THE IMPACT OF EDUCATION ON STUDENTS' UNDERSTANDING OF THE PET FOOD INDUSTRY

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Master of Professional Studies

by

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August 2024

ABSTRACT

Numerous misconceptions circulate within the pet food industry, with a notable lack of scholarly literature supporting them. These misconceptions significantly impact consumer decisions regarding pet nutrition. With the rise of social media and increased reliance on online sources, misinformation has become more widespread, frequently presenting biased perspectives on specific feeding practices. While the Internet can offer valuable insights into pets' nutritional needs, the quality of information is highly variable, making it challenging for consumers to discern accurate from misleading content. To address this issue, I designed and facilitated a senior animal science course at Cornell University (ANSC 4290/6290) in the Spring 2024 semester, aimed at educating students on common misconceptions within the pet food industry. The course covered topics such as pet food safety, the role of the rendering industry in pet nutrition, and the feasibility of vegan diets for dogs. This study assesses the impact of the course on students' perceptions through pre- and post-lecture surveys, focusing on topics where misunderstandings frequently arise. Results suggest that the course effectively improved students' understanding of complex issues in pet nutrition, highlighting the importance of targeted education in mitigating misinformation. As studies examining consumer perceptions of the pet food industry are limited, it is challenging to quantify the extent of misinformation and its impact on consumers. Therefore, this research not only contributes to enhancing public education but also helps quantify the level of misinformation present in the industry.

BIOGRAPHICAL SKETCH

Asmaa Ali grew up in Lansing, Michigan with an unwavering passion for animals from a young age. This dedication drove her to pursue a Bachelor of Science degree in Zoology at Michigan State University, with aspirations of becoming a veterinarian. After completing her undergraduate studies, Asmaa's growing interest in animal nutrition - particularly for felines and canines - motivated her to pursue a Master of Professional Studies in Animal Science at Cornell University, with a concentration in animal nutrition.

Upon graduation, Asmaa aspires to work for pet food companies to develop nutritionally complete and balanced diets tailored to the diverse needs of pets. She is also committed to advancing public education in pet nutrition, seeking to address the numerous misconceptions that currently exist within the industry.

ACKNOWLEDGMENTS

I am deeply grateful to the many individuals who have contributed to the success and progression of this project. First and foremost, I would like to thank my academic advisor, Dr. Nathalie Trottier, for her invaluable guidance, unwavering support, and insightful feedback throughout this journey. Her expertise and mentorship have been instrumental in shaping the direction of this work. I also extend my gratitude to the faculty and staff of the Animal Science department at Cornell University for providing me with the knowledge and resources necessary for the development of this project. Additionally, I would like to thank the students in my Spring 2024 course (ANSC 4290/6290) for allowing me to utilize their survey data, as well as the course speakers whose contributions were crucial in shaping the information provided throughout this project. Last but certainly not least, I would like to express my heartfelt thanks to my family and friends for their support and encouragement throughout this journey, especially my parents, who have been there for me every step of the way.

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LIST OF ABBREVIATIONS

FDA – US Food and Drug Administration

FD&C Act – Federal Food, Drug, and Cosmetic Act

FSMA – Food Safety Modernization Act

GRAS – Generally Recognized as Safe

AAFCO – The Association of American Feed Control Officials

FDAAA – Food and Drug Administration Amendments Act

RFR – Reportable Food Registry

DCM – Dilated Cardiomyopathy

BA – Bile Acids

AWA – Animal Welfare Act

PHS Policy – Public Health Service Policy on Humane Care and Use of Laboratory Animals

RMBD – Raw meat-based diet

INTRODUCTION

Numerous misconceptions circulate within the pet food industry, with a notable lack of scholarly literature supporting them. These misconceptions significantly impact the average consumer's decisions regarding pet nutrition. Previous studies have highlighted the importance of public education on consumers' feeding practices.

For example, a survey study by Schleicher et al. (2019) found that approximately 24.6% of cat and dog owners cited Internet sources as their primary source of information for their pets' nutrition. In another survey study conducted by Kogan et al. (2018) in the UK, it was found that the most frequently used source for pet health information was the Internet (78.6%), with the topics searched for most often being specific medical problems (61.3%) and diet/nutrition (58.5%). Although the Internet can be a reliable source for receiving information on pets' nutritional needs, the quality of information can be highly variable and biased toward specific feeding practices. Moreover, the growing trend of humanization and anthropomorphism of pets has spurred strong marketing messages, ingredient claims, and confusing and often conflicting information on the Internet about the best food for pets. These factors have made it increasingly difficult for pet owners to make objective pet food purchase decisions. One survey of 900 dog owners found that nearly half responded that choosing the right food for their dog was the most difficult part of pet ownership. In this same survey, 52% of dog owners (and 68% of Millennial dog owners, ages 18 to 34) responded that their dogs' nutrition was more confusing than their own, with nearly 25% feeling overwhelmed with the choices available (PetFood News, 2015). This confusion is due to consumers' lack of knowledge of pet nutrition, which makes it difficult for them to identify misinformation and respond accordingly. Therefore, correcting misconceptions or directing owners to reliable sources of information about companion animal nutrition is essential for ensuring sound nutritional decisions for pets.

These findings underscore the importance of public education to ensure the proper

nutrition and welfare of pets. To address this need, I designed and facilitated a course (ANSC 4290/6290) for the Spring 2024 semester, featuring a plethora of speakers with diverse areas of expertise within the pet food industry. The course aimed to educate students on various topics where misunderstandings often arise within the industry. Building upon this educational initiative, this study aims to assess the impact of the course on students' perceptions of the pet food industry through the administration of pre- and post-lecture surveys on selected topics covered in the course. This thesis presents the study methods, in-depth descriptions of six selected topics presented in six respective chapters, along with their corresponding survey results and discussions, and a conclusion.

MATERIALS & METHODS

Study Design and Study Population

This study was designed to assess how students' understanding and opinion of the pet food industry changes through the administration of pre- and post-lecture surveys for each of the 10 topics covered in the course. The participants included 21 students enrolled in a senior animal science course (ANSC 4290/6290) at Cornell University. The cohort primarily consisted of undergraduates (19) with a small number of graduate students (2). Students had varying levels of background in animal nutrition, with most possessing a general understanding before the course began.

Pre- and Post-Lecture Surveys

Weekly pre- and post-lecture surveys were administered for each topic using Cornell University's Qualtrics survey tool. The surveys were graded based on completion, and no identifying information was included in the reported data. Pre-lecture surveys were due on Friday afternoons before the scheduled lectures, while post-lecture surveys became available after the lectures on Friday and were due the following Tuesday. Each pre-lecture survey comprised approximately 10 opinion-type questions related to a specific topic within the pet food industry. The post-lecture surveys contained around 10 questions, many of which were identical to those in the pre-lecture surveys, to evaluate the lecture's effectiveness in improving understanding or correcting misconceptions. The format of the questions was primarily multiple choice, but also included some ranking and 5-point Likert scale questions. Survey data for students who did not attend a specific lecture were omitted from the final results.

Ethical Considerations

This study was conducted in accordance with ethical standards and received approval from the Institutional Review Board (IRB) at Cornell University (Protocol Number: IRB0148559). Informed consent was obtained from all participants for their participation in the surveys.

Statistical Analysis

The survey data were analyzed using descriptive statistics to compare pre- and post-lecture survey responses.

Chapter 1: Pet Food Safety

The FDA's Regulatory Role in the Pet Food Industry

Many consumers may presume the pet food industry to be self-regulated and free of any government control or oversight. This is false and can create distrust in the pet food industry as a whole. For instance, in a survey study conducted by Morgan et al. (2017), concerns about the safety and quality control of commercially processed diets were a commonly cited reason for owners choosing to feed their pet raw food despite professional veterinary and health associations (e.g. the American Veterinary Medical Association, Canadian Veterinary Medical Association, and Center for Disease Control) advising against it. This is an example of why it is critical for pet owners to understand who regulates their pets' food and the extensive guidelines and rules that must be met before a pet food product can be commercially available for purchase.

Pet foods are regulated by multiple agencies on both the federal and state level. Among the agencies involved in the regulation of pet foods is the US Food and Drug Administration (FDA) – a federal agency. The lecture material presented for this topic highlighted the extensive regulation measures in place to ensure pet food safety. One of the key regulations is the Federal Food, Drug, and Cosmetic Act (FD&C Act), established in 1938 and enforced by the FDA. It requires that all animal foods, like human foods, be safe to eat, produced under sanitary conditions, contain no harmful substances, and be truthfully labeled. It also prohibits the distribution of adulterated and/or misbranded products across state lines. Adulterated products are those that are deemed defective, unsafe, unapproved, filthy, putrid, or decomposed, and/or produced under unsanitary conditions. Misbranding refers to false or misleading product labeling and/or failure to provide the required label information for a pet food. The FD&C Act also

distinguishes between a ‘food’ and a ‘drug.’ ‘Food’ is essentially a product or component of a product that is used mainly for nutritive, taste, or aroma purposes. A ‘drug’ includes articles intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease in humans or other animals, and articles (other than food) intended to affect the structure or any function of the body of humans or other animals. Under this premise, veterinary prescription diets would be classified as unapproved animal drugs as they are meant to treat or help prevent certain diseases but are typically not approved by the FDA. They do not contain drugs as the term is typically contemplated by the public, but rather are intentionally formulated to exert an effect on a disease or condition by virtue of manipulation of common feedstuffs to alter nutrient content (e.g. controlled protein/phosphorus for the management of chronic kidney disease) (Dzanis et al., 2023). Therefore, they must be sold by a veterinarian or require a veterinary prescription to be purchased through a retail store or the Internet. The lecture reiterated, however, that aside from therapeutic diets (or veterinary prescription diets), there has never been an encounter of a pet food that would otherwise be classified as a ‘drug.’ Another act enforced by the FDA’s regulatory authority is the Food Safety Modernization Act (FSMA), established in 2011. While the FD&C Act ensures pet food safety through a reactionary approach, the FSMA was passed to ensure pet food safety through preventative means and was meant to amend the FD&C Act. It gave the FDA new authority and tools for preventative controls, inspection and compliance, and import standards among other things.

Federal requirements for a pet food label include the following: an identity statement, net contents, a statement of ingredients, and the name and address of the manufacturer or distributor. Each ingredient in a pet food product must also be approved by the FDA, meaning it must be GRAS (Generally Recognized as Safe) and/or an approved color or food additive. For an

ingredient to be GRAS for an intended use, it must have evidence of safety through a scientific basis or be commonly used in foods prior to 1958. Its safety must also be universally known and accepted. The GRAS classification is species-specific, and FDA approval is not required for an ingredient under this classification. It's important to note that an ingredient recognized as 'safe' in another country isn't necessarily recognized as 'safe' in the USA. Examples of food additives include minerals, vitamins, and preservatives. Just like human food products, pet food formulations are not subject to FDA approval before being made commercially available. However, the ingredients used in either human food products or pet food formulations must have been FDA-approved prior to their use, and the product labels must comply with federal and state regulations. Therefore, the pet food manufacturer or distributor do not have free say over the ingredients used or the content of the labels. They are subject to extensive regulation on both the federal and state levels. State regulatory measures will be discussed more extensively later in this chapter. The FDA also works closely with the Association of American Feed Control Officials (to be further discussed in the forthcoming section) to help establish and implement universal recommendations and standards applied across each state. Overall, this lecture effectively affirmed the extensive federal regulation that ensures our pets' food is safe.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture are shown in **TABLE 1A** and **TABLE 1B**. It is important to note that many of the students (~57%) had previously completed a course on the nutrition of cats and dogs before the initiation of this seminar. The FDA's role in the pet food industry, although not extensively covered, was briefly mentioned in that course; therefore, the survey results below may not be fully representative of the general consumer population. Nonetheless, when students were asked

where they would normally choose to obtain information regarding the safety and/or quality of a pet food product, a significant number still selected Internet sources, with 11% of students relying on social media outlets and 39% relying on online reviews (**TABLE 1A**). This is noteworthy because, as previously mentioned, the Internet can be a substantial source of misinformation, especially if the reader is not properly educated on the nutrition of cats and dogs.

Before the lecture, the majority (89%) of the students were already aware of FDA regulation in pet food (**TABLE 1A**). However, when asked about their familiarity with the FDA's role in regulating pet foods on a scale of 1 to 5—where 1 is 'Not familiar at all' and 5 is 'Extremely familiar'—the majority of students (89%) were not very familiar with the FDA's regulatory role. Specifically, 17% indicated they were 'Not familiar at all,' 28% were 'Slightly familiar,' and 44% were 'Moderately familiar.' Only 11% of students indicated they were 'Very familiar,' and none (0%) indicated they were 'Extremely familiar' (**TABLE 1B**). This suggests that even among students with some knowledge of animal nutrition, the FDA's role was not well understood. When the same question was posed in the post-lecture survey, significantly more students indicated that they were 'Very familiar' and 'Extremely familiar' with the FDA's role (**TABLE 1B**). A similar trend was observed when students were asked to rate the safety of the ingredients included in pet foods, with 1 being 'Very unsafe' and 5 being 'Very safe.' In the pre-lecture survey, 0% of students selected 'Very safe' as their answer, while 33% selected it as their response in the post-lecture survey (**TABLE 1B**). These results demonstrate increased trust in the pet food industry and the regulation responsible for ensuring pet food quality and safety when students learned more about the FDA and its role in the pet food industry.

TABLE 1A. *Survey student responses on the FDA's regulatory role in the pet food industry (n = 18)*

Questions and Answer Choices	%
Have you ever looked into how pet foods are regulated to ensure safety? –	
Yes	72
No	28
What sources would you normally choose to obtain information from to ensure the safety and/or quality of a pet food product (select all that apply)? –	
Social media outlets	11
Veterinarians	89
Pet store staff	17
Online reviews	39
Other	39
Before coming into this course, were you aware of the presence of FDA regulation in pet food? –	
Yes	89
No	11

–This question was not asked in the post-lecture survey for this topic.

TABLE 1B. *Pre- and post-lecture survey student responses on the FDA's regulatory role in the pet food industry (n = 18)*

Questions and Answer Choices	%*	%**
On a scale of 1 to 5, how familiar are you with the FDA's role in regulating pet foods, where 1 is 'Not familiar at all' and 5 is 'Extremely familiar'?		
1 - Not familiar at all	17	0
2 - Slightly familiar	28	0
3 - Moderately familiar	44	33
4 - Very familiar	11	50
5 - Extremely familiar	0	17
On a scale of 1 to 5, how safe do you think the ingredients included in pet foods are, with 1 being 'Very unsafe' and 5 being 'Very safe'?		
1 - Very unsafe	0	0
2 - Unsafe	0	0
3 - Moderately safe	39	11
4 - Safe	61	56
5 - Very safe	0	33
Each feed ingredient listed on a pet food product label has been approved by the FDA.		
Strongly disagree	11	17
Somewhat disagree	22	6
I do not know	22	0
Somewhat agree	28	28
Strongly agree	17	50
The information provided on a pet food product label is regulated by the pet food manufacturer.		
Strongly disagree	6	17
Somewhat disagree	33	39

I do not know	11	0
Somewhat agree	39	17
Strongly agree	11	28
All pet food products must be approved by the FDA before they are available for consumer purchase.		
True	56	17
False	33	83
Not sure	11	0

*Pre-lecture survey responses
**Post-lecture survey responses

State Regulation & AAFCO's Role in the Pet Food Industry

As previously mentioned, the pet food industry is extensively regulated at both the federal and state levels. While the FDA enforces regulations federally, state regulation is typically upheld through each state's Department of Agriculture. Regulatory measures at the state level may include facility inspections, pet food sampling and analysis, firm inventories, tonnage/annual fees, product registrations, and label reviews. Although each state has its own set of laws and regulations pertaining to pet foods, many states participate in the activities of the Association of American Feed Control Officials (AAFCO) to help mitigate inconsistencies.

The Association of American Feed Control Officials (AAFCO) is a non-profit organization established in 1909. It consists of regulatory officials from federal, state, and international agencies, all of whom act as volunteers. The FDA, as previously discussed, works closely with AAFCO and many of its officials are members of the association. AAFCO's primary role is to annually publish the AAFCO *Official Publication*, which includes ingredient definitions and other recommendations. Additionally, it maintains the AAFCO Dog and Cat Food Nutrient Profiles, establishes labeling standards, and provides proficiency testing programs for laboratories. It's important to note that AAFCO's guidelines for pet food labeling include requirements that go beyond those mandated by the FDA (Dzanis et al., 2023). AAFCO also conducts biannual meetings open to the public to discuss changes in pet food labeling (AAFCO, 2023a). While AAFCO itself holds no regulatory authority, it provides model regulations that states can choose to adopt. Most states' labeling requirements closely align with AAFCO's Model Regulations, making it easier for companies to label their products in compliance with various state laws. Following AAFCO's Model Pet Food Regulations ensures that products meet or exceed each state's requirements (AAFCO, 2023b). This consistency is why a pet food

product label from any pet food company contains the same information, regardless of the state in which it is sold or purchased.

On January 1, 2024, AAFCO implemented new Model Regulations for Pet Food and Specialty Pet Food, marking the first major update to pet food labeling standards in over 40 years. These updates, developed with input from consumers and industry advisors, aim to make pet food labels more user-friendly by aligning them more closely with the labels on human food products. The changes, expected to be fully implemented within the next six years, include an Intended Use Statement, a Nutrition Facts Box, an Ingredient Statement, and Handling and Storage Instructions. The Intended Use Statement, which will now be required on the principal display panel, identifies the intended life stage and purpose of the pet food or specialty pet food, such as complete foods, treats, food mixers, food supplements, veterinary diets, and daily foods. For example, instead of a label merely indicating the species and life stage (e.g., 'For cats'), it would also specify the product's actual intended use (e.g., 'Cat food mixer'). This addition is designed to help consumers easily identify whether the food is complete and balanced and how it should be fed to their pets. The Nutrition Facts Box has been updated to resemble the format used on human food labels, providing nutrition information in a consistent and easy-to-read format. The Ingredient Statement has been revised to ensure consistent terminology and to allow the use of parentheticals and common or usual names for vitamins. While the Handling Instructions are optional, they have been updated and standardized with optional icons for greater consistency.

A pet food label must also include the product and brand name, quantity statement, feeding directions, and the manufacturer or distributor's address. AAFCO also defines specific rules regarding the mention of ingredients in the product name, depending on their percentage

inclusion. These are known as the 100%, 95%, 25%, "with," and "flavor" rules, designed to prevent false or misleading claims that could mislead consumers. For example, if a product is labeled as "beef dog food," the name implies that the product is primarily composed of beef meat, and the regulation requires that it meets this expectation. If it claims to contain beef, chicken, or mackerel, the name must accurately reflect the major ingredients, rather than relying on less expensive byproducts, meals, or flavors. For instance, beef dog food must be mostly (>95%) beef meat, not beef meal or beef byproduct, thus adhering to the 95% rule. AAFCO's Model Regulations also specify how ingredients should be listed on the ingredient statement, requiring that each ingredient is declared in descending order of predominance by weight. among other requirements. Additionally, pet foods labeled as "complete," "balanced," or by words of similar intent must include a statement attesting to the food's nutritional adequacy for its intended use. The precise verbiage must cite either conformance with the AAFCO Dog or Cat Food Nutrient Profiles for the intended life stage or the successful passage of feeding trials following AAFCO protocols. Claims on pet food labels must be substantiated and can only relate to the taste, aroma, or nutritive value of the food. For example, a claim such as "Contains omega 3 and 6 fatty acids to promote a healthy shiny coat" must be supported by scientific literature or feeding trials. In conclusion, this overview reaffirms the highly structured and stringent nature of pet food regulation at both the federal and state levels, ensuring that products meet rigorous standards for safety and accuracy.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture are shown in **TABLE 2A** and **TABLE 2B**. It is important to note that a significant portion of the students (~57%) had previously completed a course on the nutrition of cats and dogs before this

seminar. Since AAFCO's role and labeling standards in the pet food industry were discussed in that course, these findings may not fully represent the general consumer population. To explore this further, when isolating the survey responses of students who had completed the course (n = 11), all indicated they were already aware of AAFCO's presence in the pet food industry. In contrast, among students who had not completed the course (n = 8), only one (12.5%) was already aware of AAFCO's presence, while two (25%) selected 'Maybe,' and five (62.5%) responded with 'No.' The collective responses to this question are shown in **TABLE 2A**. The same trend was generally observed across all questions in **TABLE 2A** and **TABLE 2B** when the results were analyzed based on prior completion of the nutrition course. Students who had completed the course already possessed more knowledge about AAFCO prior to the seminar compared to those who had not taken the course. Nonetheless, for the purpose of assessing students' learning, the collective survey results were primarily analyzed and used to present the findings in this thesis.

When students were asked if they were aware of the extensive regulation of pet food on both the federal and state levels before the start of the course, a significant portion (37%) indicated they were not aware (**TABLE 2A**). This is noteworthy because understanding the extent of regulation in the pet food industry may help increase consumer trust in the safety of commercial pet foods. Students were also asked about their familiarity with AAFCO's role in setting standards for pet food on a scale of 1 to 5—where 1 is 'Not familiar at all' and 5 is 'Extremely familiar.' The majority of students (79%) were not very familiar with AAFCO's role, with 16% indicating they were 'Not familiar at all,' 16% 'Slightly familiar,' and 47% 'Moderately familiar.' Only 16% of students indicated they were 'Very familiar,' and 5% were 'Extremely familiar' (**TABLE 2B**). This suggests that even among students with some

knowledge of animal nutrition, knowledge gaps still exist on this topic. When the same question was posed in the post-lecture survey, a significantly higher number of students indicated that they were 'Very familiar' or 'Extremely familiar' with AAFCO's role (**TABLE 2B**). This trend was observed across most of the questions in **TABLE 2B**, suggesting that students' understanding and familiarity with the topic improved as a result of their exposure to the lecture material.

TABLE 2A. *Survey student responses on state regulation & AAFCO's role in the pet food industry (n = 19)*

Questions and Answer Choices	%
Before coming into this course, were you aware of AAFCO's presence in the pet food industry? –	
Yes	63
Maybe	11
No	26
On a scale of 1 to 5, how confident do you feel in understanding the nutritional information provided in the guaranteed analysis section of pet food labels? (example label provided) –	
1 - Not confident at all	5
2 - Slightly confident	5
3 - Moderately confident	58
4 - Very confident	21
5 - Extremely confident	11
Before coming into this course, were you aware of the extensive regulation of pet food on both the federal and state levels? +	
Yes	42
No	37
Maybe	21

+This question was not asked in the pre-lecture survey for this topic.
–This question was not asked in the post-lecture survey for this topic.

TABLE 2B. *Pre- and post-lecture survey student responses on state regulation & AAFCO's role in the pet food industry (n = 19)*

Questions and Answer Choices	%*	%**
On a scale of 1 to 5, how familiar are you with AAFCO's role in setting standards for pet food, where 1 is 'Not familiar at all' and 5 is 'Very familiar'?		
1 - Not familiar at all	16	0
2 - Slightly familiar	16	0
3 - Moderately familiar	47	16
4 - Very familiar	16	74
5 - Extremely familiar	5	11
AAFCO has regulatory authority in the pet food industry.		
True	32	32
False	53	68
Not sure	16	0
Although each state has its own set of requirements and regulations when it comes to pet foods, the AAFCO model is meant to provide a universal set of standards that can be implemented across all states.		
True	89	100
False	0	0
Not sure	11	0
I trust the accuracy of the information provided on a pet food label.		
Strongly disagree	5	0
Somewhat disagree	5	0
I do not know	5	0
Somewhat agree	58	47
Strongly agree	26	53
The pet food manufacturer has free say on what is included and not included on a pet food label.		

Strongly disagree	26	32
Somewhat disagree	37	47
I do not know	11	0
Somewhat agree	11	16
Strongly agree	16	5

*Pre-lecture survey responses
**Post-lecture survey responses

The FDA's Role in Pet Food Complaints & Recalls

Although pet foods are generally safe, incidents of contamination may still occur, leading to recalls. A recall, whether for human food or pet food or treats, removes products deemed hazardous due to chemical, microbiological, or foreign object contamination from the marketplace and is an integral part of the United States food safety system (Enright, 2017). Examples of potential contaminants in pet foods include foodborne pathogens, such as *Salmonella*, toxins, mainly mycotoxins in grains, adulterants, such as melamine, and foreign objects, such as metals. It's important to note that only 1.7% of reported poisonings in dogs and cats have been attributed to pet foods, making the risk of illness due to pet food contamination very small (Bischoff, 2013). Nonetheless, it is critical for consumers to stay informed about pet food recalls to ensure their pet's safety and health (click here for a continuously updated list of pet food recalls).

Prior to 2007, pet food recalls were generally limited in scope, often involving a single manufacturer and a quickly identifiable contaminant, such as *Salmonella* or mycotoxins (Dzanis, 2008). The extensive recall that occurred in 2007 was unprecedented and remains the largest in U.S. history. The recall was initiated on March 15, 2007, due to the reported deaths of 14 cats and dogs. It involved dog and cat foods manufactured by Menu Foods, Inc. Approximately 60 million containers of 'cuts and gravy' style dog and cat food were recalled by Menu Foods, and over the subsequent months, more than 150 brands of dog and cat foods were involved in the recall. Consumer complaints indicated that cats and dogs were becoming ill or dying after eating wet 'cuts and gravy' food products, with acute renal failure identified as the cardinal effect of this toxicosis. Following an extensive FDA investigation, the adulteration by melamine and cyanuric acid was confirmed as the cause, which had been intentionally and fraudulently added

to wheat gluten by Chinese suppliers to falsely increase the protein content. Estimates of the number of pets impacted by this outbreak vary, but one survey reported 424 confirmed cases (66% cats and 34% dogs) (Swirski et al., 2022). The 2007 recall was a challenge because it took at least three weeks before the causal adulterants were identified, and even longer for federal regulators and the scientific community to prove that indeed it was the interaction between melamine and cyanuric acid that was responsible for the acute renal failure in cats and dogs. That recall also exposed significant deficiencies in the recall process, which prompted the enactment of new regulations for a pet food surveillance system, culminating in the passage of "The Food and Drug Administration Amendments Act" (FDAAA) in September 2007 (Rumbeiha & Morrison, 2010). Under the FDAAA, the FDA was required to establish a Reportable Food Registry (RFR), implement an early warning and detection program for potentially contaminated pet food products, and improve coordination efforts with State Departments of Agriculture (Dzanis, 2008). The RFR required the FDA to establish an electronic portal to which reports about instances of reportable food must be submitted within 24 hours by responsible parties, and through which public health officials may also submit reports. The RFR was established to prevent widespread contamination and improve response times by the FDA and other relevant regulatory authorities. A reportable pet food product is considered any animal food that has been distributed to the marketplace and is likely to lead to illness or injury to humans or animals (FDA, 2024).

A recall may be initiated by the U.S. Food and Drug Administration (FDA) under three conditions: the product falls under the FDA's regulatory jurisdiction, the product's adulteration and/or misbranding can be substantiated, and the product is sold in multiple states. Products under FDA jurisdiction include animal drugs, veterinary devices, and animal foods. If a product

is only sold in one state, it would fall under that state's regulatory oversight, and the FDA would not regulate complaints or recalls for that product, even if the other two criteria are met. The FDA specifically regulates products involved in interstate commerce. Recalls can be initiated through consumer complaints, FDA facility inspections, FDA sampling, state sampling, reports through the Reportable Food Registry (RFR), or notification from international partners regarding possible U.S. consignees. Consumer complaints may be reported through the Safety Reporting Portal online or by telephone via each state's designated Consumer Complaint Coordinator (each state's Consumer Complaint Coordinator's phone number can be found here).

The routes for pet food recalls include the following: A pet food manufacturer or distributor may issue product recalls themselves following internal monitoring and safety programs; federal or state regulators can request that a pet food maker initiate a recall, such as after reviewing feedback from pet owners or veterinarians or testing finished products; or the FDA can mandate a recall under authority provided by the Food Safety Modernization Act (FSMA) (Pet Food Institute, n.d.). However, the action of recalling itself is voluntary and takes place because manufacturers and distributors carry out their responsibility to protect public health and well-being from products that present a risk of injury, gross deception, or are otherwise defective. That being said, the FDA can still mandate a recall if the manufacturer or distributor is non-compliant, although this rarely occurs as it is not in a firm's best interest to not cooperate with the FDA.

Apart from the public health concerns associated with pet food recalls, they can also decrease consumer confidence in the pet food industry and lead to significant economic losses (Ostroff, 2018). A 2018 survey by a market research firm revealed that approximately 50% of dog and cat owners agreed that fear of pet food contamination and product safety was a key

consideration in what pet foods they buy, while more than 60% of pet owners agreed that they are concerned about the safety of the pet food, treats, and chews they purchase (Packaged Facts, 2019). Additionally, a survey conducted by Thomas et al. (2020) found that when pet owners were asked what they would do after discovering that a pet food or treat was recalled due to microbial contamination, 31% indicated they would never buy related products from the recalled brand, and 23% would never buy the recalled product from that brand. Therefore, it is in a pet food manufacturer or distributor's best interest to continuously uphold the best manufacturing practices to not only ensure the health of pets but to avoid the negative costs associated with potential pet food recalls. Vigilance in pet food safety, supported by extensive regulations and active consumer participation, is essential in maintaining the health of pets and the trust of consumers. Overall, this lecture affirmed the extensive regulation in place to ensure pet food safety and minimize the occurrence of recalls.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture are shown in **TABLE 3**, **FIGURE 1**, and **FIGURE 2**, revealing some interesting trends. Before the lecture, a significant portion of students had limited engagement with pet food recalls, with 40% reporting that they had never looked into which pet foods were recalled within the past year (**TABLE 3**). This finding aligns with previous research. For example, a study by Thomas et al. (2020) found that 78% of pet owners were unaware of pet food recalls or outbreaks associated with foodborne pathogens, indicating that most do not actively monitor pet food recalls. Of the students who had looked into pet food recalls within the past year, 75% relied on news sources for information, followed by veterinarians (58%), social media outlets (33%), and pet food companies (33%). Only 17% of students selected the FDA as a source of information (**TABLE**

3). This supports findings in the literature that suggest owners increasingly trust nutritional advice from veterinarians and online sources. Kamleh et al. (2020) found that 44.1% of pet owners cited veterinarians and 38.8% cited online information as influential in their decisions on pet food. Not surprisingly, given these results, only 40% of students were aware of the FDA's involvement in pet food recalls, with 25% uncertain (**TABLE 3**). When asked to rate their familiarity with the FDA's role on a scale of 1 to 5, 90% of students were not very familiar, with 25% indicating they were 'Not familiar at all,' 45% 'Slightly familiar,' and 20% 'Moderately familiar.' Only 10% were 'Very familiar,' and none were 'Extremely familiar' (**TABLE 3**). After the lecture, there was a marked increase in familiarity, with more students indicating they were 'Very familiar' or 'Extremely familiar' with the FDA's role (**TABLE 3**). This suggests that the lecture effectively enhanced students' understanding of this topic. Post-lecture, when asked to rate their satisfaction with the FDA's involvement in ensuring pet food safety, most students rated their satisfaction as 'Somewhat satisfied' (45%) or 'Extremely satisfied' (50%). Although this question was not asked in the pre-lecture survey, the responses suggest increased trust in the FDA's role, especially considering that many students were previously unaware of the FDA's regulatory role prior to this course (**TABLE 1B**).

When students were asked to rank what they thought were the most common reasons for pet food recalls (**FIGURE 1**), 45% identified 'bacterial contamination of animal products' as the most common reason, while 40% ranked 'adulteration' as the least common reason. Although the prevalence of specific causes for pet food recalls can vary annually, bacterial contamination, particularly with *Salmonella*, is frequently the leading cause of recalls. According to FDA recall data from 2017 through November 2023, *Salmonella* contamination accounted for 44% of pet food recalls in the US (Phillips-Donaldson, 2024a). When students were also asked to rank

different pet food formats in terms of safety, 60% ranked dry kibble as the safest, while 80% ranked raw diets as the least safe (**FIGURE 2**). Raw, minimally processed, and freeze-dried diets are more susceptible to foodborne pathogens and are considered less safe for pets, as well as posing a risk to humans through unsafe handling. Dry food dominates the market and, while it may appear more frequently in recall reports due to its larger market share, raw pet foods still rank highest in recall frequency when accounting for brand names and common contract manufacturers (Clyma, 2023; Fox, 2020). After the lecture, 84% of students ranked dry kibble as the safest, and 95% ranked raw diets as the least safe (**FIGURE 2**). These results suggest that the lecture effectively enhanced students' understanding of pet food safety and recalls.

TABLE 3. *Survey student responses on the FDA's role in pet food complaints and recalls (n = 20)*

Questions and Answer Choices	%
Within the past year, how often have you looked into which pet foods are recalled? –	
Never	40
Rarely	25
Sometimes	20
Often	15
All the time	0
How do you typically stay informed about pet food recalls? (select all that apply) –	
Veterinarians	58[1]
Pet food companies	33[1]
FDA	17[1]
News sources	75[1]
Social media outlets	33[1]
Other	8[1]
Prior to this course, were you aware of the FDA's involvement in pet food complaints and recalls? –	
Yes	40
Maybe	25
No	35
On a scale of 1 to 5, how familiar were you (prior to this course) with the FDA's role in pet food complaints and recalls, with 1 being 'Not familiar at all' and 5 being 'Extremely familiar'? +	
1 - Not familiar at all	25
2 - Slightly familiar	45
3 - Moderately familiar	20

4 - Very familiar	10
5 - Extremely familiar	0
On a scale of 1 to 5, how familiar are you now with the FDA's role in pet food complaints and recalls, with 1 being 'Not familiar at all' and 5 being 'Extremely familiar'? +	
1 - Not familiar at all	0
2 - Slightly familiar	0
3 - Moderately familiar	25
4 - Very familiar	65
5 - Extremely familiar	10
On a scale of 1 to 5, how satisfied are you with the safety of pet food? +	
1 - Extremely dissatisfied	0
2 - Somewhat dissatisfied	5
3 - I do not know	5
4 - Somewhat satisfied	85
5 - Extremely satisfied	5
On a scale of 1 to 5, how satisfied are you with the FDA's involvement in ensuring the safety of pet food? +	
1 - Extremely dissatisfied	0
2 - Somewhat dissatisfied	5
3 - I do not know	0
4 - Somewhat satisfied	45
5 - Extremely satisfied	50

+This question was not asked in the pre-lecture survey for this topic.
–This question was not asked in the post-lecture survey for this topic.
[1]n = 12

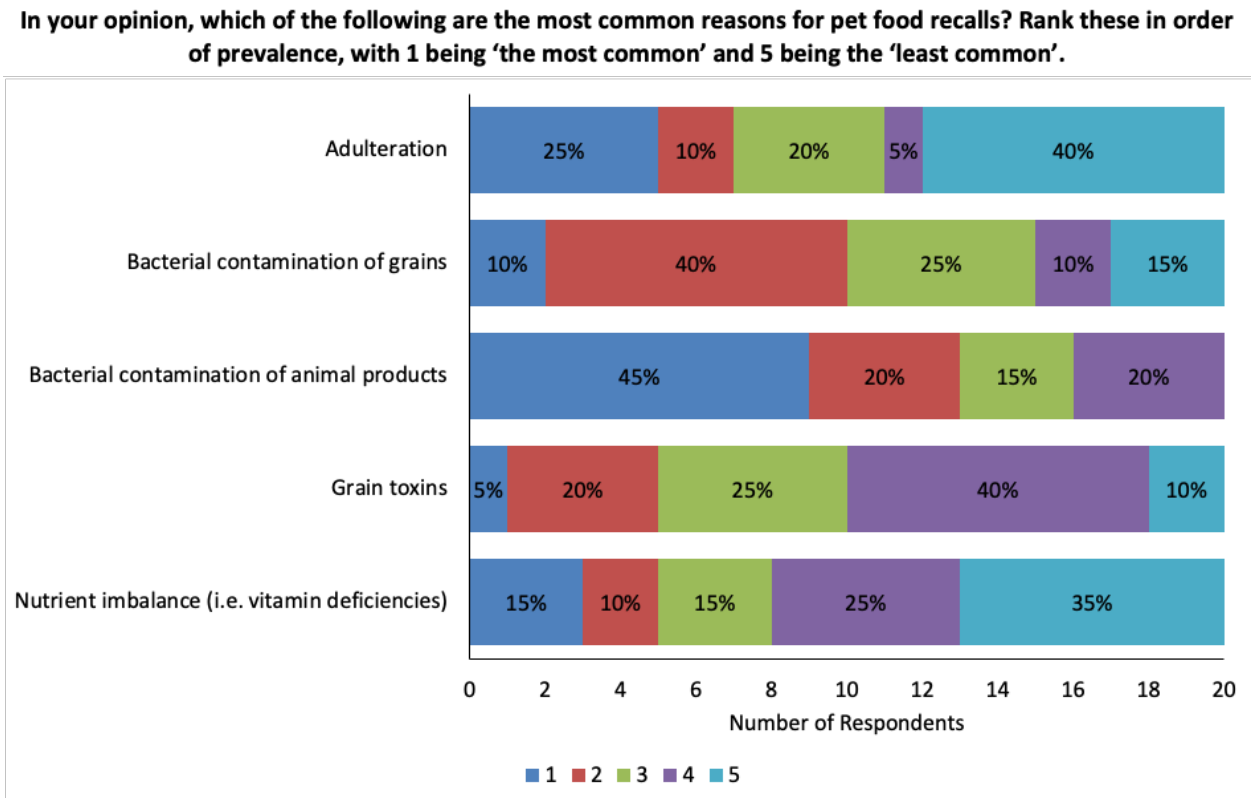

FIGURE 1. *Student responses to a ranking question on the FDA's role in pet food complaints and recalls (n = 20). This question was not included in the post-lecture survey for this topic.*

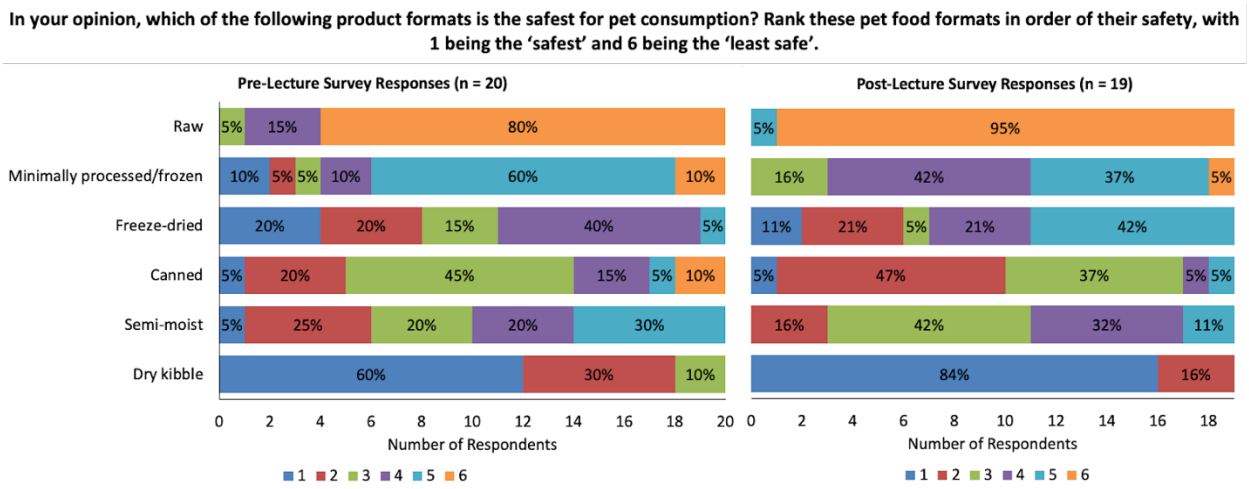

FIGURE 2. *Pre- and post-lecture survey student responses to a ranking question on the FDA's role in pet food complaints and recalls.*

Chapter 2: The Role of the Rendering Industry in Pet Nutrition

In recent years, there has been a growing aversion among consumers towards animal byproducts and their rendered counterparts in pet foods. For instance, a survey conducted by Schleicher et al. (2019) found that when respondents were asked to rate the importance of various pet food characteristics on a 5-point Likert scale, "no animal byproducts" was ranked with a mean importance rating of approximately 3 out of 5. This placed it among the top 10 highest-rated pet food characteristics out of 24 options, indicating its significance to many consumers. Animal byproducts refer to parts of an animal that are typically not consumed by humans, such as the liver, heart, and kidneys (Thompson, 2008). Many pet owners believe that their pets should be eating meat products in forms similar to those consumed by humans. This aversion may also be influenced by prevalent marketing claims on pet food labels, such as “No poultry byproducts,” which imply that byproducts are undesirable ingredients in pet foods. However, this perception overlooks the fact that animal byproducts and rendered products are high-quality sources of protein and contain a favorable amino acid profile for pets. They are also an excellent source of minerals like calcium and phosphorus. According to the Association of American Feed Control Officials (AAFCO), rendering is a process that cooks products to remove fat and water, destroying any harmful bacteria, and leaving behind primarily protein and minerals. These rendered products are often ground into uniform-sized particles and are commonly referred to as “meal” in ingredient lists. Examples of rendered products in pet foods include meat meal, poultry meal, and poultry byproduct meal (AAFCO, 2023c.).

The North American rendering industry consists of more than 49 firms operating more

than 180 plants across the United States and 20 in Canada. It includes plants that are "integrated" with meat processing companies to process the "captive" byproducts generated by these firms, and it also includes "independent" renderers that are not directly owned or operated by meat processing companies but instead collect and process byproducts from many different sources, including livestock slaughter and processing facilities, grocery stores, restaurants, and other entities along the meat production chain. Rendering plants comply with a large number of federal, state, and local regulations to ensure clean air, clean water, and safe working conditions, in addition to food safety requirements (Meeker & Meisinger, 2015). Therefore, when misconceptions such as the use of euthanized pets in the rendered products used for pet foods arise, they are often false and without precedent. Most pet food companies screen raw materials for pentobarbital and other barbiturates to ensure that euthanized pets were not part of the materials that went into the rendered products used as ingredients. In an analysis of a wide variety of pet foods purchased at retail, FDA results showed that no dog, cat, or horse DNA were present in their sampling. Researchers at the FDA further concluded that the low levels of pentobarbital that dogs might receive through such food are unlikely to cause any adverse health effects and that further research on that theoretical risk was unnecessary (Meeker & Meisinger, 2015).

Apart from rendered ingredients being excellent sources of protein for pets, they also significantly contribute to environmental sustainability. Rendering itself is a form of recycling and is involved in the concept of a circular bioeconomy. A circular bioeconomy focuses on maximizing the value of biomaterial resources for as long as possible and minimizing waste generation (Venugopal, 2022). Roughly 50% of an animal is considered indedible by Americans and would otherwise go to waste if not consumed. Rendering takes these animal byproducts from

the human industry and cooks and dehydrates them into a final product that is then utilized in our pets' food, among other things such as biodiesel, cosmetics, soaps, hygiene products, cleaning products, paints, dyes, resins, fertilizers, and feedstuff. The leftover water from the dehydrating process is recycled back into the environment in its clean form, and the rendered fats, such as chicken fats, are also utilized in pet foods. In the U.S., about 33% of the animal protein products produced from the rendering industry are utilized in pet food, whereas 5% of the animal fats are utilized. If not rendered, these biological materials would be deposited in landfills, burned, buried, or inappropriately dumped, leading to large amounts of carbon dioxide, ammonia, and other compounds polluting air and water. The rendering process not only yields safe animal food ingredients but also removes potential biohazards and environmental threats because typical pathogens are destroyed rapidly by processing at lethal temperature. Most alternative disposal methods, such as composting, burials, and landfill use, do not include these added safeguards as well as providing usable products. The rendering industry also collects about 4.4 billion pounds of used cooking oil per year in the U.S. and Canada and upcycles it into renewable biofuel. Rendering reduces greenhouse gas emissions by 72% and fossil fuel use by 80%. Although rendering plants generally utilize a significant amount of energy through the rendering process, they still manage to sequester about five times more greenhouse gas emissions from the environment than they emit. With the world population's projected growth and the increased meat production to accommodate this growth, the wise use of all resources is imperative, including the animal byproducts, to ensure people and animals are fed sustainably. Overall, this lecture affirmed the safety and nutritional value of rendered products in pet food, while also highlighting the significant contribution of the rendering industry to environmental sustainability.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture are shown in **TABLE 4A** and **TABLE 4B**. A significant portion of the students (~57%) had previously completed a course on the nutrition of cats and dogs before this seminar. While the course did not cover details of the rendering industry itself, it extensively discussed animal byproducts and their rendered counterparts. Therefore, these findings may not fully represent the general consumer population, as students who completed this course already had a solid background in animal byproducts and rendered animal products. When isolating the pre-lecture survey responses of students who had completed the course (n = 11), all thought it was an acceptable practice to render animal products for use as ingredients in pet food products. In contrast, among students who had not completed the course (n = 9), four (44%) thought it was an acceptable practice, whereas five (56%) were uncertain. The collective responses to this question are shown in **TABLE 4B**. This trend was generally observed across many questions in **TABLE 4A** and **TABLE 4B** when results were analyzed based on prior completion of the nutrition course. Students who had completed the course already had more knowledge about rendering before the seminar compared to those who had not. Nonetheless, for the purpose of assessing students' learning, the collective survey results were primarily analyzed and used to present the findings in this thesis.

When students were asked if they thought higher-priced pet food products, or so-called "premium" pet foods, used rendered animal products in their formulations, most (60%) responded 'Yes,' while 40% were either unsure or did not think that to be the case (**TABLE 4A**). A quick Internet search for 'premium pet foods' confirms that many of these pet foods do, in

fact, use rendered ingredients. This is noteworthy because most dog and cat owners consider their pets members of the family and are therefore willing to pay more for a "premium" pet food they perceive as healthier for their pets (AVMA, 2022). In a survey by Schleicher et al. (2019), most pet owners reported giving equal (53.1%) or more priority (43.6%) to buying healthy food for their pets compared with themselves. The anthropomorphism of pets has also become more common, resulting in pet owner preferences for pet foods containing ingredients similar to their own diet and processed in a way that maintains nutritional integrity and ensures food safety. As a result, contemporary trends in human diets have made their way to pet diets. For instance, the natural pet food trend focuses on including whole ingredients like meats, fruits, and vegetables, avoiding heavily processed ingredients such as refined grains, fiber sources, byproducts, and rendered ingredients, and feeding according to ancestral or instinctual nutritional philosophies (Buff et al., 2014). The term "natural," when used to market commercial pet foods or pet food ingredients in the United States, has been defined by AAFCO as: "a feed or feed ingredient derived solely from plant, animal or mined sources, either in its unprocessed state or having been subject to physical processing, heat processing, rendering, purification, extraction, hydrolysis, enzymolysis, or fermentation, but not having been produced by or subject to a chemically synthetic process and not containing any additives or processing aids that are chemically synthetic except in amounts as might occur in good manufacturing practices (AAFCO, 2024)." However, pet owners may interpret "natural" differently from its regulatory definition and pay more for a "premium" product labeled as such, not realizing that it may contain rendered ingredients. Rendered ingredients are high-quality protein sources for pets, as previously discussed. This example simply underscores the importance of consumer education, highlighting

that owners don't need to pay a premium price to provide their pets with a nutritious and balanced diet, particularly when financial constraints are a concern.

It is important to note that the regulatory measures and standards governing the use of rendered ingredients in pet food were not extensively covered in this lecture. Hence, the post-lecture survey responses may not show major improvements in students' confidence in these measures, although federal and state regulation of pet foods was covered in previous lectures (**TABLE 4B**). Nonetheless, when students were asked to identify rendered ingredients from a list, on average, more students selected the correct responses (beef meal, fish meal, chicken by-product meal, meat and bone meal, and chicken fat) in the post-lecture survey than in the pre-lecture survey (**TABLE 4B**). Students were also asked about their familiarity with the rendering industry's role in pet nutrition on a scale of 1 to 5—where 1 is 'Not familiar at all' and 5 is 'Extremely familiar.' The majority of students (75%) were not very familiar, with 20% indicating they were 'Not familiar at all,' 20% 'Slightly familiar,' and 35% 'Moderately familiar.' Only 20% were 'Very familiar,' and 5% were 'Extremely familiar' (**TABLE 4B**). This suggests that even among students with some knowledge of the topic, knowledge gaps still existed. When the same question was posed in the post-lecture survey, a significantly higher number of students indicated that they were 'Very familiar' or 'Extremely familiar' with the rendering industry's role (**TABLE 4B**). These trends were observed across most of the questions in **TABLE 4B**, suggesting that students' understanding and familiarity with the topic improved as a result of their exposure to the lecture material.

TABLE 4A. *Survey student responses on the role of the rendering industry in pet nutrition (n = 20)*

Questions and Answer Choices	%
Do you think that higher priced pet food products or the so-called "premium" pet foods use rendered animal products in their formulations? –	
Yes	60
No	10
Not sure	30
Rendered animal products are a low-quality ingredient for pets. +	
Strongly disagree	45
Somewhat disagree	50
I do not know	0
Somewhat agree	5
Strongly agree	0
Rendering is an environmentally friendly way to recycle material that would otherwise go to waste. +	
Strongly disagree	0
Somewhat disagree	0
I do not know	0
Somewhat agree	10
Strongly agree	90

+This question was not asked in the pre-lecture survey for this topic.
–This question was not asked in the post-lecture survey for this topic.

TABLE 4B. *Pre- and post-lecture survey student responses on the role of the rendering industry in pet nutrition (n = 20)*

Questions and Answer Choices	%*	%**
To what extent are you familiar with the term 'rendered' in the context of animal products, using a scale of 1 to 5?		
1 - Not familiar at all	15	0
2 - Slightly familiar	15	0
3 - Moderately familiar	45	30
4 - Very familiar	5	40
5 - Extremely familiar	20	30
Which of the following do you think are rendered ingredients? (select all that apply)		
Beef meal	84[1]	100
Chicken	0[1]	0
Salmon	0[1]	0
Fish meal	79[1]	95
Chicken by-product meal	89[1]	100
Liver	0[1]	5
Meat byproducts	63[1]	55
Turkey	0[1]	0
Poultry byproducts	63[1]	55
Meat and bone meal	95[1]	100
Chicken fat	32[1]	45
Do you think that it is an acceptable practice to render animal products for their use as ingredients in pet food products?		
Yes	75	95
No	0	0

Not sure	25	5
On a scale of 1 to 5, how familiar are you with the role of the rendering industry in pet nutrition, where 1 is 'Not familiar at all' and 5 is 'Extremely familiar'?		
1 - Not familiar at all	20	0
2 - Slightly familiar	20	5
3 - Moderately familiar	35	25
4 - Very familiar	20	60
5 - Extremely familiar	5	10
How confident are you in the regulatory measures and standards governing the use of rendered ingredients in pet food?		
Not confident at all	20	0
Slightly confident	15	15
I do not know	25	5
Moderately confident	30	65
Very confident	10	15
To what extent do you think the rendering industry contributes to the overall sustainability of the pet food industry?		
Not at all	0	0
Slightly	0	0
I do not know	15	0
Moderately	45	15
Significantly	40	85

*Pre-lecture survey responses
**Post-lecture survey responses
[1]n = 19

Chapter 3: Pulses in Dog Food & their Association with Dilated Cardiomyopathy

In recent years, many consumers have increasingly preferred feeding their pets a "grain-free" diet. In a July/August 2019 survey of U.S. pet owners by Packaged Facts, approximately 50% of respondents perceived that "grain-free" diets were healthier for their pets (Banton et al., 2021). This perception may stem from the belief that cats and dogs are not well-equipped to consume grains and utilize starch from their diets, viewing grains as mere "fillers" with no nutritional purpose, which is a misconception. Banton et al. (2021) found that people who prioritize the ingredients in pet food and specifically look for terms like "no fillers" and "no by-products" are more likely to select "no grain" options, supporting the idea that grains are often considered "fillers" by pet owners. While carbohydrates from cereal grains are not essential nutrients for cats and dogs, they provide starch, which is crucial for the structure formation of dry foods and the viscosity of wet foods. Starch also serves as a digestible energy source (Watson, 2005). Cereal grains also provide essential fatty acids, protein, amino acids, dietary fiber, and vitamins (Laflamme et al., 2014). Another reason consumers may choose a grain-free diet is the belief that grains exacerbate allergy symptoms, especially in dogs. In the same study by Banton et al. (2021), people who believed their dog had a food allergy were four times more likely to choose "no grain" pet food. However, research shows that environmental allergens are the primary cause of allergies in dogs, with food allergens playing only a minor role. And of the food allergens, the most common ones in dogs with diagnosed food allergies are beef and dairy, accounting for more than 60% of food allergy cases reviewed by Verlinden et al, followed by wheat, egg and chicken, while the least common food allergens in dogs are soy, corn, fish, pork, and rice (each accounting for less than 6% of all food allergies diagnosed) (Mueller et al., 2016;

Verlinden et al., 2007). Despite animal protein allergies being far more common than grain allergies in dogs, these results indicate that consumers may believe a “grain-free” diet can alleviate their pet's allergy symptoms. The practice of feeding “grain-free” diets may also be influenced by the increasing anthropomorphism of pets, with owners projecting their dietary preferences onto their pets. For instance, Banton et al. (2021) found that people who followed multiple dietary routines themselves and those who avoided grains in their own diets were more likely to choose grain-free pet food. Although ample evidence supports the benefits of whole grains and fiber for human cardiovascular health, and no scientific evidence suggests that grains are harmful to dogs or cats, these results suggest that pet owners' beliefs about grains may be largely shaped by marketing claims like “no fillers” or “no by-products” (Banton et al., 2021). What many consumers may not realize is that many dry foods marketed as “grain-free” are actually just cereal-grain-free, meaning they exclude grains like corn, wheat, and rice. To replace these cereal grains, “grain-free” diets typically include pulses, which are leguminous crops harvested for their dry seeds, hence they are also called legume grains. Pulses are high in proteins and carbohydrates, particularly starch, and low in fat. Compared to cereal grains, legume grains tend to be higher in lysine and lower in sulfur amino acids like methionine and cysteine. Common pulses include garbanzo beans, lentils, fava beans, and peas. While “grain-free” diets may benefit dogs prone to weight gain or diabetes due to pulses' higher fiber content, regular consumption of such diets has recently been associated with the development of canine dilated cardiomyopathy (DCM).

Canine DCM is a heart disease that weakens the heart muscles, reducing the heart's ability to pump blood effectively. The heart becomes enlarged and flabby, leading to fluid accumulation in the lungs and, eventually, congestive heart failure (Case, 2019). Dilated

cardiomyopathy is often referred to as “heart disease” in veterinary practice and is primarily diagnosed by echocardiography, though other methods like thoracic radiography or electrocardiography may also be used (Cornell University College of Veterinary Medicine, n.d.). While genetic predisposition plays a significant role in DCM, particularly in large and giant breeds such as Dobermans, Boxers, and Great Danes, diet and physiology are also potential contributing factors (Mansilla et al., 2019).

In July 2018, the FDA issued a warning about a possible link between DCM in dogs and the consumption of dog food with high levels of potatoes and/or pulse ingredients, which are common in “grain-free” diets. This warning caused widespread concern among both consumers and the veterinary community, as many of the affected dogs were not from breeds typically predisposed to DCM. A significant number of these dogs had reduced taurine levels in their blood and responded positively to taurine supplementation, leading to speculation that these cases were related to diets that negatively affect taurine status, resulting in taurine deficiency DCM (Case, 2019). Taurine is a non-essential amino-sulfonic acid that dogs synthesize if sufficient methionine and cysteine, its precursors, are provided in their diet. Because pulses are low in methionine, “grain-free” diets often need to be supplemented with taurine to meet dogs' nutritional needs. This is why many “grain-free” dog foods list taurine as an added ingredient. However, simply meeting AAFCO recommendations may not be sufficient, as individual breed requirements can vary. For example, Mansilla et al. (2020) found that Miniature Dachshunds, Beagles, and Labrador Retrievers have higher methionine requirements than the AAFCO minimum, with differences in sulfur amino acid metabolism between breeds. Other dietary factors, such as the concentrations of carbohydrates, protein, fiber, and fats, also play a role in bile acid losses, which can affect taurine and glycine metabolism. Bile acids, produced in the

liver and conjugated with glycine or taurine, aid in lipid digestion. Excessive bile acid losses through feces may require increased bile acid production by the liver, thus increasing the net utilization of taurine and/or glycine. A meta-analysis by Pezzali et al. (2021) found that higher levels of soluble fiber, dietary fat, and protein led to greater bile acid losses, while higher dietary carbohydrate levels resulted in lower bile acid excretion, potentially altering taurine and glycine metabolism. Consequently, this may increase the taurine requirement from the diet to compensate for the bile acid losses.

Although further studies are needed to establish more defined causative factors leading to taurine deficiencies, recent research suggests that the concern over pulses in "grain-free" diets may be less about the pulses themselves and more about the overall formulation of the diet. For instance, Singh et al. (2023) found that feeding healthy dogs "grain-free," pulse-inclusive diets with up to 45% inclusion of pulses like green peas, pinto beans, chickpeas, and lentils for five months did not negatively impact their cardiac health. These diets, which exceeded AAFCO's minimum methionine and cysteine requirements by more than 60% and included micronutrient supplementation, did not affect plasma or whole blood taurine concentrations, indicating that when formulated correctly, "grain-free" diets can be nutritionally complete and balanced for dogs. Overall, this lecture affirmed the importance of proper diet formulation to ensure micronutrient needs are met in "grain-free" diets for dogs, emphasizing that nutrient requirements are not static and can be influenced by both genetic and non-genetic factors.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture are shown in **TABLE 5A** and **TABLE 5B**. A significant portion of the students (~57%) had previously completed a course on the nutrition of cats and dogs before this seminar. While the

course did not cover DCM, it extensively covered and defined legume grains, pulses, cereal grains, and "grain-free" pet foods. Therefore, these findings may not fully represent the general consumer population, as students who completed the nutrition of cats and dogs course already had a solid background on "grain-free" diets for dogs and the significance of legume grains, pulses, and cereal grains in pet foods. When isolating the pre-lecture survey responses of students who had completed the course (n = 12), all thought it was appropriate for cereal grains to be included in pet foods. In contrast, among students who had not completed the course (n = 7), three (43%) thought it was appropriate, whereas four (57%) were uncertain. The collective responses to this question are shown in **TABLE 5B**. This trend was generally observed across many questions in **TABLE 5A** and **TABLE 5B** when results were analyzed based on prior completion of the nutrition course. Students who had completed the course already had more background knowledge on this topic compared to students who did not. Nonetheless, for the purpose of assessing students' learning, the collective survey results were primarily analyzed and used to present the findings in this thesis.

It's important to note that cereal grains were not extensively covered in this lecture, hence the pre- and post-lecture survey responses for those questions may not show significant changes in student responses. Nonetheless, when students were asked in the pre-lecture survey to select the choices that best describe the main function of cereal grains in pet foods, all of the students selected at least one of the two correct responses ('a source of energy for the animal' and 'a source of starch for dry kibble structure formation') (**TABLE 5A**). The differentiation between legume grains and pulses was also not extensively covered in the lecture, although pulses specifically were. Not all legume grains would be classified as pulses. For instance, soybeans and peanuts, although considered legumes, would not fall under the classification of pulses due

to their high fat content. By definition, pulses are going to be lower in fat. When students were asked to identify the pulses from a list, they were significantly more likely to select the correct responses (lentils, chickpeas, beans, and peas) in the post-lecture survey than in the pre-lecture survey, showing a marked increase in their level of learning (**TABLE 5B**). Many of the students (42%) were also unaware of DCM in dogs before the course (**TABLE 5A**). Of the students who were aware of DCM in dogs, most of the students (64%) found out about it through previous courses or veterinary sources (**TABLE 5A**). This is in agreement with the survey study by Banton et al. (2021), which found that a majority of respondents selected that they get their information about pet food from their veterinarian (57.6%). Since DCM has been established to potentially be linked to a pet's nutrition, it is not surprising that many of the students found out about DCM through veterinary sources. When students were asked how much they thought DCM in dogs was associated with their diets, the pre- and post-lecture survey responses did not reveal a distinct pattern or direction. The data indicate that the majority of students initially believed there was a moderate to strong association between diet and DCM, with 72% (36% moderate and 36% strong) selecting these options. After the lecture, students' views became slightly more varied, with an increase in those believing there is no or little association (37% combined), while those perceiving a strong or direct association decreased slightly to 21% (**TABLE 5B**). This shift could suggest that the lecture provided additional context or evidence that led some students to reconsider the strength of the association between diet and DCM in dogs. As the lecture suggested, the relationship is likely multifactorial, involving a combination of diet, genetics, and other physiological or environmental factors. Therefore while diet, particularly certain "grain-free" diets, may be linked to an increased risk of DCM in some dogs, it is not considered a direct cause in all cases. The condition is complex, and more research is

needed to fully understand the connections between diet and DCM. Overall, these findings suggest that students' understanding and familiarity with the topic improved as a result of their exposure to the lecture material.

TABLE 5A. *Survey student responses on pulses in dog food and their association with DCM (n = 19)*

Questions and Answer Choices	%
In your opinion, which of the choice(s) below best describe the main function of cereal grains in pet foods? (select all that apply) –	
A significant source of protein for the animal	0
A source of energy for the animal	100
A source of fat for the animal	0
A source of starch for dry kibble structure formation	79
Did you know what pulses were prior to this course? +	
Yes	68
No	21
Maybe	11
Before this course, were you aware of dilated cardiomyopathy's occurrence in dogs? –	
Yes	58
No	42
Where did you hear about dilated cardiomyopathy in dogs? (select all that apply) –	
Previous courses	64[1]
Veterinarian or vet clinic	64[1]
Social media outlets	18[1]
Friends or family	9[1]
Pet food websites	18[1]
Scientific journals	9[1]
Other	9[1]
When formulated correctly, grain-free diets can be nutritionally balanced for dogs. +	
Strongly disagree	0

Somewhat disagree	5
I do not know	5
Somewhat agree	32
Strongly agree	58
Pulses cause dilated cardiomyopathy in dogs. +	
Strongly disagree	32
Somewhat disagree	53
I do not know	11
Somewhat agree	5
Strongly agree	0

+This question was not asked in the pre-lecture survey for this topic.
–This question was not asked in the post-lecture survey for this topic.
[1]n = 11

TABLE 5B. *Pre- and post-lecture survey student responses on pulses in dog food and their association with DCM (n = 19)*

Questions and Answer Choices	%*	%**
Do you think that it is appropriate for cereal grains to be included in pet food products?		
Yes	79	95
No	0	5
Not sure	21	0
Do you think it's misleading for a label to contain a 'grain-free' claim?		
Definitely not	0	5
Probably not	11	11
Not sure	16	5
Probably yes	53	53
Definitely yes	21	26
Which of the following do you think are cereal grains? (select all that apply)		
Sorghum	84	68
Lentils	0	0
Chickpeas	5	0
Corn	68	79
Wheat	100	95
Beans	0	0
Potatoes	0	5
Oats	100	100
Sweet potatoes	0	0
Rice	79	84
Peas	0	0

Which of the following do you think are legume grains? (select all that apply)		
Sorghum	16	21
Lentils	95	89
Chickpeas	95	84
Corn	5	0
Wheat	5	0
Beans	84	89
Potatoes	5	5
Oats	0	0
Sweet potatoes	5	5
Rice	5	5
Peas	89	95
Which of the following do you think are pulses? (select all that apply)		
Sorghum	11	0
Lentils	63	100
Chickpeas	63	89
Corn	5	0
Wheat	0	0
Beans	58	79
Potatoes	32	0
Oats	5	0
Sweet potatoes	26	0
Rice	11	0
Peas	53	95
Legume grains are a healthier choice for pets in comparison to cereal grains.		
Strongly disagree	11	0

Somewhat disagree	26	32
I do not know	37	37
Somewhat agree	26	32
Strongly agree	0	0
Grain-free diets contain less carbohydrates than diets containing grains.		
Strongly disagree	0	21
Somewhat disagree	47	37
I do not know	26	11
Somewhat agree	21	32
Strongly agree	5	0
How much do you think dilated cardiomyopathy in dogs is associated with their diets?		
No association	0[1]	16
Little association	18[1]	21
Moderate association	36[1]	42
Strong association	36[1]	21
Direct association	9[1]	0

*Pre-lecture survey responses
**Post-lecture survey responses
[1]n = 11

Chapter 4: The Role of Academia in Pet Food Nutrition Research

Advancements in the pet food industry would not be possible without the significant contributions of academic research. Academic research plays a pivotal role in addressing industry challenges, such as the 2018 scare linking many "grain-free" dry dog foods to dilated cardiomyopathy (DCM) (see Chapter 3 for more information on this topic). Without these research contributions, our current understanding of "grain-free" diets and DCM would be significantly limited.

Moreover, one of the fundamental steps in developing a new pet food product is establishing proof of the diet's efficacy through rigorous research. This research can be based on existing data that demonstrate an ingredient or diet's safety and effectiveness, or it can be newly conducted by the pet food company, ingredient supplier, contract research organization, or within an academic institution. Often, pet food companies collaborate with academic institutions to conduct research, particularly when they lack the facilities necessary for animal experimentation. In academic settings, research involving animal subjects is non-invasive, focusing on aspects such as feeding, weighing, feces or urine collection, and blood sampling. There are also strict federal and state regulations in place to ensure the safety and welfare of the animals involved in research, such as the Animal Welfare Act (AWA) and the Public Health Service Policy on Humane Care and Use of Laboratory Animals (PHS Policy), among others (learn more about the regulation of animal research here). With the advancements in technology, there are also more sophisticated research tools, including genomics, nanotechnology, and advanced imaging techniques, which are non-invasive research tools ensuring the animal's welfare.

The food science or chemistry aspects of an ingredient, such as its stability/shelf life, bioavailability, and purity, are typically tested in the laboratory by the ingredient supplier or the pet food company, often without academic involvement. However, the bulk of research conducted in academia involves animal experimentation studies. Animal nutrition experimentation studies are primarily conducted through academia or contract research organizations but can also be done within pet food companies. The most tested measures include palatability, gastrointestinal tolerance and fecal quality, nutrient digestibility, and safety/toxicity. Basic research conducted for pet nutrition studies may involve assessing physiological responses to different diet interventions, nutrient metabolism or interactions, interdisciplinary work, and disease models. Interdisciplinary research is any study or group of studies undertaken by scholars from two or more distinct scientific disciplines, such as immunology, microbiology, and genomics (Aboelela et al., 2007). A disease model is a cell or animal with pathological processes similar to those found in cats or dogs, used to understand how nutrition impacts the development, progression, and management of diseases in pets. Common disease models used in companion animal nutrition studies are poultry and rodent models. Basic research seeks answers to universal, theoretical questions, focusing on uncovering specific knowledge rather than developing immediate solutions. Conversely, applied research discovers answers to specific questions and is used to solve specific problems (Lawrence Berkeley National Laboratory, n.d.). Most research done in academia falls under applied research, involving measures looking at food safety and quality, ingredient testing, palatability testing, and digestibility testing *in vivo* (within the animal) or *in vitro* (outside the animal, in a test tube, culture dish, or elsewhere). *In vitro* digestion and fermentation assays are typically conducted before *in vivo* testing as they offer a quicker and more cost-effective way to assess digestibility.

While most research is conducted on feline and canine subjects, other animal models, such as the rooster, have also proven effective in studying certain aspects of pet nutrition. The cecectomized rooster assay, for instance, has shown efficacy in estimating the amino acid digestibility of novel protein sources (e.g., alligator, calamari, and venison) or those processed differently (e.g., raw chicken versus chicken meal) in cats and dogs. The removal of the rooster's twin ceca makes their excreta very similar to the ileal digesta of cats and dogs. Other methods of analyzing pet food protein and amino acid digestibility have drawbacks compared to the cecectomized rooster assay. For example, estimates of digestibility using fecal analysis are often inaccurate due to the influence of bacteria and other microorganisms in dogs' and cats' large intestines, which alter the final results. The cecectomized rooster assay also allows for the testing of individual ingredients, which is not possible in dog or cat studies where complete diets must be fed, and the ingredient in question is only a proportion of the diet. *In vitro* lab experiments also fall short compared to the cecectomized rooster assay because they focus on specific ingredient categories, such as soy or chicken-based proteins. This limitation makes it especially challenging to test novel pet food ingredients (Wall, 2018). Conventional roosters are also used to examine the total metabolizable energy (TMEn) of novel carbohydrates and complete diets.

Academic studies have also explored the relationship between nutrition and various health conditions in cats and dogs, such as obesity (Fischer et al., 2017; Oba et al., 2023). It is important to note that health conditions are never induced in the studied animal subjects. Instead, subjects with specific conditions are often recruited through pet owner participation and/or veterinary oversight or veterinary clinical trials for these studies.

Many of the studies conducted within academia are fueled by consumer demand. For

example, the use of probiotics in pet foods has garnered increasing interest in recent years among consumers. One study found that 47% of U.S. cat owners and 53% of dog owners are giving their pets probiotics, up from just 22% and 32%, respectively, in 2021. In the same study, among a host of functional ingredients, probiotics ranked high for their relation to health and wellness, second only to vitamins for dog owners and fourth for cat owners (behind vitamins, omega-3s, and minerals) (Phillips-Donaldson, 2024b). Probiotic use among humans has also increased in recent years. This, coupled with the dramatic rise in usage rates for pets, underscores the importance of functional ingredients and claims to pet owners, as well as the growing focus on gut health. For pet food companies to include probiotics in their formulations, they need established studies demonstrating efficacy for pets, often conducted through academic institutions. Multiple studies on this topic have been published, leading to the inclusion of probiotics in pet food formulations across the market (Belchik et al., 2023; Rossi et al., 2017a; Rossi et al., 2017b; Wernimont et al., 2020; White et al., 2017).

In conclusion, academic research serves as the backbone of innovation within the pet food industry. It not only addresses pressing challenges and fills critical knowledge gaps but also drives the development of new products that meet the evolving needs of pets and their owners. As consumer demands grow and new health trends emerge, the partnership between academia and the pet food industry will continue to be essential in advancing the science of pet nutrition, ensuring that pets receive the best possible care through evidence-based dietary solutions.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lecture

are shown in **TABLE 6A** and **TABLE 6B**. When students were asked if they were aware that research was conducted within the field of pet nutrition in academia, all students indicated 'yes.' However, when asked how often they relied on or referenced academic studies when making decisions about their pets' nutrition, a significant proportion (35%) indicated they never have, 35% indicated 'rarely,' and only 30% indicated occasional reliance. Notably, none of the students reported frequently relying on or referencing academic studies (**TABLE 6A**). This finding is significant, though not entirely surprising, given that while public confidence in science and scientists remains high among Americans, most rarely engage in scientific activities. Americans also tend to learn about science from general news sources rather than dedicated scientific sources. This may be due to a lack of knowledge on how to properly research and understand relevant literature, or due to the convenience offered by general news sources compared to published studies. Although 60% of American adults report understanding experimental logic, noting that a control group can be useful for a study, only 50% could correctly identify a scientific hypothesis. Familiarity with scientific concepts, like identifying a hypothesis or the scientific method, is positively correlated with overall trust in science and scientists to act in the public's interest (National Science Board, 2024). These findings underscore the importance of public education not only in pet nutrition but across other STEM fields. In agreement with these results, when students were asked to what extent they believed the general public was aware of academic research findings in the field of pet nutrition, only 5% indicated 'high awareness,' while most (60%) indicated 'low awareness' (**TABLE 6A**). Additionally, when students were asked about their familiarity with academic research in pet nutrition, most (90%) reported low familiarity, with 5% indicating they were 'not familiar at all,' 60% 'slightly familiar,' and 25% 'moderately familiar.' Only 5% of the students were 'very

familiar' or 'extremely familiar' with the research. However, in the post-lecture survey, familiarity significantly increased, with 65% of students indicating they were 'very familiar' (**TABLE 6B**).

Interestingly, when asked what specific topics within pet nutrition research they believed academia should prioritize, the top choice was 'nutritional requirements for different life stages' (**TABLE 6A**). This is significant because this specific area appears to be lacking in scientific studies. Furthermore, when students were asked in both the pre- and post-lecture surveys whether they believed pet nutrition studies in academia were invasive, there was a significant increase in the number of students selecting 'non-invasive' in the post-lecture survey compared to the pre-lecture survey (**TABLE 6B**). This trend was generally observed across many questions in **TABLE 6B**, suggesting increased familiarity with the topic as students were exposed to the lecture material.

TABLE 6A. *Survey student responses on the role of academia in pet food nutrition research (n = 20)*

Questions and Answer Choices	%
Prior to this class, were you aware that research was conducted in the field of pet nutrition in academia (i.e. university institutions)? –	
Yes	100
No	0
Have you ever relied on or referenced academic studies when making decisions about your pet's nutrition? –	
Yes, frequently	0
Yes, occasionally	30
Rarely	35
Never	35
In your opinion, what specific topics within pet nutrition research should academia prioritize? (select all that apply) –	
Ingredient nutritional evaluation	65
Novel ingredient testing (e.g. insect meals)	80
Nutritional requirements for different life stages	90
Targeted health conditions (e.g. diabetes, kidney disease, etc.)	85
Gut health & physiology (e.g. probiotics and microbiome)	80
Other	0
To what extent do you believe the general public is aware of academic research findings in the field of pet nutrition? –	
Not aware at all	15
Low awareness	60
Moderate awareness	20
High awareness	5

To what extent do you believe the general public trusts academic research findings in the field of pet nutrition? –	
No trust	0[1]
Low trust	25[1]
Moderate trust	69[1]
High trust	6[1]

–This question was not asked in the post-lecture survey for this topic.
[1]n = 16

TABLE 6B. *Pre- and post-lecture survey student responses on the role of academia in pet food nutrition research (n = 20)*

Questions and Answer Choices	%*	%**
How familiar are you with the academic research conducted in the field of pet nutrition?		
Not familiar at all	5	0
Slightly familiar	60	0
Moderately familiar	25	30
Very familiar	5	65
Extremely familiar	5	5
To what extent do you believe academic research contributes to advancements in pet nutrition?		
Not at all	0	0
Minimally	0	0
I do not know	0	0
Moderately	40	20
Significantly	60	80
How would you rate the importance of academic research's impact in pet food industry practices and standards?		
Not important at all	0	0
Not very important	0	5
I do not know	5	0
Important	50	15
Very important	45	80
How often do you think academic institutions work directly with pet food companies for research development?		
Never	0	0
Rarely	0	5

I do not know	10	0
Often	90	65
Very often	0	30
In your opinion, the research conducted in pet nutrition studies in academia is most likely:		
Invasive (e.g. surgeries)	0	0
Non-invasive (e.g. feeding, weighing, collecting feces and/or urine, and/or blood sampling)	45	75
Both invasive and non-invasive	55	25

*Pre-lecture survey responses
**Post-lecture survey responses

Chapter 5: The Role of Pet Food Companies in Pet Nutrition

Pet ownership in the U.S. has surged over the past three decades, with 66% of U.S. households (more than 84 million homes) owning at least one pet as of 2024. This increase in pet ownership has led to significant demands within the pet food industry, with the U.S. pet food market size estimated at $35.18 billion in 2023 and expected to expand at a compound annual growth rate (CAGR) of 3.7% from 2024 to 2030 (Grand View Research, n.d.). As most pet owners consider their pets to be family members, anthropomorphism has become a significant driver behind the pet food industry's ongoing success, evolving from a mere trend to a foundational force (AVMA, 2022). However, what is beneficial for humans is not always suitable for dogs and cats, and it's crucial for pet owners to recognize this distinction. Anthropomorphism—attributing human characteristics to animals—can heavily influence pet food selection and purchasing decisions, posing a substantial threat to pet welfare since pets have nutritional needs that differ significantly from those of humans. For instance, cats are obligate carnivores and therefore have high protein requirements. There are also nutrients, such as arachidonic acid, arginine, and taurine, that are considered essential in feline diets because cats lack the enzymatic activity to synthesize these amino acids in sufficient quantities (Fascetti et al., 2023). Understanding these requirements is key to providing optimal nutrition for pets, and it is what pet food companies strive to achieve.

A survey conducted in 2018 found that consumer trust in the quality of food produced by pet food companies was underwhelming. Nearly two-thirds of dog and cat owners neither agreed nor disagreed that they trust the quality of pet foods produced by larger companies with leading mass-market brands, natural/organic specialist companies, or smaller/regional companies

(Sprinkle, 2018). This reduced trust, or lack thereof, has been associated with an increase in alternative feeding practices, such as the feeding of a raw meat-based diet (RMBD) to pets. These diets typically include raw meat, offal, bones, fish, dairy products, vegetables, fruits, various oils, and other additives, and can be homemade or bought premade, usually frozen, from pet food manufacturers (Baum et al., 2024). The practice of feeding RMBD, especially to dogs, has gained popularity among both pet owners and veterinary professionals with Google searches for "raw dog food" quadrupling over the past decade (Google Trend Data, 2024). While estimates of the percentage of dog owners who feed RMBD vary, experts agree that the practice is increasing in both the United States and Europe (Empert-Gallegos et al., 2020). Studies have found that feeding raw and homemade diets is more prevalent among owners who express greater mistrust of commercial pet foods and the pet food industry (Bulchova et al., 2021; Laflamme et al., 2008; Morelli et al., 2019). Despite the lack of scientific evidence demonstrating the superiority of raw meat-based diets over commercial pet foods, the popularity of RMBD continues to rise, facilitated by the vast availability and exchange of information online. Social media, non-certified or improperly credentialed nutritionists, and pet health activists all contribute to promoting this trend. Scientific studies have highlighted various health risks associated with RMBD, including the presence of pathogenic microorganisms such as *Salmonella*. One survey found that about 93% of respondents who fed their pets a raw meat-based diet believed it to be a more natural and species-appropriate diet, based on the notion that cats and dogs evolved from carnivores that hunted prey and were biologically designed to eat raw meat (Bulchova et al., 2021). However, this belief is incorrect; dogs have evolved to be omnivores, and although cats are carnivorous, they can efficiently digest and utilize the starch in commercial pet foods (Laflamme, 2010).

What many consumers may not realize is that commercial pet food companies, especially the leading ones in the industry, conduct and implement rigorous research to develop their products. Throughout the course, representatives from three of the top global pet food companies shared their pet food development processes, clearly demonstrating that these companies prioritize pet health and longevity above all else when formulating their products. Although some of the research conducted by these companies is not accessible to the general public due to its proprietary nature, much of their research is peer-reviewed and publicly available. These companies also have dedicated websites for both the veterinary and consumer communities, where they share their scientific innovations and findings. As observed in academic settings, research conducted by or for pet food companies must be non-invasive in nature and abide by strict federal and state regulations to ensure the safety and welfare of the animals involved. The intended use of the pet food product generally dictates who conducts the research and who formulates the diet. Clinical nutritional research is conducted to assess the effectiveness of veterinary prescription diets (or therapeutic diets) intended to treat or mitigate certain health conditions in pets. This type of research is often conducted through private veterinary clinical trials in collaboration with veterinarians in academic institutions. The pets are normally recruited via pet owner participation, and the health conditions must be naturally occurring and never induced upon the participants. These diets are formulated by in-house board-certified veterinary nutritionists in collaboration with other in-house scientists including animal nutritionists, food engineers, and food technologists.

Nutritional well-being research is conducted to assess the effectiveness of pet foods intended to promote the health and longevity of already healthy pets. This type of research is primarily conducted in-house within the pet food company through their pet research centers, in

collaboration with academia, or through contract research organizations. Larger pet food companies normally conduct their own research in-house, but smaller pet food companies may oftentimes rely on academic institutions or contract research organizations as they may not have the capacity to conduct their own research in-house. These diets may be formulated by in-house nutritionists, food engineers, food technologists, and other in-house scientists. The pet partners (or research test subjects) across the three pet food companies live very structured, enriched lives from their onboarding up until their retirement, where their final fate is adoption. Human panelists may also be recruited to assess the sensory perceptions (i.e., palatability and smell) of pet foods.

Pet food is among the most highly regulated of all food products. Pet food companies must adhere to extensive regulations on both the federal and state levels. As such, each ingredient included in a pet food product must be FDA approved for its use in pet foods (see Chapter 1 for more information on pet food regulation). The manufacturing of pet food also requires the following of rigorous safety and quality protocols. It begins with the design of a complete and balanced recipe based on research and scientific findings, as well as intended purpose, species, life stage, and health status. The individual ingredients, as well as the product prototype(s), go through extensive analytical testing, processing evaluations, and pet feeding studies to determine the safety, bioavailability, and taste to the animal. Besides ensuring nutrient profile and sensory standards are met, pet food companies also analyze fecal and urine samples to determine digestibility and assess urine acidity (pH). Ingredients are sourced from trusted ingredient suppliers who are audited and inspected by the state regulatory officials. These suppliers may also conduct their own research on their ingredients to examine their food science and chemistry aspects. As the pet food is made, inspections, tests, and monitoring ensure safety

at every step. Every manufactured pet food product undergoes a complete nutrient profile analysis to ensure consistency and that each product meets pets' needs before it becomes available to the consumer. Many pet food companies, including the three companies represented in the course, also continuously monitor their pet foods after they are commercially available to ensure there are no recipe or packaging drifts from the original marketed product.

The pet food industry is a complex field driven by consumer demands, scientific research, and rigorous safety standards. While consumer trust and the increased anthropomorphism of pets present ongoing challenges, leading pet food companies continue to prioritize the health and welfare of pets through diligent research and compliance with regulatory standards. As the industry evolves, ongoing education will be key to maintaining and improving consumer trust and ensuring the well-being of pets.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for these lectures are shown in **TABLE 7A** and **TABLE 7B**. A significant portion of the students (~57%) had previously completed a course on the nutrition of cats and dogs before this seminar. Although the course did not cover the topic extensively, it briefly mentioned the role of pet food companies in the industry. Therefore, these findings may not fully represent the general consumer population. In the pre-lecture survey, when students were asked if they believed pet food companies engage in or utilize research for pet food development, 90% answered 'yes,' and 10% indicated 'no.' In the post-lecture survey, 100% of the students indicated 'yes,' demonstrating an improvement in understanding (**TABLE 7B**). When asked whether they thought the research conducted by pet food companies was invasive or not, 72% of students initially indicated they believed it was non-invasive, while 28% thought it was both invasive and

non-invasive. After the lecture, a larger proportion of students (90%) believed the research was non-invasive, with only 10% selecting 'both invasive and non-invasive' (**TABLE 7B**). This significant shift suggests increased clarity on the topic after the lectures.

While there was generally an improvement in learning across many of the questions in **TABLE 7B**, some questions seemed to create confusion. This could be due to the rapid coverage of certain topics during the lecture(s) or slight discrepancies in the answers provided by the three speakers. For instance, the correct answer for where research is conducted for a disease-specific condition is "clinical trials in collaboration with academia" or "private veterinary clinics with pet owner participation" (**TABLE 7B**). However, the efficacy of veterinary prescription diets that are not disease-specific can be assessed in-house. An example is a diet designed to improve the gastrointestinal health of Persian cats, which are prone to digestive issues compared to other cat breeds. Responses to this question did not show a distinct pattern between the pre- and post-lecture surveys, although there was a notable increase in students selecting "private veterinary clinics with pet owner participation" in the post-lecture survey compared to the pre-lecture survey (**TABLE 7B**). There was also some confusion about who formulates therapeutic and non-prescription diets for pet food companies (**TABLE 7A**). This confusion might have been caused by slight rewording of the question or additional answer choices that could have misled some students. It could also be due to variations in the answers given by the different speakers. Pet food is always formulated in-house by qualified scientists. Although in-house veterinarians do not directly formulate pet diets, they may assist in the research development process. In-house veterinary nutritionists are typically involved in formulating therapeutic diets due to their qualifications. General in-house staff, nutritionists from academic institutions, and veterinarians from private clinics are not specifically involved in the pet food formulation process. The answer

to where the majority of research is conducted for pet food development is situation-dependent (**TABLE 7A**). It depends on the size of the pet food company and whether the diet is intended to treat a specific disease or condition. This is why all the answer choices are technically correct for this question.

Overall, the lecture demonstrated improvements in students' understanding of the role of pet food companies in pet nutrition. However, the results also indicate some confusion among students regarding certain topics. This may be due to students hearing slightly different perspectives from the different pet food companies. While most pet food companies follow the same core guidelines for pet food development, there may be slight differences in how each speaker presented the material, how each company conducts its product development process, and what their teams consist of.

TABLE 7A. *Survey student responses on the role of pet food companies in pet nutrition based on the lectures presented by 3 well-established pet food companies. This data is a collection of 3 pre- and post-lecture survey sets and some of the questions may be slightly reworded to maintain the pet food companies' anonymity (n = 20).*

Questions and Answer Choices	%
In your opinion, where is the majority of research primarily conducted for pet food development? +	
Academia	13[1]
Within the pet food company	50[1]
Independent contract laboratories	17[1]
Veterinary clinics	0[1]
Who do you believe formulates non-prescription diets for pet food companies? (select all that apply) +	
In-house nutritionists	100
In-house veterinarians	35
In-house general staff	55
Nutritionists from academic institutions	50
Veterinarians from private clinics	20
Who do you believe formulates therapeutic diets for pet food companies? (select all that apply) +	
In-house nutritionists	100[2]
In-house veterinary nutritionists	0[2]
In-house veterinarians	100[2]
In-house general staff	35[2]
Nutritionists from academic institutions	76[2]
Veterinarians from private clinics	29[2]
Who formulates therapeutic and non-prescription diets for pet food companies? (select all that apply) –	
In-house nutritionists	95

In-house veterinarians	85
In-house veterinary nutritionists	90
In-house general staff	40
Nutritionists from academic institutions	90
Veterinarians from private clinics	40
Food engineers	60
Food technologists	55
Do you think that expert human panelists are recruited to assess the palatability and/or smell of pet foods? +	
Yes	50
No	0
Not sure	50

+This data was taken from one of the pre-lecture surveys.
–This data was taken from one of the post-lecture surveys.
[1]n = 18
[2]n = 17

TABLE 7B. *Pre- and post-lecture survey student responses on the role of pet food companies in pet nutrition based on the lectures presented by 3 well-established pet food companies. This data is a collection of 3 pre- and post-lecture survey sets and some of the questions may be slightly reworded to maintain the pet food companies' anonymity (n = 20).*

Questions and Answer Choices	%*	%**
Do you believe that pet food companies engage in or utilize research for pet food development?		
Yes	90	100
No	0	0
Not sure	10	0
In your opinion, the research conducted for pet food development is most likely _____.		
Invasive (e.g. surgeries)	0[1]	0
Non-invasive (e.g. feeding, weighing, collecting feces and/or urine, and/or blood sampling)	72[1]	90
Both invasive and non-invasive	28[1]	10
How do you think the effectiveness of veterinary prescription diets is assessed? (select all that apply)		
In-house clinical trials (within the pet food company)	100[2]	90
Clinic trials in collaboration with academia (within academia)	88[2]	85
Private veterinary clinics with pet owner participation	65[2]	90
Online surveys and customer feedback	82[2]	85
All new pet food formulations are tested on live cats and dogs before they are available on the market.		
Strongly disagree	30	10
Somewhat disagree	30	10
I do not know	25	10
Somewhat agree	10	25
Strongly agree	5	45

Every manufactured pet food product undergoes a complete nutrient profile analysis.		
Strongly disagree	5	0
Somewhat disagree	10	10
I do not know	20	0
Somewhat agree	35	15
Strongly agree	30	75

*Pre-lecture survey responses
**Post-lecture survey responses
[1]n = 18
[2]n = 17

Chapter 6: Can we Feed Dogs a Healthful Vegan Diet?

While many misconceptions in the pet food industry can be refuted through ample scientific literature, there are still some novel ideas that lack robust scientific backing or are surrounded by controversy within the scientific community. One increasingly popular topic, particularly among consumers who follow a vegan lifestyle, is the idea of feeding pets a balanced and nutritionally complete vegan diet. Recent surveys have shown that pet owners who choose to feed their pets a vegan diet are almost exclusively vegan themselves (Dodd et al., 2019; Knight et al., 2022). This trend suggests that with the increased anthropomorphism of pets, owners are more inclined to feed their pets in a way that mirrors their own dietary preferences. Over the past decade, human diets that minimize animal products ('ovo-lacto vegetarian', 'vegetarian') or eliminate them entirely ('strict vegetarian', 'vegan') have become more prevalent worldwide. As a result, we can expect a rise in the number of pet owners who are interested in or already feeding their pets vegan or vegetarian diets. Notably, vegetarian dog foods are almost always vegan, which is why this discussion focuses specifically on vegan diets. The primary reason cited by pet owners for feeding their pets a vegan diet is concern for animal welfare (reported by 39% of respondents). Other reasons include personal religious beliefs, concerns about ingredients, and environmental sustainability (Dodd et al., 2019; Knight et al., 2022). These motivations are similar to those reported in studies examining the reasons behind the adoption of a vegan lifestyle among humans (Statista, 2024). Although many ingredients used in commercial pet foods are sustainably sourced from the human food byproduct industry, a plant-based diet is generally considered more sustainable in the long term compared to a meat-based diet.

However, the most common concern about vegan pet foods is their nutritional completeness (reported by 74% of respondents), with other concerns including perceptions of unnaturalness, cost, and veterinary advice against such diets. Among pet owners who are not currently feeding plant-based diets but have shown interest in doing so, a significant proportion (45%) expressed a desire for more information about the nutritional adequacy of these diets (Dodd et al., 2019; Knight et al., 2022).

The question that remains under investigation in the scientific community is whether vegan diets can be formulated to meet the nutritional needs of dogs and cats. Although some studies have shown vegan diets to produce health outcomes comparable to or better than non-vegan diets, there is a pressing need for large-scale, population-based studies to thoroughly assess the nutritional adequacy of vegan diets for pets, particularly for cats (Domínguez-Oliva et al., 2023; Harsini et al., 2024). From the lecture material presented, it is clear that dogs, as omnivores, can obtain all their essential nutrients from plants. Therefore, a nutritionally balanced vegan diet can potentially meet all of a dog's nutritional needs. However, certain aspects must be considered when formulating a complete and balanced vegan diet for dogs. First, the protein and amino acid content of vegan diets must be carefully compared to that of animal-based diets. Three key factors to consider when formulating a diet for dogs are protein quantity (18% for dogs at maintenance and 22.5% for growing or reproducing dogs according to AAFCO), amino acid content (balancing for essential amino acids), and digestibility. These factors vary between animal and plant-based protein sources. Plant-sourced proteins tend to lack certain essential amino acids, so it's crucial to combine different plant-based protein sources to complement each other and enhance the overall amino acid profile. Animal-based proteins, on the other hand, generally provide all essential amino acids but can be affected by heat processing, which may

damage the proteins and lead to a loss of certain amino acids. Additionally, plant-sourced proteins usually contain a carbohydrate fraction, which necessitates consideration of the types of fiber, resistant starches, and starches present. In contrast, animal-sourced proteins do not contain carbohydrates. Legume protein sources, such as soy, often have antinutritional factors that must be denatured through heat processing. Antinutritional factors are compounds in foods that reduce nutrient bioavailability. Most animal-sourced proteins do not contain antinutritional factors, though there are some exceptions. Moreover, plant-sourced proteins lack taurine, which is conditionally essential for dogs, unlike animal-sourced proteins. Common plant protein sources used in vegan diets include soybean products combined with corn gluten meal, pulses, potato protein, dried yeast, sunflower meal, and flaxseed meal. Soybean products combined with corn gluten meal have been historically popular for their favorable amino acid profile and extensive scientific study, though they have recently fallen out of favor with the public. Consequently, other plant-based sources such as pulses and potato protein have gained popularity. Vegan diets generally provide an adequate amount of carbohydrates and dietary fiber, so these are not usually a concern. However, the utilization of starch is an important factor—cooked starch is more efficiently utilized than raw starch. In terms of dietary fat, plant oils, such as flaxseed oil, provide alpha-linolenic acid (ALA), which is not typically a concern in vegan diets. However, long-chain omega-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are not commonly found in plant oils. While these fatty acids are not required in the diet, they offer potential health benefits for pets due to their anti-inflammatory effects. Microalgae is a potential option for a vegan source of EPA and DHA, although it is not as great of a source of EPA. Vitamin A is typically not a concern in vegan diets for dogs, as they can utilize carotenoid pigments from plants that are sufficiently present in vegan diets. However, vitamin D and

vitamin B12 can be potential concerns. Dogs cannot produce vitamin D internally, so it must be provided through their diet. In vegan diets for dogs, vitamin D2 (ergocalciferol) is usually provided synthetically, as vitamin D3 (cholecalciferol) is an animal-based source. Although studies have shown that cats do not efficiently utilize ergocalciferol, dogs have not demonstrated issues with it. Vitamin B12 is naturally found primarily in animal tissues and yeast, so in vegan diets, it is typically provided by yeast or synthetically. It's important to note that dogs have a very small requirement for vitamin B12, as their bodies conserve it well, so it is not needed in large quantities in their diet.

For pet owners considering feeding their dogs a vegan diet, it is advisable to choose a brand supported by extensive research and to consult with a qualified nutritionist. Overall, this discussion highlights the potential for feeding dogs a complete and balanced vegan diet, while also emphasizing the importance of further research to establish firm conclusions about the suitability of vegan diets for dogs and cats.

Pre- and Post-Lecture Survey Results & Discussion

The frequency of responses to the pre- and post-lecture survey questions for this lectures are shown in **TABLE 8A** and **TABLE 8B**. When students were asked if they currently feed or have fed a vegan diet to their dogs, none of the students indicated they had (**TABLE 8A**). A significant portion of the students (76%) also would not consider feeding their dogs a vegan diet, and their thoughts did not change regardless of their exposure to the lecture material **(TABLE 8B)**. When students were asked to indicate the challenges they foresaw in feeding vegan diets to dogs, ‘ensuring proper nutrition’ was selected by all of the respondents and was the top selected answer (**TABLE 8A**). This finding is in agreement with previous mentioned studies where the most common cited concern about vegan pet foods is their nutritional

completeness (reported by 74% of respondents) (Dodd et al., 2019; Knight et al., 2022). In the pre-lecture survey, when students were also asked to select potential reasons they would consider feeding their dog(s) a vegan diet, most of the students (52%) selected that they would never consider feeding their dog(s) a vegan diet, but a significant portion of the students (33%) selected 'environmental concerns related to meat production' as one of their responses, suggesting that some of the students were willing to change their minds regarding their willingness to feed a vegan diet if they were provided with more information regarding the efficacy and environmental sustainability of vegan diets. When students were asked if they believed that a vegan diet formulated by a trained nutritionist could provide all the necessary nutrients for a dog's health, most of the students (52%) indicated they were 'not sure' in the pre-lecture survey. In the post-lecture survey, there was a marked increase in the number of students who indicated 'yes' to the question, indicating an increase in the level of learning when the students were exposed to the lecture material (**TABLE 8B**). Some of the survey results, however, also suggest that many of the students seemed to have some reservations about the practice of feeding vegan diets to dogs. For example, when students were asked how they would rate the ethical considerations of feeding dogs a vegan diet compared to traditional meat-based diets, there were not significant changes in the results observed in the pre- and post-lecture surveys. That being said, a majority of the students (86%) were unaware of any scientific research or studies regarding the health effects of feeding dogs a vegan diet, so this could also potentially explain the observed responses. Overall, while the lecture seemed to enhance students' understanding of the topic, many of the students still seemed to have some reservations on the practice of feeding vegan diets to dogs.

TABLE 8A. *Survey student responses on feeding dogs a vegan diet (n = 21)*

Questions and Answer Choices	%
Do you currently own any dogs (or have in the past)? –	
Yes	90
No	10
Do you currently feed or have fed your dogs a vegan diet? –	
Yes	0[1]
No	100[1]
For which of the following reasons would you consider feeding your dog(s) a vegan diet? (select all that apply) –	
Against raising animals for meat production	19
Personal dietary choices (e.g., vegan lifestyle)	5
Health reasons for the dog(s)	24
Environmental concerns related to meat production	33
Other	5
I would never consider feeding my dog(s) a vegan diet	52
What challenges do you foresee in feeding a vegan diet to dogs? (select all that apply) –	
Ensuring proper nutrition	100
Cost	62
Availability	62
Skepticism from others (e.g., family, friends, veterinarians)	52
Concerns about the dogs' acceptance of the diet	81
Other	5
Are you aware of any scientific research or studies regarding the health effects of feeding dogs a vegan diet? –	
Yes	10

No	86
Not sure	5
Dogs can obtain all of their essential nutrients from plants. +	
True	67
False	33
What are the macro- and micronutrients to be more mindful of when formulating a vegan diet that is absent of animal-sourced proteins? (select all that apply) +	
Sulfur amino acids (e.g., methionine and lysine)	70[2]
Taurine	90[2]
Total protein content	75[2]
Dietary fiber	35[2]
Carbohydrate content	30[2]
Vitamin D	90[2]
Vitamin B12	70[2]
Eicosapentaenoic Acid (EPA) - an omega-3 fatty acid	70[2]
Docosahexaenoic Acid (DHA) - an omega-3 fatty acid	85[2]
Alpha-linolenic acid (ALA) - an omega-3 fatty acid	60[2]

+This question was not asked in the pre-lecture survey for this topic.
–This question was not asked in the post-lecture survey for this topic.
[1]n = 19
[2]n = 20

TABLE 8B. *Pre- and post-lecture survey student responses on feeding dogs a vegan diet (n = 21)*

Questions and Answer Choices	%*	%**
Would you ever consider feeding your dog(s) a vegan diet?		
Yes	5	5
No	76	76
Not sure	19	19
Do you believe that a vegan diet formulated by a trained nutritionist can provide all the necessary nutrients for a dog's health?		
Yes	29	52
No	19	24
Not sure	52	24
How would you rate the ethical considerations of feeding dogs a vegan diet compared to traditional meat-based diets?		
Very unethical	5	0
Somewhat unethical	38	38
I do not know	33	24
Somewhat ethical	14	19
Very ethical	10	19

*Pre-lecture survey responses
**Post-lecture survey responses

CONCLUSION

In conclusion, the results of this study indicate an improvement in students' learning when they were exposed to the lecture material for each topic covered in the course. Given the limited data on consumer perceptions of the pet food industry, this study not only enhanced students' knowledge of the industry but also quantified some of the misinformation present. This quantification is crucial for identifying opportunities to expand public education efforts and addressing knowledge gaps in the industry.

While this study contributes positively to the scientific community, several limitations should be considered. Notably, approximately 57% of the students had previously completed a cat and dog nutrition course. This prior knowledge may have influenced their responses to some survey questions, as they may have been more familiar with the topics than students without such background. Additionally, although we did not release identifying information, the collection of students' names for course participation could have led some students to answer questions more favorably due to concerns about their individual responses being reviewed. There is also the possibility that some students may have provided random responses rather than reflecting their true understanding. Furthermore, some students, who were not present in-person for all lectures, viewed recorded lectures and may have completed post-lecture surveys without thoroughly engaging with the material. This could affect the accuracy of the post-lecture survey results in reflecting their actual learning.

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