their interactions with on-farm technology, specifically those that collect large datasets. Further research should investigate the relationship between dairy farm technology and data, and how this relates to research on novel feed supplements.

II. Implications and recommendations for future research:

The C3 research project and my research into knowledge networks in the dairy industry demonstrates that interdisciplinary research projects are necessary. Instead of viewing farmers as instruments of economic production, we must incorporate their practices and observations into our understanding of agroecosystems. Dairy farms are complex and while modern science still relies on removing variables to perform accurate research, more studies should be designed to reflect complexity. We can only attempt to know something in its entirety if we refuse to segment it into rational pieces of data. For the purposes of algae-based feed supplement research studies, we should design experimental animal trials with various cattle breeds in diverse production systems. We must ask how grazing dairy animals process seaweed differently than confined, conventional cattle for example, instead of problematizing local, tacit knowledge.

Secondly, the role of knowledge brokers in this type of research deserves more scrutiny. While scholars have suggested that knowledge brokers are essential to communicating knowledge between homogenous in-groups, this also contains assumptions about the positionality and knowledge paradigm the broker subscribes to (Rust et al 2022). Farmer's increasing reliance on intermediaries has been cited as problematic by other scholars, described as a sign of further alienation from their tacit knowledge (Storper 1996; Wood et al. 2014; Šūmane 2018). So, it will be necessary going forward to continually investigate the beliefs and intentions of knowledge brokers. While my research includes the finding that dairy farmers typically rely on their nutritionist to make feed decisions and investigations into nutritionist's decision-making process and trusted sources of information, I did not interrogate farmers and nutritionist's perspectives of one-another or how the exchange of knowledge between them could be altered or improved.

Thirdly, we found that farmers would adopt methane-suppressing feed supplements if they have other measurable and observable benefits to herd health, such as reducing the reliance on antibiotics or lowering veterinary bills or if they are incentivized to feed them. The scope of my research project did not include a full accounting of incentive programs or if incentivizing algae-based feeds would be effective. Policies implemented to incentivize farmers for feeding algae to reduce methane should include the perspectives of farmers to ensure the timely and equitable distribution of incentive funds. Because farmers are interested in feeding algae for herd health benefits, more in vivo animal trials should occur with various algae species that aim to investigate health benefits. Research and development into locally applicable methane mitigation strategies that account for all of the complexities found on a dairy farm are necessary – we must face the complex problem of climate change with complex solutions.

III. Conclusion:

In conclusion, dairy farmers that already feed algae-based supplements to their cows do so because they believe it offers benefits to herd health, such as reduced pink-eye infections and improved fertility. Algae-supplement users tend to be certified organic farms, because what they may feed to cows is limited by organic regulations. Conventional farmers have sometimes fed algae but ceased due to increased costs. In order to feed a novel seaweed supplement for the purposes of reducing enteric methane emissions, farmers want to be incentivized or have the supplement offer a health benefit. Farmers in focus group interviews reported trusting their nutritionist with feed recommendations, although a few farmers reported they did not use a nutritionist. Other trusted advisors include extension agents, feed suppliers, and veterinarians, although organic farmers bemoaned veterinarians lack of knowledge and understanding of organic regulations. Our findings informed the development and implementation of a survey of

dairy nutritionists at the Cornell Nutrition Conference, as well as follow up individual interviews with nutritionists and researchers familiar with the project. Nutritionists and researchers overwhelmingly reported obtaining information pertaining to feed supplements from animal science journals, specifically the Journal of Dairy Science, and highly trust raw data and data-driven nutritionists. The biases implicit in animal science research include scientist's preference of studying production systems that are "easier" to collect information from due to farm size, and use of data-gathering and recordkeeping software. This bias perpetuates the lack of research on dairy farms that do not fit into this category, which would add complexity and richness to findings. There is a tension between the urgency of needing climate change technologies as soon as possible, and ensuring experiments are designed thoughtfully and occur over longer periods of time. Concurrently, a tension exists between codified knowledge producers and tacit knowledge holders, where the flow of knowledge is top-down, reproducing existing patterns of power in the agricultural system. As Kelly Bronson so eloquently states, the focus on technological fixes creating a better future "prevents us from seeing how current problems and dominant solutions follow from the past, and they also prevent us from seeing that we have at our disposal a suite of innovations to help solve our grand challenges, if we could only recognize them as innovative" (Bronson 2022, p. 153).

APPENDICES

APPENDIX I: Questions as Basis for Interview Guide and Survey for Organic and Conventional Dairy Farmers

Introduce yourself. Explain the focus group methodology, reason for the focus group and what we wish to obtain from the interview. Informed consent given verbally. Names of participants will not be used in published findings.

1. Describe, briefly, how you came to farm in this region and how your farm has changed over time, regarding farm size, milking system, and cattle feeding regimes.
2. Have you used algae-based feed supplements in your operation? If you haven't used algae-based feed supplements, have you heard of dairy farmers using them?
3. For what reasons do you use algae-based feed supplements or believe others use them?
4. If you do not use algae-feed supplements, why not?
5. I have compiled a list of potential benefits of algae-feed supplements. I will read the potential benefit and please indicate if you are aware of it, not aware, or unsure.

Attribute	Aware	Not Aware	Unsure
Increase Milk Yield			
Source of Vitamin C			
Source of Magnesium			
Source of Calcium			
Source of Zinc			
Enhance immune function			
Increase weight gain			
Reduce weaning stress			
Improve fatty acid profile of milk			
Increase milk fat content			
Reduce somatic cell counts in milk			

6. Do you believe it's difficult to access algae-based feed supplements? Why?
7. It's often said that organic dairy farmers use algae-based feed supplements more than conventional dairy farmers- do you agree and if so, why do you think that is?
8. Do you believe algae-based feed supplements have potential negative effects? What are the negative effects (on dairy production or cow health, others)?
9. Have you heard that feeding algae supplements can reduce methane emissions from cattle? Is this something in which you are interested?
10. Have you heard of C offset (OR INSET) programs or other types of programs to incentivize farmers to reduce GHG emissions? Is this something in which you are interested?
11. Does your milk buyer have sustainability goals? What are they and how are they implemented?

12. Has your milk buyer-imposed caps on production? Has this changed your feeding regimes or the type of cow you milk? More emphasis on component pricing? Please explain.
13. Have you heard of on-farm micro-algae production? Would you consider installing a micro-alga growing system on your farm?
14. Do you have an anaerobic digester on your farm? Would you consider linking it with a micro-algae system (using effluent from the AD as growth medium for the algae? (Closed system with effluent to grow algae to feed to cows and cow waste fed into AD).
15. Who or what are your most trusted/valued info sources for cow nutrition?
16. Are there other people to whom we should speak about this topic? OV nutritionist Dr. Silvia Abel-Caines.
17. Is there any other information you wish to provide, or questions you need answering before adopting algae-based feed supplements?

APPENDIX II: Survey of Dairy Nutritionists on Algae-Based Feed Supplements

Informed Consent statement:

We are Professor Rick Welsh from Syracuse University, and Michelle Tynan, and Ryan Fitzgerald, two graduate students also at Syracuse University. We are inviting you to participate in a research study.
We are interested in learning the opinions of dairy nutritionists about algae feed supplements (e.g. kelp, seaweed, and microalgae). You will be asked to fill out a short survey, either on paper or a personal electronic device. It will take approximately 5 minutes of your time.

Involvement in the study is voluntary. This means you can choose whether to participate and that you may withdraw from the study at any time without penalty. There is no incentive provided for participation in the study.

If you have any questions, concerns, or complaints about the research please contact Professor Rick Welsh at jrwelsh@syr.edu.

Whenever one works with email or the internet, there is always the risk of compromising privacy, confidentiality, and/or anonymity. Your confidentiality will be maintained to the degree permitted by the technology being used. It is important for you to understand that no guarantees can be made regarding the interception of data sent via the internet by third parties.

I am 18 years of age or older, and by continuing I agree to participate in this research study.

Survey:

1. **Does your job involve recommending or assessing dairy feed supplements?**
   ___ No, I don't recommend or assess dairy feed supplements (**end of survey**- thank you for participating)

   ___ Yes, I do recommend or assess dairy feed supplements for the following (check all that apply):

   ___ Grain or Feed Company

   ___ Dairy Farmers

   ___ Extension personnel

   ___ Dairy Cooperative

   ___ Dairy Products Manufacturer

   ___ Other:

   _____

   _____

2. **Have you heard of algae feed supplements, e.g. products containing seaweed, kelp, or microalgae?**
   ___ Yes

   ___ Maybe

   ___ No (**END OF SURVEY - THANK YOU FOR PARTICIPATING**)

---

3. **Have you ever recommended using algae feed supplements?**

   ___Never (go to question 4)

   ___Sometimes (go to question 5)

   ___Frequently (go to question 5)

4. **If not, why not? (Choose all that apply)**

   ___ They don't work

   ___ There are better alternatives

   ___ I don't know enough about them

   ___ My clients do not want to use them

   ___ They are too expensive

   ___ They are difficult to find

   ___ Other:

   _____

5. **Here is a list of attributes or claims made about algae feed supplements. For each please indicate if you are aware of the claim and whether the claim has little or no scientific support, some scientific support, or strong scientific support. If you have not heard of this claim, leave the row blank.**

Attribute/Claim	Claim has little or no scientific support	Claim has some scientific support	Claim has strong scientific support
Source of vitamins			
Source of minerals			
Source of Iodine			

Enhances immune function			
Increases weight gain			
Increases milk yield			
Increases milk fat content			
Improves fatty acid profile of milk			
Reduces somatic cell counts in milk			
Improves calf health			
Treats pink-eye infection			
Helps with cow's reproductive/fertility issues			
Helps with fly control			
Reduces methane emissions			

6. **Are there any ingredients within a diet or TMR (total mixed rations) that you believe algae feed supplements could replace?**

___ No

___ Maybe (list components below)

___ Yes (list components below)

Possible replaceable ingredients include:

_____

_____

7. **Could the use of algae-feed supplements reduce the use of antibiotics in dairy production?**

___ Not likely

___ Maybe

___ Yes

8. **Where do you obtain trusted information for recommending dairy feed supplements**?

_____
_____
_____
_____

9. Do you hesitate to recommend new feed supplements to your clients?

___ No, if there is good evidence for its use, I would recommend it

___ No, it depends on the client's needs

___ Yes, I'm conservative in that way

10. What convinces you to recommend new supplements?

_____
_____
_____

11. Please indicate your level of agreement with the following statements:
The effectiveness of a feed supplement is best determined by the…

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Dairy Farmer/ Herd Manager	◯	◯	◯	◯	◯
Consultant or Extension Specialist	◯	◯	◯	◯	◯
Research Scientist	◯	◯	◯	◯	◯

12. What is your current position or job title?

_____
___

13. Type of organization for which you work.

___ University or college

___ Extension Service

___ Grain or Feed company

___ Veterinary Science/Animal Health

___ Consulting firm

___ Dairy Cooperative

___ Milk processor

___ Dairy Farm

___ Other:

14. What is the highest degree you have obtained:

___ High School Diploma

___ Associates Degree

___ Bachelor's Degree

___ Master's Degree

___ PhD.

___ Other: _____

15. In what discipline did you earn your highest degree?

_____

16. **What is your age?** _____

17. With which gender do you identify?

___ Male
___ Female
___ Non-binary
___ Transgender
___ Other
___ Prefer not to say

18. Do you wish to see a copy of the survey results? If yes, please provide your name and email address.

_____
_____
_____

19. May we contact you in the future to ask more questions on this topic?

___ Yes, my email address is _____

___ No

20. Is there anything else you'd like to share with us today about this topic?

_____
_____
_____
_____
_____
_____

Thank you for taking our survey.

APPENDIX III: Questions as Basis for Interview Guide for Dairy Nutritionists

Introduce ourselves. Explain reason for the interview, what we wish to obtain, and the methodology.

Explain that this is not a test. We just want to know more from them; and to learn what they know and don't know. Determine baseline knowledge level. Also, sometimes answers to questions may seem obvious to you; but we still need you to answer in order for us to develop a reliable data set. If you need a question clarified, please do not hesitate to ask us.

Rapport + background questions:

1. How did you end up in your current job? How has your job changed over time?

Algae-Feed questions

2. Have you ever recommended or analyzed algae-based feeds?
    a. If yes, why
    b. If no, why not
3. For what reasons do you think algae feeds are used?
4. Are algae feeds difficult to access?
    a. If yes, why? (Cost? Availability?)
5. Do you think algae feeds have potential positive effects on cows? On milk?
6. Do you think algae feeds have potential negative effects on cows? On milk?

GHG/Methane questions

7. Does your company have climate/sustainability goals?
8. Do your clients seek or ask you about feeds that reduce methane emissions?
9. Have you heard of claims that feeding algae can reduce methane emissions?

Decision-making questions

1. What drives the decision-making behind creating a total mixed ration/TMR?
2. How are prices set for TMRs? How much negotiation takes place between buyers and sellers? On what basis do buyer and sellers negotiate over price?
3. On what bases do the components of TMRs vary? Why would you include or exclude ingredients? Why would buyers demand different ration mixes?
4. How do you communicate changes in rations/sourcing to clients?
5. What convinces you to recommend feeds/supplements?
6. What or who are your most trusted/valued information sources for cattle nutrition?

Closing questions

7. Is there anything else you'd like to mention on the subject of algae-based feeds?
8. Who else should we speak to about this topic?

APPENDIX IV: Questions as Basis for Interview Guide for Experts

Introduce self. Explain the reason for the interview, what I wish to obtain, and the methodology. Informed consent statement and include that interviewees will be anonymous in research findings.

Request permission to record this conversation on Zoom. This allows for the transcription service to take the notes for me, so I can better engage in our conversation.

Rapport + background question:

1. How did you end up in your current job?

Algae-Feed questions:

2. Do you think algae feeds have potential positive effects on cows? On milk? (what are they?)

3. Do you think algae feeds have potential negative effects on cows? On milk? (what are they?)

4. Why do you think some dairy farmers feed algae? What are the top 3-5 reasons?

5. Do you think the reasons farmers feed algae are backed by science/research? Please explain.

6. Where do you think most farmers get their information about feed supplements?

7. Do you notice differences between organic and conventional dairy farmers in this regard? Please elaborate.

Decision-making questions:

8. What convinces you to recommend feeds/supplements?

9. What or who are your most trusted/valued information sources for cattle nutrition?

Closing question:

10. Is there anything else you'd like to mention on the subject ?

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CURRICULUM VITAE/RESUME

EDUCATION

M.S. Food Studies: Syracuse University – Syracuse, NY Aug. 2021-May 2023
Thesis on Dairy Farmer's Perception and Knowledge of Seaweed as a Livestock Feed
B.A. Environmental Studies: Lewis & Clark College – Portland, OR Aug. 2008- May 2012
Concentration in Sustainable Agriculture & Food Systems

EXPERIENCE

Graduate Research Assistant – Syracuse University July 2022- May 2023

- Researcher on USDA NIFA grant funded "Coast-Cow-Consumer" project, studying herd health benefits and enteric methane reduction potential of seaweed-based livestock feeds.
- Engaged dairy farmers, nutritionists, and scientists through outreach, education, surveys, and interviews.
- Analyzed data and synthesized findings into academic journal articles, news articles, and presentations.
- Collaborated with large interdisciplinary team including biologists, economists, and extension specialists.

Graduate Teaching Assistant – Syracuse University Aug. 2021- July 2022

- Teaching assistant for Labor Across the Food Chain (Fall 2021) and Agroecology (Spring 2022)
- Created exam questions, rubrics, and project ideas and graded all student work.
- Guest-lectured on rotational grazing practices and indigenous intertidal agroecology practices.
- Co-authored an academic journal article on the H-2A agricultural visa program.

Organic Crop & Livestock Certification Specialist Feb. 2017- July 2021
Washington State Department of Agriculture – Olympia, WA

- Staff point-person for dairy farm clients, with specialized knowledge of complex regulatory landscape.
- Evaluated applications, grazing plans, inspection reports, and input materials for compliance.
- Made certification decisions, issued organic certificates, and communicated with clients to summarize findings and identify areas for improvement.
- Provided knowledgeable technical assistance to existing and prospective clients.
- Worked with industry partners and stakeholders to adapt to changing regulations.
- Represented WSDA at Western Organic Dairy Producers Association annual meeting, Cascadia Grains Conference, Country Living Expo/Cattlemen's Winter School (WSU), Tilth Alliance farm walks, and Washington Women in Agriculture Conference.
- *Training*: IOIA Crop & Livestock, Western WA Pasture Calendar (WSARE), Farmer Suicide Prevention.

Creamery Manager, Lead Cheesemaker, and Cow Milker Sept. 2013- Sept. 2016
Mermaid Farm & Dairy – Chilmark, MA

- Milked herd of Jersey cows year-round and cared for calves, pigs, and sheep.
- Streamlined cheesemaking operations, established a Hazard Analysis and Critical Control Point protocol for food safety, and developed new cheese recipes.
- Practiced rotational grazing, manure composting, conventional and organic animal healthcare, and soil testing and amending.
- Managed seasonal staff, farmer's market stall, wholesale accounts, and farmstand.
- *Training*: Online Dairy Production & Management Course taught by Penn State (Spring 2016)

Crew Leader at North Tabor Farm – Chilmark, MA April 2013- Sept. 2013

- Managed seasonal staff, farmer's market stall, wholesale accounts, and farmstand.
- Grew mixed vegetables, fungi, flowers, laying hens, and broiler chickens using organic practices.

Farm-Based Educator at The Farm Institute – Edgartown, MA June 2012- Sept. 2012

- Designed lesson plans and taught K-8 students about sustainable agriculture via hands-on experience with multi-species rotational grazing.
- Cared for heritage beef cattle, sheep, pigs, and poultry.

PUBLICATIONS & PRESENTATIONS

Tynan, M. (2023) "Why Feed Seaweed? Tacit and Codified Knowledge Networks in the Dairy Industry." *Syracuse University, Graduate Thesis.*

Tynan, M. K., Bryant, M. C., Welsh, R., & Greenwood, S. L. (2023). Preliminary findings of northeast organic and conventional dairy farmers' perception of benefits and challenges in feeding algae. Renewable Agriculture and Food Systems, 38, e23. https://doi.org/10.1017/S1742170523000157

Minkoff-Zern, L.A., M. Tynan, A. Zudzsma, and M.J. Dudley. (2023) "Agrarian Hierarchies in the H-2A Guestworker Program: Temporal and Spatial Limitations to Worker and Farmer Coping Strategies" *Agriculture, Food, and Human Values Annual Conference, Boston, MA. Policy and Promise in Farm Labor session, June 2, 2023.*

Welsh, R., and M. Tynan (2023) "Dairy Nutritionists' Opinions of Efficacy of Feeding Algae Feed Supplements to Dairy Cattle" *American Association of Geography Annual Conference.* Presented March 24, 2023.

Tynan, M. (2022) "Will the Dairy and Seaweed industries in the Northeast Work Together to Reach Net-Zero?" *Northeast Dairy Magazine.* Q4 2022. P. 34-36.

VOLUNTEER WORK

Graduate Student Org.– Senator Food Studies Department - Syracuse University (2022-2023)
Thurston County Food Bank – Olympia, WA (2019- 2021)
United Way of Thurston County: COVID-19 vaccination clinics – Olympia, WA (2021)
Island Grown Gleaning – West Tisbury, MA (2013- 2016)