Impact of chicken protein variables in feline dry kibble on feline and consumer acceptance measured by utilizing sensory analysis

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Abstract

The global pet food market is valued at approximately $161.7 billion and is projected to expand by almost 5% annually. In the United States, cats reside in 53% of the nation's 95 million pet-owning households. However, companion animal formulas account for an estimated 25–30% of the environmental impacts associated with domestic livestock production, emphasizing the need for sustainable animal protein alternatives. This study evaluated four poultry-based protein sources in dry feline kibble—poultry by-product meal (PBPM), chicken meal (CM), dried chicken (DC), and fresh chicken (FC)—to analyze environmental impacts as well as feline and human consumer acceptance. Among the evaluated ingredients, PBPM contributes the lowest greenhouse gas emissions (~1.0–1.8 kg of CO_2 - eq/kg), whereas FC contributed the highest (~5.0–8.0 kg CO_2 - eq/kg). In the feline palatability trial (n = 25), PBPM achieved the highest number of preference wins and demonstrated the greatest apparent dry matter digestibility across all formulations. In addition, a blinded consumer acceptance panel (n = 109) ranked PBPM highest overall; however, preference inverted completely upon ingredient disclosure, with FC becoming the most preferred and PBPM the least, illustrating strong consumer bias against poultry by-product meal. A trained descriptive sensory panel (n = 7) evaluated aroma and appearance. The aroma results were used to evaluate relationships between aroma attributes and volatile compounds identified via Gas Chromatography-Mass Spectrometry (GC-MS) using Partial Least Squares Regression (PLSR) modeling. These findings demonstrate that while PBPM offers substantial nutritional, palatability, and environmental advantages, consumer perception remains a critical barrier to its commercial adoption in feline kibble formulas.

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Chapter 1 - Introduction

The pet food industry continuously grows in tandem with the steady increase in the pet population in the United States. Whilst acknowledging this growth, it is important to notice the impact that the production of pet food ingredients may have on the environment. Pet food often includes meat ingredients as a source of protein and other nutrients (Okin 2017). The production of these meat ingredients imparts a measurable impact on greenhouse gas emissions and the overall environmental footprint associated with pet food production. When considering the environmental impact of by-product meals, it is significantly less than dried chicken, mechanically de-boned fresh chicken or even rendered meats such as chicken meal. However, by-products hold a notoriously negative connotation with the general human population. When considering purchasing kibble made with by-product meal, it is often not preferred compared to dried chicken, chicken meal or mechanically de-boned fresh chicken due to the perception of by-products being low-quality, less nutritious, and less palatable to pets (Shields et al., 2023). Poultry by-products may help bridge the gap between the potential waste of human food production and the environmental impact of using meat ingredients in pet food. This research will address both the functional and perception associated with poultry by-product meal, chicken meal, dried chicken and mechanically de-boned fresh chicken. The hypothesis of this study is that poultry by-product meal used in dry feline kibble performs equal or better than chicken meal, dried chicken, and mechanically de-boned fresh chicken as defined by feline palatability evaluation, feline digest evaluation, feline stool analysis and blinded consumer acceptance test, but consumers will find it the least acceptable when compared to chicken meal, dried chicken, and mechanically de-boned fresh chicken as defined by an informed acceptance test.

Chapter 2 - Systematic Literature Review

Pet Food Industry

As the United States pet population continues to grow; the pet food industry maintains an upward trajectory as a result. According to the 2025 National Pet Ownership Survey conducted by the American Pet Products Association, 95 million United States households own a pet, and 53% of those households own at least one feline (American Pet Products Association, 2026). Due to the rise in pet ownership, the value of the worldwide pet food market has reached a total of $161.72 Billion in 2026 and is expected to grow 4.84% annually (*Pet food - worldwide: Statista market forecast* 2026).

Sustainability of Animal By-Products in the Pet Food Industry

Pet Food Industry Contribution to Environmental Sustainability

Using by-products allows the meat and poultry industries to utilize high-protein, nutrient-dense material which lowers the overall environmental impact of the industry and offsets food cost inflation. Incorporating by-products also reduces organic pollution from slaughterhouse disposals and prevents massive landfill waste. The protein market is projected to double by 2050, further increasing the environmental impact of meat and poultry production (Henchion, 2017). Poultry by-product meal widely contributes to carbon emissions through rendering plant natural gas and electricity. *Life-cycle assessment of animal feed ingredients: Poultry fat, poultry by-product meal and hydrolyzed feather meal* found that 1 Kg of poultry by-product meal carries a small carbon footprint of 1.0-1.8 kg CO_2-eq which is up to three times less than chicken breast (GLFI 2026).

Production and distribution of pet food exhibit a significant environmental footprint throughout its supply chain. Pet food production has directly contributed to a steady increase in

greenhouse gas emissions in the United States (Ai et al., 2025). According to Okin, pet food accounts for 25–30% of the environmental impact of animal production in the United States, because felines and canines consume roughly 9% of all livestock globally (Nicholles & Knight, 2025). Agriculture production accounts for 14.5% of global greenhouse gas emissions (Kristiansen, 2021). In 2020, *The global environmental paw print of pet food* estimated that global pet food production contributes approximately 56–151 million tons of CO_2 - equivalent emissions—which represents about 1.1–2.9% of total agricultural emissions. Researchers also identified that global pet food production accounts for an estimated 41–58 million hectares of agricultural land use (0.8–1.2% of the global total) and 5–11 cubic kilometers of freshwater consumption (0.2–0.4% of total agricultural use) (Alexander et al., 2021). Overall, the review found that pet food production is a significant component of the global food system and should be further considered in food sustainability research.

Pet Food Ingredient Impact on Environmental Sustainability

Utilizing meat by-products allows for increased utilization of the production animal, reducing the number of animals needed for raising and processing to meet the market demand. According to *Companion Animals Symposium: Rendered ingredients significantly influence sustainability, quality, and safety of pet food,* using animal by-products in pet food supports sustainable animal production by recycling proteins and fats that are not usually consumed by humans, which assists with the reduction of the environmental footprint of livestock farming. They also included that mechanically de-boned fresh chicken carries a Dry Matter Basis footprint of ~5.0-8.0 kg CO_2-eq / kg based on calculations for a 70% moisture wet pet food product (Meeker & Meisinger, 2015; Acuff et al., 2021). The Global Feed LCA Institute Database showed that Chicken meal production emits ~2.5-4.5 kg CO_2-eq / kg, Dried chicken

production emits ~4.0-6.0 kg CO_2-eq / kg, and Poultry by-product meal emits ~1.0-1.8 kg CO_2-eq / kg, showing the significantly lower environmental impact made by Poultry by-product meal compared to other chicken protein ingredients (Global Feed LCA Institute [GFLI], 2026). The article, *Utilization of Poultry Slaughter Byproducts to Develop Cost Effective Dried Pet Food* addresses the cost-effectiveness and sustainability of using meat by-products in pet food by examining the economic and environmental effects of meat by-products. In the study, the control formula used 50% chicken meat powder, and three test formulas used 20% chicken meat powder with 30% poultry by-products powder, 10% chicken meat powder with 40% poultry by-products powder, and 50% poultry by-products powder. All formulas were evaluated for various physio-chemical properties, as well as sensory parameters. Researchers determined that there was no significant difference in general appearance, odor, crispiness, meat flavor intensity, and overall acceptance between the control and treatment formulas. In this study, the cost of the control formula was estimated as 366.31 Rupees per Kilogram where the cost of a 50% poultry byproduct powder formula was 205.63 Rupees per Kilogram. When converted to American dollars, the control formula would be estimated at approximately $1.83 per pound, and the 50% poultry byproduct powder formula would be estimated around $1.03 per pound (Kumar et al., 2023). The study concluded that well accepted and cost-effective dried pet food can be prepared from incorporation of 50% poultry by-products to accommodate the nutritional requirements of adult canines (Kumar et al., 2023). In addition, the research article *Impact of animal by-products on formula digestibility and fecal quality in Beagle Dogs* evaluated the impact of poultry by-product meal as a primary protein source in dry canine food and determined the effect on nutrient digestibility and fecal quality. The study demonstrated that the formula containing poultry by-product meal presented a high apparent nutrient digestibility and was well-accepted by the

canines. The study concluded that the use of poultry by-products resulted in firm stools with optimal fecal scores and increased fecal dry matter (Chuppava et al., 2023).

Pet Food Ingredients – Consumer's Perception

The term “consumers” will be used to define pet owners. Considering that cat-owners cannot experience kibble taste, flavor, freshness and ingredients themselves without consuming their pets’ food, they rely on external cues to inform purchasing decisions (Ai 2025). In addition to their own perception, they depend on socio-cultural factors such as trust and information that is available to them to make purchasing decisions (Ai 2025). Chicken products are a common raw material utilized in pet foods. A multitude of factors come into play when understanding which kind of chicken ingredient, a pet owner would prefer in their pet’s food. Chicken by-product meals are often associated with a negative connotation; however, there are lesser-known positive incentives that make poultry by-product meal desirable to not only the pet, but possibly desirable to the pet owner as well. The Association of American Feed Control Officials (AAFCO) is an advisory body that sets standards and guidelines that are enforced by state and federal regulatory agencies. AAFCO recognizes by-products as “(Part) secondary products produced in addition to the principal product.” Dried chicken does not relate to a specific AAFCO definition.

Poultry by-product meal is defined by AAFCO as

> “The ground, rendered, clean parts of the carcass of poultry, such as necks, feet, undeveloped eggs, viscera, and whole carcasses, exclusive of added feathers, except in such amounts as might occur unavoidably in good processing practices. The label shall include guarantees for minimum crude protein, minimum crude fat, maximum calcium (Ca), and minimum phosphorus (P). The calcium (Ca) level shall not exceed the actual level of phosphorus (P) by more than 2.2 times. If the product bears a name descriptive of its kind, the name must correspond thereto. It shall be suitable for use in animal food,” (Association of American Feed Control Officials [AAFCO], 2026).

Poultry meal is defined by AAFCO in chapter 9 section 71 as

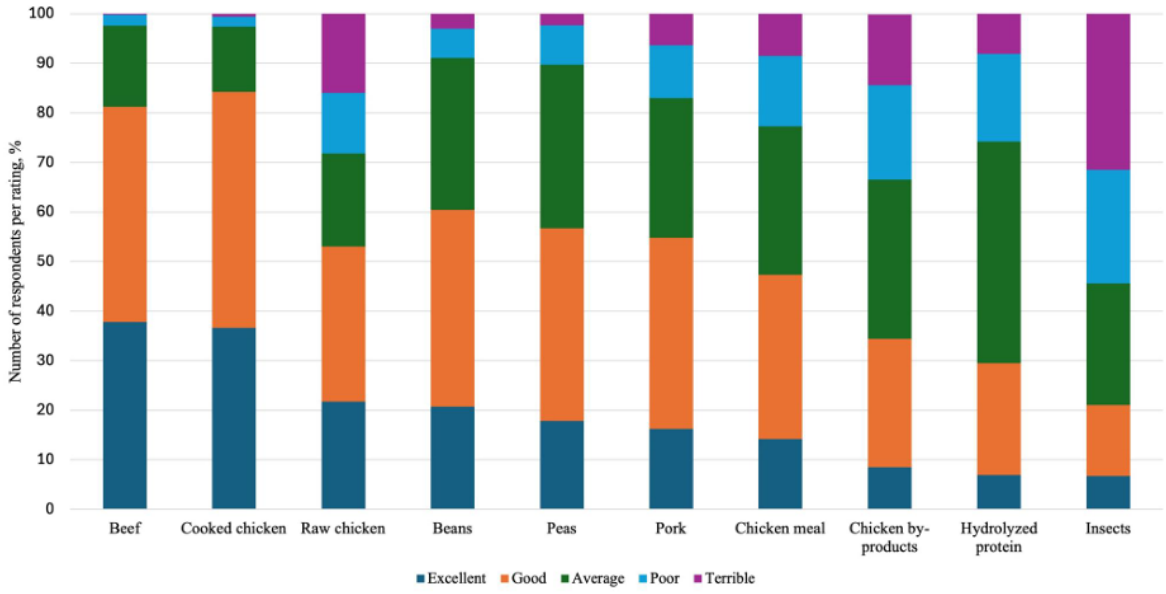
> "The wet rendered or dry rendered product from a combination of clean flesh and skin with or without accompanying bone derived from the parts of whole carcasses of slaughtered poultry, or a combination thereof, exclusive of feathers (except as unavoidable in good processing practices), heads, feet and viscera. The label shall include guarantees for minimum crude protein, minimum crude fat, maximum calcium (Ca), and minimum phosphorus (P). The calcium (Ca) level shall not exceed the actual level of phosphorus (P) by more than 2.2 times. If it bears a name descriptive of its kind, it must correspond thereto. It shall be suitable for use in animal food." (Association of American Feed Control Officials [AAFCO], 2026).

Poultry is defined by AAFCO as,

> "A clean combination of flesh and skin, with or without accompanying bone, derived from the parts or whole carcasses of slaughtered poultry (or a combination thereof), exclusive of feathers (except as unavoidable in good processing practices), heads, feet, and viscera and preserved with a natural antioxidant" (Association of American Feed Control Officials [AAFCO], 2026).

While 'protein quality' is a foundational concept amongst the pet nutrition community, it can remain widely misunderstood by consumers. In the article *Does quantity equal quality? Source of protein influences American dog owner purchasing decisions more than the quantity of protein in the absence of marketing claims*, researchers conducted a survey including 691 canine owners. When asking the canine owners to identify the correct definition of 'protein quality,' only 18% of respondents were able to identify the correct answer, "protein quality is the ability of an ingredient to meet the AA requirements of an individual." Most respondents (30.8%) selected "protein quality is the total amount of protein in an ingredient, such that a higher quantity of protein means better quality." It is important to understand the disconnect between pet owners' perception of protein ingredients and the true physio-chemical components of what contributes to high-quality protein (Singh, 2026). **Figure 1** shows pet owners' perceptions of pet food ingredients based on quality of protein.

Figure 2.1. Respondents' perception of protein quality for various ingredients in the canine diet, presented as the percentage of total ratings for each ingredients, ordered from highest to lowest proportion of "excellent" rating (Singh 2026)



Feline Nutrition

The Evaluation of meat meal, chicken meal, and corn gluten meal as formulary sources of protein in dry cat food utilized twelve felines that were given ad libitum access to food and water, and the three variables were tested using a Latin Square design. The study highlighted that meat meal, chicken meal and corn gluten meal contribute protein that are all metabolized in the same manner by the feline pets. The only exception is that poultry meal typically possesses a higher in phosphorus and calcium content compared to the other sources, which may require some manipulation of the formula to accommodate an appropriate target urine pH for the felines (Funaba et al., 2005).

The study *Cats Have Increased Protein Digestibility as Compared to Dogs and Improve Their Ability to Absorb Protein as Dietary Protein Intake Shifts from Animal to Plant Sources* was conducted at Hill's Pet Nutrition, Topeka KS to further understand true protein digestibility by felines and canines and compare the results. Researchers determined that protein digestion for

extruded kibbles that comply with Hill's Pet Nutrition's standards were digested similarly for both felines and canines regardless of if they contained plant proteins or animal proteins. Felines presented increased protein digestibility in response to an increase in plant protein, but canines did not support any change in protein digestibility with an increase in plant protein. Since it was determined that plant protein inclusion is not associated with reduced protein digestibility, it can be inferred that plant protein provides a satisfactory complement to animal protein in pet food. This combination can help ensure that all necessary amino acid requirements are accommodated by the Formula (Golder 2020). The study *Cats Have Increased Protein Digestibility as Compared to Dogs and Improve Their Ability to Absorb Protein as Formulary Protein Intake Shifts from Animal to Plant Sources,* completed at Hill's Pet Nutrition Center in Topeka, Kansas, was conducted to further understand true protein digestibility by felines and canines and compare the results. Golder determined that protein digestion for extruded kibbles designed to adhere to Hill's Pet Nutrition's standards were digested similarly for both felines and canines despite the inclusion of plant or animal proteins. Felines presented increased protein digestibility in response to an increase in plant protein, but canines did not support any change in protein digestibility with an increase in plant protein. Since it was determined that plant protein inclusion is not associated with reduced protein digestibility, it provides a satisfactory complement to animal protein in pet food. This combination can help ensure that all necessary amino acids requirements are accommodated by the formula (Golder 2020).

Most mammals can synthesize taurine from other sulfur containing-amino acids, but cats are obligate carnivores, as their ability to do this is very minimal. Cats exclusively use taurine for bile conjugation and are not able to substitute glycine for taurine compared to canines, so it is necessary that taurine is replenished through their diet. By supplementing taurine through the

feline's food intake, it is possible to mitigate the likelihood of depletion of taurine stores. Additionally, taurine is essential for retina maintenance (Hayes, 1982), and taurine deficiency in felines can lead to a condition known as Feline Central Retinal Degeneration which causes progressive destruction of photoreceptor cells and the tapetum lucidum. The damage from this condition can often progress without being noticed until vision loss is advanced and irreversible (Schmidt et al., 1976). Taurine is essential for normal central nervous system function, muscle function, and developmental and reproductive health (Hayes, 1982). High taurine concentrations are present in skeletal and cardiac muscles where it is linked to supporting normal muscle contraction (Hayes, 1982). Hayes states that taurine is vital for feline reproduction and the growth and development of kittens (Hayes, 1982). Additionally, *Taurine: An Essential Nutrient for the Cat,* conducted testing with a casein formula versus a casein formula with taurine supplemented and found that felines are only able to produce very little taurine from cystine, which does not meet their dietary needs. The results of this study heavily support that taurine is an essential nutrient for felines (Knopf et al., 1978).

Sensory Analysis

Sensory analysis is critical for the development of a successful product. Analyzing sensory attributes of a finished product allows a company to continuously uphold internal company standards and maintain marketable products that meet the demands of consumers.

Feline Palatability Testing

Palatability measures the degree to which a pet accepts and enjoys their food. Palatability drives product acceptance and owner satisfaction which assists research and development within the pet food industry to continuously meet evolving market and sustainability demands (Watson et al., 2023). It is critical that companion animals find their food palatable, so they are able to

consume enough food to meet daily nutritional requirements. The subjective properties of pet food such as taste, aroma, and texture, heavily influence palatability (Zaghini & Biagi, 2005). Palatability testing relies on two primary methods: the single-bowl test, which measures general palatability and acceptance, and two-bowl preference testing. The two-bowl test is the most common methodology in use today. The two-bowl test establishes a preference based on quantity of food consumed (Aldrich, 2015). Two-bowl tests can be conducted over periods of two days or more, which allows mitigation of "side bias" where bowl positions will be switched. While these test methods allow for a broad understanding of palatability preference, there is still room for improved method development (Aldrich, 2015).

Feline Sensory Behaviors

Consumption tests are more commonly used to measure intake to determine palatability. There are two types of consumption tests; one uses a single bowl and is focused on general acceptance, the other features two-bowls to force a preference of choice. The most common type of palatability test in pet food is the two-bowl test (Aldrich & Koppel, 2015). For this study, a two-bowl test will be conducted for two days for each formula. Two-bowl tests can be conducted in periods of two days or more, which allows mitigation of "side bias" where bowl positions will be switched. While these test methods allow for a broad understanding of palatability preference, there is still room for improved method development.

Feline appetite is primarily centered and regulated in the hypothalamus, which responds to signals from the digestive tract and adipose tissue (Erlanson-Albertsson, 2005). *Behaviour in order to evaluate the palatability of pet food in domestic cats* utilized intake ratios to assess palatability along with behavioral. In addition, researchers tested whether behavioral cues could be related to kibble palatability. Seventeen felines were utilized in a palatability test where they

were given two different foods to understand behavioral cues when consuming the more palatable food. Researchers noticed that the felines spent less time sniffing the food when fed a formula that is highly palatable. They also found that the speed in which felines consumed the kibbles was not relevant to the palatability of the kibbles (Becques et al., 2014).

Feeding cats for optimal mental and behavioral well-being highlights that felines eat 8-20 times naturally, and that felines prefer to control the frequency at which they eat throughout the day. Additionally, Delgado discusses that felines experience a quick burst in alertness, arousal and locomotor activity around mealtimes, which is the cause of food-anticipatory activity (FAA). Therefore, the more frequent a feline is fed throughout the day, more active the feline is overall due to FAA.

Summary and Research Objective

This thesis will evaluate and compare four distinct chicken ingredients – poultry by-product meal (PBPM), chicken meal (CM), dried chicken (DC), and mechanically deboned chicken (FC) within an extruded dry feline formula. Mechanically deboned meat (FC) will be referred to as fresh chicken as well as "FC" throughout the study. To determine how these protein sources influence sensory characteristics, palatability, and chemical profiles, this study uses a four-pronged analytical approach. A trained descriptive sensory panel will quantify certain sensory attributes (aroma, texture, appearance, and flavor profiles) of the kibbles. A consumer acceptance panel is used to evaluate the degree of the acceptability and preference of a product by the consumer. A feline palatability study will evaluate behavioral indicators and intake ratios will be calculated to determine real-world formula preferences. Results will be analyzed alongside the volatile compound profiling via Gas Chromatography-Mass Spectrometry (GC-MS) results which will be used to qualify, correlate, and interpret the impact of each chicken

variable in each of the five formulas. This research aims to identify key volatile compounds that drive feline palatability and buyer choice. Ultimately, this work provides the pet food industry with evidence-based insights to optimize sustainable poultry ingredient selection without sacrificing sensory quality or feline acceptance.

Chapter 3 - The Impact of Chicken Protein in Dry Feline Kibble on Feline Palatability

Abstract

Animal protein sources can significantly influence feline kibble processing, physical attributes, and palatability. This study aims to evaluate five different dry experimental feline maintenance formulas formulated with distinct chicken protein sources: poultry by-product meal (PBPM), chicken meal (CM), dried chicken (DC), mechanically deboned chicken recognized as fresh chicken (FC) and fresh chicken-protein match (FCPM). Each formula was formulated using Concept 5 software to meet AAFCO feline maintenance minimum nutrition requirements. Extrusion was conducted using a single-screw extruder (Wenger X-85) with a target moisture of 6.0% +/- 1.0% and added lactic acid to accommodate a lower pH for antimicrobial control. Kibble attributes were assessed using a two-bowl preference test with trained feline panels (n=25 per panel) to determine the Intake Ratio (IR) and overall preference (t-test, AA= 0.05). The average bulk density (26.54 lb/ft^3), average moisture (5.86%), average pH (5.19) and average water activity (aw = 0.41) remained consistent across all five formulas. Overall, palatability testing revealed that PBPM achieved the highest overall preference, which significantly outperformed CM and FC while achieving a parity against DC and FCPM. DC significantly outperformed CM and CM outperformed FC. The FCPM v. CM comparison yielded invalid intake rates both initially and upon retesting due to low overall intake.

Introduction

Felines heavily rely on animal protein sources to fulfill nutritional requirements for essential amino acids, taurine, and arachidonic acid (National Research Council, 2006). In dry pet food manufacturing, protein sources contribute to the overall amino acid profile, extrusion

behavior of the product, physical kibble attributes, and palatability. Variation amongst these protein variables will result in variation amongst finished product kibbles due to the protein being rendered such as poultry by-product meal (PBPM), dehydrated like dried chicken (DC) or mechanically de-boned (wet input) like fresh chicken (FC) (Aldrich & Koppel, 2015). Pet parents often and increasingly are seeking formulas that contain "fresh meats" rather than by-products or meat meals under the impression that fresh meats contribute higher-quality nutrition and palatability amongst their pets (Boyd et al., 2014). Due to the high moisture content of mechanically deboned meat, this ingredient can present more processing challenges for the extrusion step such as introducing new thermal energy requirements, starch gelatinization and final kibble density variation compared to using a dry protein ingredient (Riaz, 2003). In *Nutritional peculiarities and formula palatability in the cat* study, researchers found that cats tend to show specific sensory preferences that are influenced by macronutrient ratios, moisture levels, kibble hardness, kibble texture and kibble pH (Zaghini & Biagi, 2005). Cats typically show a distinct preference for low-moisture kibble, around 6.0% moisture on an As Fed Basis (Ahuja et al., 2014), where low moisture levels correlate directly with optimal crispness and shelf stability. When analyzing feline palatability preferences, researchers primarily rely on the two-bowl preference test, which quantifies preference via Intake Ratio (IR) (Aldrich & Koppel, 2015). The two-bowl study allows for isolation of ingredient-driven taste preferences. It is important to note that tests conducted on uncoated formulas over extended periods of time can be impacted by oxidation or moisture migration, leading to low overall intake (Koppel, 2014). This study aims to examine the effects of processing parameters, varying kibble aesthetics, and feline palatability of five experimental formulas containing separate chicken protein variables.

Materials and Methods

Formulation

All five experimental chicken formulas were completed using the computer software Concept 5 (Creative Formulation Concepts, LLC Annapolis, MD, USA), using four different chicken protein variables; poultry by-product meal (PBPM; Tyson Foods Scranton, AR, USA), chicken meal (CM; Pet Solutions LLC, Danville, AR, USA), dried chicken (DC; International Dehydrated Foods Monett, MO, USA), fresh chicken (FC; BHJ USA, LLC Hartwell, GA, USA) and fresh chicken-protein match (FCPM; BHJ USA, LLC Hartwell, GA, USA). It is important to acknowledge that “FC” and “FCPM” will be used to represent the “Fresh Chicken” and "Fresh Chicken Protein Match” formulas throughout the study, however, the FC ingredient was previously frozen and thawed upon use for production. Four of the formulas included the chicken variable at 20% (poultry by-product meal, chicken meal, dried chicken, and fresh chicken). The FCPM formula contained fresh chicken at a 27% inclusion rate with an approximate additional 10% rice protein concentrate to accommodate a 33% crude protein content on a dry matter basis in the overall formula. The objective was to prepare a formula that delivered a comparable protein content while using FC, when compared to the poultry by-product meal, chicken meal and dried chicken formulas which contain approximately 33-35% crude protein on a dry matter basis. For the fresh chicken formula with a 20% inclusion rate, the dry matter basis protein content was only approximately 25% due to the additional moisture the FC contained. Each formula maintained a target moisture of 6.0% +/- 1.0% on an as is basis after processing. The remaining ingredients of each of the formulas included brewers rice, yellow peas, rice protein concentrate, cellulose, soybean oil, vitamins and minerals. Additionally, lactic acid was added to lower the pH to address any mycotic or pathogenic concerns within the finished product (Hand

& Lewis, 2010). All five experimental formulas were formulated to meet 2026 AAFCO feline maintenance nutritional requirements (Appendix A).

Table 3.1. Predicted Pre-Processing Formula Nutrient Comparison As Is Basis and Dry Matter Basis

		PBPM		CM		DC		FC		FCPM	
Description	**Unit**	**As Is Basis**	**Dry Matter Basis**	**As Is Basis**	**Dry Matter Basis**	**As Is Basis**	**Dry Matter Basis**	**As Is Basis**	**Dry Matter Basis**	**As Is Basis**	**Dry Matter Basis**
Dry Matter	G	92.4441	100	92.6732	100	92.4429	100	80.0831	100	75.2315	100
Fat	G	9.8527	10.658	9.6029	10.362	9.9255	10.737	10.3493	12.923	12.8115	17.029
Protein	G	31.6397	34.226	32.2609	34.811	33.394	36.124	21.9692	27.433	31.6347	42.05
Ash	G	7.0284	7.603	7.0352	7.591	6.1376	6.639	4.2703	5.332	4.3786	5.82
Crude Fiber	G	7.7174	8.348	7.8648	8.487	7.5786	8.198	7.7305	9.653	7.5068	9.978
Insoluble Fiber	G	12.4868	13.507	12.9021	13.922	12.4807	13.501	12.3927	15.475	12.9542	17.219
Dietary Fiber	G	13.8227	14.952	14.3694	15.505	13.7757	14.902	13.5183	16.88	13.9662	18.564
Soluble Fiber	G	0.6001	0.649	0.7711	0.832	0.5946	0.643	0.6029	0.753	0.4546	0.604
Atwater Energy	KCK	3212.0742	3474.612	3202.2049	3455.373	3251.7112	3517.535	2900.3447	3621.669	2857.6906	3798.529
Sulfur	G	0.452	0.489	0.4125	0.445	0.4537	0.491	0.3211	0.401	0.4569	0.607
Sodium	G	0.5217	0.564	0.5205	0.562	0.473	0.512	0.4465	0.558	0.4682	0.622
Calcium	G	1.2653	1.369	1.3676	1.476	1.0892	1.178	0.4971	0.621	0.5158	0.686
Phosphorus	G	0.6488	0.702	0.7302	0.788	0.6299	0.681	0.4511	0.563	0.4498	0.598
Calcium : Phosphorus ratio	RCO	1.9501	2.109	1.8729	2.021	1.7294	1.871	1.102	1.376	1.1469	1.524
Potassium	G	0.7013	0.759	0.7594	0.819	0.6752	0.73	0.615	0.768	0.58	0.771
Magnesium	G	0.0665	0.072	0.0717	0.077	0.0667	0.072	0.0436	0.054	0.0324	0.043
Chloride	G	1.1031	1.193	1.0618	1.146	1.0271	1.111	0.9413	1.175	0.9489	1.261
Iron	PPM	363.0564	392.731	315.1066	340.019	331.4632	358.56	81.922	102.296	83.6827	111.234
Zinc	PPM	912.292	986.858	911.6115	983.684	912.0999	986.663	97.1399	121.299	111.4572	148.152

Copper	PPM	61.8898	66.948	60.3793	65.153	60.4789	65.423	6.4933	8.108	6.9902	9.292
Manganese	PPM	70.575	76.343	69.4399	74.93	70.1547	75.89	12.5598	15.683	10.4183	13.848
Selenium	PPM	0.3314	0.358	0.4342	0.469	0.3548	0.384	0.2785	0.348	0.2315	0.308
Iodine	PPM	4.8864	5.286	4.567	4.928	5.0786	5.494	0.8421	1.052	0.8956	1.19
Oxalate	PPM	94.367	102.08	48.717	52.569	46.717	50.536	40.7386	50.87	22.9195	30.465
Tryptophan	G	0.3148	0.341	0.3419	0.369	0.3921	0.424	0.2522	0.315	0.3632	0.483
Aspartate	G	2.6483	2.865	2.7942	3.015	2.9895	3.234	1.9488	2.433	2.6972	3.585
Threonine	G	1.1041	1.194	1.1484	1.239	1.2642	1.368	0.7687	0.96	1.0951	1.456
Serine	G	1.5575	1.685	1.3615	1.469	1.4389	1.557	1.0084	1.259	1.4483	1.925
Glutamate	G	4.5964	4.972	4.8938	5.281	5.0857	5.501	3.5165	4.391	5.0473	6.709
Glutamine	G	0	0	0	0	0	0	0	0	0	0
Glycine	G	2.0448	2.212	2.1204	2.288	1.7474	1.89	0.9555	1.193	1.3579	1.805
Alanine	G	1.7294	1.871	1.853	1.999	1.8286	1.978	1.1415	1.425	1.6648	2.213
Valine	G	1.5924	1.723	1.5694	1.693	1.7129	1.853	1.1491	1.435	1.6721	2.223
Isoleucine	G	1.1412	1.234	1.2203	1.317	1.3912	1.505	0.8552	1.068	1.2211	1.623
Leucine	G	2.2266	2.409	2.2867	2.467	2.5186	2.724	1.644	2.053	2.3884	3.175
Tyrosine	G	1.1244	1.216	1.1527	1.244	1.2664	1.37	0.9053	1.13	1.3789	1.833
Phenylalanine	G	1.4102	1.525	1.4042	1.515	1.5122	1.636	1.0597	1.323	1.5364	2.042
Lysine	G	1.4166	1.532	1.6994	1.834	2.0039	2.168	1.0214	1.275	1.3138	1.746
Histidine	G	0.6379	0.69	0.7253	0.783	0.7986	0.864	0.5026	0.628	0.7101	0.944
Arginine	G	2.2853	2.472	2.3789	2.567	2.4471	2.647	1.6521	2.063	2.3509	3.125
Proline	G	1.6824	1.82	1.6316	1.761	1.4842	1.606	0.8985	1.122	1.3021	1.731
Cystine	G	0.4996	0.54	0.4061	0.438	0.4746	0.513	0.3471	0.433	0.4995	0.664
Methionine	G	0.5792	0.627	0.6786	0.732	0.786	0.85	0.4677	0.584	0.706	0.938
Taurine	PPM	1499.999	1622.601	1393.3323	1503.49	1199.999	1298.098	1100.049	1373.634	1150.399	1529.145
Carnitine	PPM	13.8628	14.996	19	20.502	11.8933	12.866	4.2834	5.349	6.439	8.559
Hydroxyproline	G	0	0	0.482	0.52	0	0	0.285	0.356	0.4284	0.569
Choline	PPM	11846.4925	12814.763	12043.895	12996.093	12185.2783	13181.411	9505.8757	11870.015	9312.827	12378.893

Vitamin A	IU K	58949.445	63767.666	12878.81	13897.017	13030.41	14095.631	25844.2755	32271.822	25887.8848	34410.965
Vitamin D	IU K	3515.23	3802.547	758.94	818.942	758.94	820.982	1560.9015	1949.102	1582.552	2103.576
Vitamin E	IU K	386.1265	417.686	92.9628	100.312	95.684	103.506	177.4622	221.598	177.8632	236.421
Vitamin K	PPM	0	0	0	0	0	0	0	0	0	0
Vitamin C	PPM	506.988	548.427	121.864	131.499	137.464	148.702	225.328	281.368	225.328	299.513
Thiamine	PPM	139.7189	151.139	32.3771	34.937	32.4377	35.089	62.8796	78.518	62.0904	82.532
Riboflavin	PPM	34.752	37.592	8.5345	9.209	7.9785	8.631	14.8269	18.514	14.9303	19.846
Pantothenic Acid	PPM	52.8396	57.158	16.5534	17.862	15.7914	17.082	26.3814	32.943	26.0899	34.679
Folic Acid	PPM	8.422	9.11	2.1051	2.272	2.0274	2.193	3.7614	4.697	3.7924	5.041
Niacin	PPM	515.9529	558.124	148.3856	160.117	137.0336	148.236	230.7659	288.158	228.4861	303.711
Pyridoxine	PPM	27.8661	30.144	8.1095	8.751	8.7955	9.515	13.0323	16.273	12.4826	16.592
Biotin	PPM	0.9391	1.016	0.3045	0.329	0.3045	0.329	0.3755	0.469	0.3822	0.508
Vitamin B12	PPM	0.3846	0.416	0.082	0.088	0.0746	0.081	0.1474	0.184	0.1491	0.198
C14:0 Myristic Acid	G	0.02	0.022	0.0361	0.039	0.0359	0.039	0.0212	0.026	0.0271	0.036
C16:0 Palmitic Acid	G	1.6715	1.808	1.5504	1.673	1.5614	1.689	0.9682	1.209	1.1107	1.476
C16:1 Palmitoleic Acid	G	0.2382	0.258	0.1816	0.196	0.1836	0.199	0.0183	0.023	0.0278	0.037
C17:0 Margaric Acid	G	0.0085	0.009	0.0085	0.009	0.0085	0.009	0.0045	0.006	0.0045	0.006
C17:1 Margaroleic Acid	G	0.0045	0.005	0.0045	0.005	0.0045	0.005	0.0025	0.003	0.0025	0.003

C18:0 Stearic Acid	G	0.4747	0.513	0.4435	0.479	0.4663	0.504	0.26	0.325	0.2919	0.388
C18:1 Oleic Acid	G	2.8817	3.117	2.7168	2.932	2.8768	3.112	3.87	4.832	5.0977	6.776
C18:2n6 Linoleic Acid	G	3.6735	3.974	3.4799	3.755	3.5692	3.861	3.449	4.307	3.7027	4.922
C18:3n3 a-Linolenic Acid	G	0.3907	0.423	0.3844	0.415	0.3882	0.42	0.3859	0.482	0.3908	0.519
C18:4n3 Stearidonic	G	0.006	0.006	0.002	0.002	0.004	0.004	0.002	0.002	0.002	0.003
C20:0 Arachidic Acid	G	0.0303	0.033	0.0283	0.031	0.0283	0.031	0.0272	0.034	0.0345	0.046
C20:1 Gadoleic Acid	G	0.0527	0.057	0.0488	0.053	0.0485	0.052	0.0361	0.045	0.0413	0.055
C20:2n6	G	0.0102	0.011	0.006	0.006	0.008	0.009	0.0052	0.006	0.0068	0.009
C20:3n3	G	0	0	0	0	0.002	0.002	0	0	0	0
C20:3n6 DHGLA	G	0.0137	0.015	0.0095	0.01	0.0155	0.017	0.0068	0.008	0.0101	0.013
C20:4n6 Arachidonic Acid	G	0.0609	0.066	0.0471	0.051	0.0911	0.099	0.0185	0.023	0.0321	0.043
C20:4n3 Eicossatetra acid	G	0	0	0	0	0	0	0.002	0.002	0.003	0.004
C20:5n3 EPA	G	0.003	0.003	0	0	0.004	0.004	0.0014	0.002	0.0021	0.003
C21:5n3	G	0.002	0.002	0.002	0.002	0.002	0.002	0.0032	0.004	0.0038	0.005
C22:0 Behenic Acid	G	0.0271	0.029	0.0231	0.025	0.0211	0.023	0.0213	0.027	0.0248	0.033
C22:1 Erucic Acid	G	0.0066	0.007	0.0066	0.007	0.0046	0.005	0.0048	0.006	0.0078	0.01
C22:2n6	G	0.0028	0.003	0.0008	0.001	0.0008	0.001	0.0008	0.001	0.0008	0.001
C22:4n6 Docosatetra Acid	G	0.0138	0.015	0.0106	0.011	0.0226	0.024	0.0047	0.006	0.0079	0.011
C22:5n3 DPA	G	0.0034	0.004	0.0034	0.004	0.0074	0.008	0.0063	0.008	0.0088	0.012

C22:5n6	G	0.003	0.003	0.002	0.002	0.0027	0.003	0.008	0.01	0.012	0.016
C22:6n3 DHA	G	0.004	0.004	0.002	0.002	0.006	0.006	0.0012	0.001	0.0018	0.002
AAFCO N6:N3 fatty acid ratio	RCO	9.389	10.156	9.1274	9.849	9.1917	9.943	8.9243	11.144	9.462	12.577

Table 3.2: Experimental Formula Comparison

Ingredient	PBPM	CM	DC	FC	FCPM
Poultry By-Product Meal	20.0000				
Chicken Meal		20.0000			
Chicken Dried			20.0000		
Chicken, MDM				20.0000	30.0800
Brewers Rice	28.9500	29.3000	28.3000	29.0800	15.0000
Yellow Split Peas, Toll Milled	15.0000	15.0000	15.0000	15.0000	5.0000
Rice Protein Concentrate Powder	15.0000	15.0000	15.0000	15.0000	29.0000
Powdered Cellulose	10.0000	10.0000	10.0000	10.0000	10.0000
Soybean Oil	5.0000	5.0000	5.0000	5.0000	5.0000
Choline chloride, dry	2.5000	2.5000	2.5000	2.0000	2.0000
Mineral Premix	1.0000	1.0000	1.0000		
Potassium citrate	1.0000	1.0000	1.0000	1.0000	1.0000
Sodium chloride	1.0000	1.0000	1.0000	1.0000	1.0000
Vitamin Premix	0.4500	0.1000	0.1000	0.2000	0.2000
Taurine	0.1000	0.1000	0.1000	0.1000	0.1000
Dicalcium phosphate			1.0000	1.6000	1.6000
Mineral premix				0.0200	0.0200
Total Components	100.0000	100.0000	100.0000	100.0000	100.0000
Theoretical Yield	98.345	98.588	98.344	85.153	80.034

Chicken Variable Ingredient Specification Definitions

Each of the chicken ingredients meet their corresponding namer for ingredient labeling. In addition, each ingredient meets their ingredient definition that specifies acceptable contents. Poultry By-Product Meal is the material obtained by grinding, rendering and pressing of clean parts of the carcasses of slaughtered chicken, including heads, feet, undeveloped eggs, gizzards, and viscera, exclusive of feathers and intestinal contents except as contained within the viscera. It shall not contain the carcasses of other animals. Chicken Meal is a dry rendered product from a combination of clean flesh and skin with or without accompanying bone, derived from the parts of whole carcasses of chicken or a combination thereof, exclusive of feathers, heads, feet, and entrails. Dried Chicken is a clean combination of flesh and skin, with or without accompanying bone, derived from the parts or whole carcasses of slaughtered poultry (or a combination thereof), exclusive of feathers (except as unavoidable in good processing practices), heads, feet, and viscera and preserved with a natural antioxidant. Material from which water or other liquid has been removed where the ingredient is not nutritionally altered from the original. Fresh chicken is 100% chicken product produced by the grinding and chilling of breast frames and other chicken parts. The raw ingredient mix consists of other parts such as backs, necks, carcasses (frames with back attached), and skin.

Formula Production

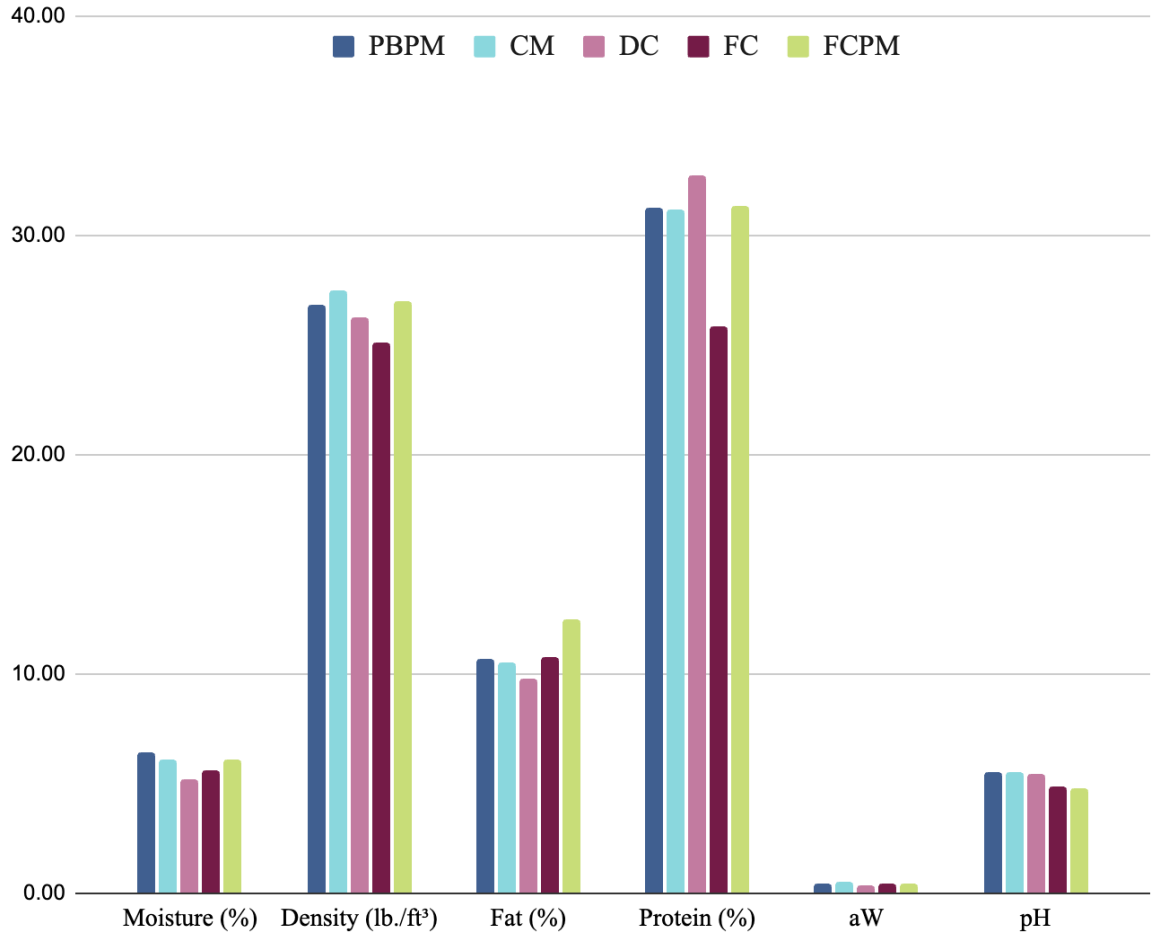
All five experimental formulas were produced at the Experimental Food Lab at Hill's Pet Nutrition Center in Topeka, KS, USA. A ribbon blender (Wenger Mfg., Sabetha, KS, USA) was used to mix all of the weighed dry ingredients in the feeder and delivery system. After five minutes of mixing, the dry ingredients passed through a hammer mill (Jacobs Corporation, Harlan, IA, USA) to be ground to size (No. 16 mesh sieve). Once homogeneous, the dry ingredients were placed into a bin that was taken to the preconditioner (Wenger Mfg., Sabetha,

KS, USA). The dry ingredients were introduced into the preconditioner at a feed rate of 14-14.5 lb./min. While in the precondition stage, steam, choline chloride, and lactic acid were incorporated with the dry ingredients and mixed with paddles at 235-240 rpm. The target temperature prior to exiting the preconditioner was 185°F. The extruder is a single screw extruder (Model X-85; Wenger Mfg., Sabetha, KS, USA) that features a common medium shear pet food screw profile that utilized a 0.201 diameter die. Following extrusion, the pet food was conveyed through a dual pass dryer (AeroDry; Buhler Aeroglide, Cary, NC, USA) which maintained a temperature of 150-155°F to maintain a final moisture target of 6.0% +/- 1% moisture on an As Is Basis. Once the kibbles were dry and cooled to ambient temperature, they were packaged in poly-lined 15lb plastic bags with a non-vented 25mm Press-to-Close (PTC) tear notch closure, the bags were then passed through a metal detector and stored in ambient conditions until opened for scheduled testing.

Kibble Analysis

Through near-infrared light spectroscopy (NIR; Foss NIRS DS2500, Eden Prairie, MN, USA), each of the five experimental formulas were analyzed for moisture, fat, and crude protein periodically throughout production. Once the production team obtained consistent target levels for moisture, fat, and crude protein, the product was collected. During production, the bulk density target was 33 lb/ft³ and samples were analyzed at regular periods. Bulk density resulted in an average of 26.5 lb/ft³ across all formulas with a low of 25.12 lb/ft³ for the FC formula and a high of 27.52 lb/ft³ for the CM formula. The production crew maintained a bulk density of 26 lb/ft³ +/- 2 lb/ft³ which was below target density and remained consistent across all five formulas.

Figure 3.1: Finished Product Kibble Analysis



Following production, twenty kibbles from each formula were analyzed for texture and measured for diameter, cut length, and weight. Measurements for diameter, cut length, and weight were measured using digital calipers (Mitutoyo ABSOLUTE A500-171, Aurora, IL, USA) in millimeters. An analytical scale (Ohaus Explorer Scales, Pleasant Prairie, WI, USA) was used to measure weight in grams. Water activity was measured using a water activity meter (Aqua Lab 4TEV, Pullman, WA, USA). The pH was measured with a probe (VWR Symphony SP70P, Radnor, PA, USA). The kibbles were then evaluated for hardness using a TA.XT Plus

Texture Analyzer (Texture Technologies Corporation, Hamilton, MA, USA) outfitted with a50kg load cell. During this test, a compression test was conducted using a 25mm cylindrical probe at a pre-test speed of 2 mm/s, a test speed of 1 mm/s, a post-test speed of 10 mm/s with 50% strain level. Upon the initial peak fracture occurred during the hardness evaluation, force was measured in kilograms.

Palatability Protocol

For this study, a two-bowl test will be conducted over two days for each comparison. Mitigation of "side bias" will be accomplished by switching the offering side between days. This study uses a trained feline panel located at the Hill's Pet Nutrition Center (Topeka, KS, USA). All feline use was approved by the Institution of Animal Care and Use Committee, Hill's Pet Nutrition Center (Topeka, KS, USA) (Hill's IACUC #CP26/permit number: 590). Five panels of 25 trained cats (mostly domestic short-haired cats) which were randomly divided by sex, participated in the palatability testing. Each feline has a pre-established caloric intake based on their current/optimal weight. During the two-bowl study, each of the two-bowls are measured with designating feeding scales to monitor caloric intake, and they are presented simultaneously to each cat. The test and control bowls were swapped on the second day of testing to avoid side bias. The weight of the bowls was monitored throughout the feedings to evaluate the consumption rate. After feeding was completed, the weight of each bowl was recorded. Following the end of the study, the intake ratio (IR) was calculated and the bowl with the most food consumed between the two was considered preferred. The Intake Ratio is defined as (Test Food Consumed) / (Test + Control Food Consumed.)

Statistical Analysis

Kibble measurements were taken for kibble cut length, kibble diameter, and kibble weight as fixed variables. The standards used for texture analysis are based on kibble hardness. All means determined were separated using Fisher's Least Significant Difference (LSD) with a significance level of ($\alpha = 0.05$). LSDs are present and accompanied by superscript letters that determine a ($p<0.05$) difference between samples.

Food consumption for the palatability equivalency testing was measured using the Intake Ratio. A t-test was used to identify the results of the overall palatability panel. First bite data was utilized for the Chi2 test. Additionally, a p-value of <0.05 showed that the IR for that test was either greater than or less than 0.50, with a 95% confidence interval of statistical certainty (Vondran 2013).

Stool Quality Assessment Procedure

Stool quality was measured using Grade 1 being the lowest quality stool and Grade 5 being the highest ideal quality stool. A Grade 1 stool would resemble feces that have lost solid form, watery diarrhea, and >75% of the stool is liquid. A Grade 5 stool would hold a cylindrical shape, >90% of the stool is firm, and is consistently segmented throughout the singular stool. The stool score grading system utilizes internal standards (Hill's Pet Nutrition, Topeka, KS) to identify stool characteristics. A stool score ≥ 3.0 is relatively acceptable; however, a score of ≥ 4.0 is most desired. Stool will be collected on days 11-15 of the digest study.

Digest Calculations

Apparent dry matter digestibility measures the percentage of kibble (Dry Matter Basis) that is absorbed by the feline and not excreted. Apparent dry matter digestibility is calculated by subtracting the mean fecal dry matter excreted from the mean dry matter intake, dividing that value by the mean dry matter intake and multiplying by 100.

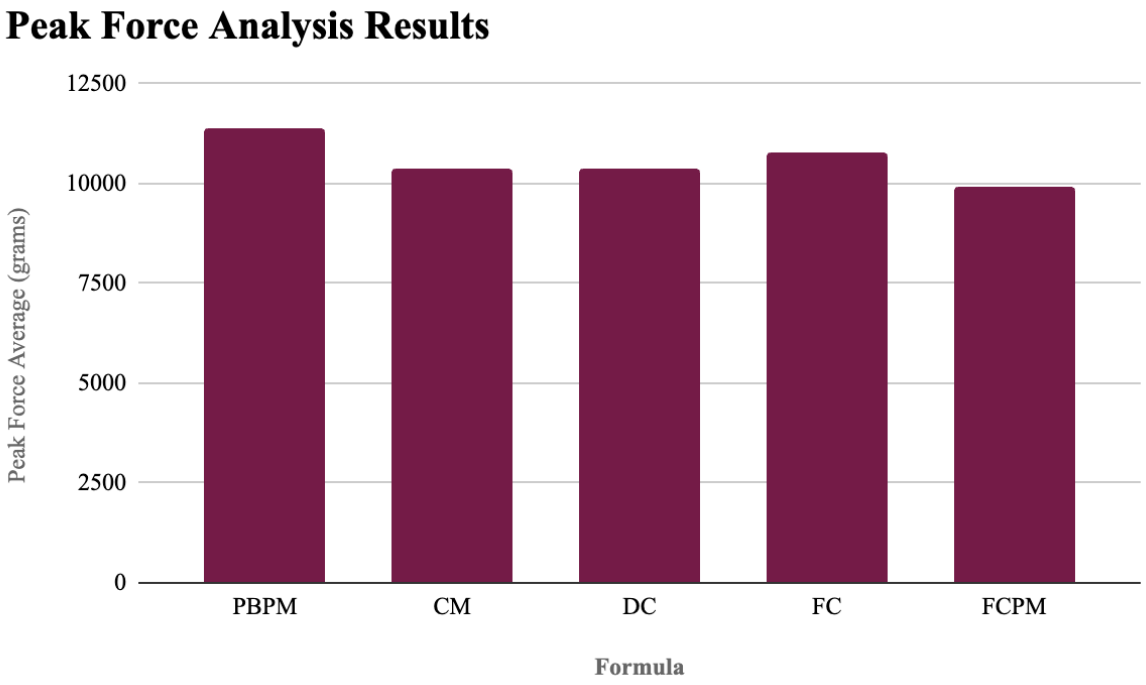
Results and Discussion

Physiochemical Kibble Analysis

Bulk density resulted in an average of 26.5 lb/ft³ with a low of 27.5 lb/ft³ for the CM formula and a high of 29.2 lb/ft³ for the FC formula. The production crew maintained a bulk density of 26 lb/ft³ +/- 2 lb/ft³ which was below target density and remained consistent across all five formulas. Due to the high-moisture content of the FC ingredient, production operators were unable to meet the density target of 33 lb./ft³. Since the FC and FCPM formulas were produced approximately 24 hours prior to the other three formulas, the operators were instructed to match the following three formulas as closely as possible to the density obtained by the FC formula to maintain uniformity across all experimental formulas to the fullest extent to mitigate variability. The average water activity across all five formulas was 0.41 with the highest being 0.47 for the CM formula and a low of 0.31 for the DC formula. The average pH was 5.19 across all formulas with a high of 5.5 for the PBPM formula and a low of 4.75 for the FCPM formula. The kibbles were then evaluated for hardness using a TA.XT Plus Texture Analyzer (Texture Technologies Corporation, Hamilton, MA, USA) that utilized 50kg load cells. During this test, a compression test was conducted using a 25mm cylindrical probe at a pre-test speed of 2 mm/s, a test speed of 1 mm/s, a post-test speed of 10 mm/s with 50% strain level. Upon the initial peak fracture occurred during the hardness evaluation, force was measured in grams (Figure 3. PBPM required the highest peak force for fracture while FCPM required the least. This could be attributed to the extra fat brought in by the FCPM formula, as it contained approximately 10% additional FC compared to the rest of the chicken protein ingredients in all other formulas and maintained the highest fat percentage out of all five formulas at 12.45% fat while PBPM contained 10.67% fat in the finished product kibble. All peak fracture results measured within 1500 grams of each

other, showing very limited variability in kibble hardness. This can be attributed to kibble production consistencies while obtaining kibble moisture and density measurements throughout processing.

Figure 3.2: Peak Force Fracture Analysis



Finished product of each of the formulas was evaluated for 46 analytes (Appendix B).

Table 3.3: Analyzed finished product results for all five experimental formulas

Analyte	PBPM	CM	DC	FC	FCPM
Moisture (%)	5.58	5.48	5.45	5.45	5.28
Crude Fat (%)	10.34	10.57	10.43	11.18	12.93
Crude Protein (%)	32.44	32.63	33.94	25.63	32.63
Ash (%)	4.95	6.31	5.48	4.86	5.0
Crude Fiber (%)	7.40	6.2	7.2	7.7	9.3

Palatability

The results of the palatability study are summarized in Table 3. PBPM presented the highest positive palatability results amongst all other variables, presenting a palatability win over both chicken meal and fresh chicken, as well as a parity against dried chicken and fresh chicken protein match. Dried chicken was preferred over chicken meal, but fresh chicken was preferred over dried chicken. The remainder of the variables presented parities against one another. The comparison between chicken meal and the fresh protein match formulas failed intake rates, so it was retested. Even once it was retested, intake rates did not present a significant intake ratio to validate the results. Therefore, the fresh protein match formula versus the chicken meal formula had inconclusive results. Due to the shelf-life of the kibbles, the retest results reflected an accurate interpretation of the kibbles nearly two months after the initial test for 8. These results correlate with results published by Koppel (2014) who reported a decrease in palatability of uncoated kibble over time.

Table 3.4: Feline Palatability Results

Test Number	Test Dates	Control Variable	Test Variable	Result
1	05/03/26-05/04/26	Dried Chicken	Poultry BPM	Parity
2	05/01/26-05/02/26	Chicken Meal	Poultry BPM	Test win
3	05/03/26-05/04/26	Fresh Chicken	Poultry BPM	Test win
4	05/09/26-05/10/26	Fresh Chicken Protein Match	Poultry BPM	Parity
5	05/03/26-05/04/26	Chicken Meal	Dried Chicken	Test win
6	05/09/26-05/10/26	Fresh Chicken	Dried Chicken	Parity
7	05/03/26-05/04/26	Fresh Chicken	Chicken Meal	Control win
8	First: 05/03/26-05/04/26 Second: 06/28/26-06/29/26	Fresh Chicken Protein Match	Chicken Meal	invalid results due to low intake
9	05/01/26-05/02/26	Fresh Chicken Protein Match	Fresh Chicken	Parity
10	04/29/26-04/30/26	Dried Chicken	Fresh Chicken Protein Match	Parity

Table 3.5: Palatability Intake Ratio Results for PBPM v. DC, CM, FC and FCPM

Control Variable	Test Variable	Intake Ratio	p-value
Dried Chicken	Poultry By-Product Meal	0.587	0.1289
Chicken Meal	Poultry By-Product Meal	0.836	0.0002
Fresh Chicken	Poultry By-Product Meal	0.621	0.0708
Fresh Chicken Protein Match	Poultry By-Product Meal	0.599	0.1462

*p-value is 2-tailed

These results are consistent with results seen in *Effects of different chicken protein sources on palatability in dry adult dog food* where a dry chicken by-product meal (CBPM) formula was tested for canine palatability against DC, CM, and FC (14%) and FC (25%) formulas. The results of this study showed that the CBPM was preferred over FC (14%), FC (25%), and DC formulas (Shields et al., 2023).

Digest and Stool Quality

FC and FCPM shared the highest quality stool rating of 5.0/5.0 while CM presented the lowest stool quality of 4.6/5.0, which is still a very well-accepted stool score. All experimental formulas were comparable to each other for Apparent Dry Matter Digestibility with values +/- 2.7% for each of the two categories. This was anticipated due to the processing parameters and uniformity of the formulas, as well as the nature of the chicken-based protein ingredients containing comparable nutrients. PBPM reported the highest percentage of apparent dry matter digestibility.

Table 3.6: Digest Test Scores

Test Result Mean	PBPM	CM	DC	FC	FCPM
Apparent Dry Matter Digestibility (%)	76.9	75.1	76.2	74.7	74.2
Apparent Protein Digestibility (%)	85.3	80	86.4	83.1	85.8

Table 3.7: Stool Quality Results

Formula	Mean	Standard Deviation	Minimum	Maximum	Count
PBPM	4.79	0.49	3	5	29
CM	4.25	0.79	3	5	24
DC	4.58	0.72	3	5	31
FC	5	0	5	5	29
FCPM	5	0	5	5	32

Conclusion

For feline palatability testing, there was no significant difference between DC versus PBPM, FCPM versus PBPM, DC versus FC, FC versus FCPM, and DC versus FCPM. There was a significant difference between the following; PBPM won against CM and FC. DC won against CM and CM won against FC. Altogether, the most palatability wins were reflected by the PBPM. Digestion test results reflected the difference in formulas accurately and with stool quality scores were highly acceptable based on internal scoring standards with all stool scores above 4.6 on a 5.0 grading scale.

Chapter 4 - Consumer Acceptance and Descriptive Sensory Analysis of Chicken Protein Sources in Dry Feline Kibble

Abstract

Of the animal protein sources used in pet food formulations, chicken has the smallest carbon footprint from a sustainability perspective, but there is a large difference in the footprint, depending on type of chicken protein source used (Knight and Satchell, 2021). Consumer acceptance studies were used to determine the overall acceptance of a product determined by every day, untrained users. For this study, the purpose is to determine the influence of different chicken protein sources on consumer acceptance and likeness. Since consumers are only able to make decisions based on extrinsic information that is available to them, it is important to understand the drivers that influence the choice to purchase one dry feline food product over another (Ai 2025). The kibble must be accepted by the cat; however, the pet parent must also trust and prefer the product that they are choosing for their pet. Influential factors for choice include nutrient quality, ingredient sustainability, ingredient quality, formula flavor, and life stage variables (Ai 2025). The results of this study support that a deeper, more comprehensive understanding of ingredient definitions may encourage support of poultry by-product meal.

Introduction

Consumer acceptance and likeness are a prominent driver for pet food purchasers. In this study, cat-owners who are the sole-purchasers or are responsible for purchasing more than 50% of the dry feline food for their household will be referred to as ‘consumers.’ A consumer acceptance panel was conducted to evaluate the likeness and acceptability of each of the five experimental formulas (n=109). Seven trained sensory panelists will also evaluate descriptive aroma and appearance attributes. Lasty, qualitative analysis was conducted using gas

chromatography-mass spectrometry (GC-MS) with the headspace solid-phase microextraction (SPME) method on all five experimental formulas to further identify volatile compounds that potentially correlate with results from both sensory evaluations. Fourteen compounds as well as the internal standard, Thujone, were identified using the highest probability (≥75%) and highest intensity scoring of each compound present in each of the five formula samples. Utilizing results from the consumer acceptance panel, trained descriptive panel and GC-MS will allow for recognition of relative drivers for consumer acceptance and likeness and drivers for consumer rejection for dry feline kibble.

Materials and Methods

Samples

All five experimental chicken formulas use four different chicken protein variables; poultry by-product meal (PBPM), chicken meal (CM), dried chicken (DC), fresh chicken recognized as mechanically deboned meat (FC) and fresh chicken-protein match (FCPM). All five formulas were produced at the Experimental Food Laboratory (EFL) at Hill's Pet Nutrition Center in Topeka, KS, USA. Four of the formulas included the chicken variable at 20% (PBPM, CM, DC and FC). In the Consumer Acceptance study, FC was referred to as "Fresh Chicken Moderate Inclusion" and FCPM was referred to as "Fresh Chicken High Inclusion" to be easily interpreted by the participants, mitigating any kind of misinterpretation. The FCPM formula contained fresh chicken at a 27% inclusion rate with an approximate additional 10% rice protein concentrate to accommodate a 33% crude protein content on a dry matter basis in the overall formula to remain comparable to the poultry by-product meal, chicken meal and dried chicken formulas which contain approximately 33-35% crude protein on a dry matter basis. For the fresh chicken formula with a 20% inclusion rate, the dry matter basis protein content was only

approximately 25%. Each formula maintained a target moisture of 6.0% +/- 1.0% on an as is basis. All five experimental formulas were formulated to meet AAFCO (2026) feline maintenance nutritional requirements (Appendix A).

Descriptive Sensory Analysis

Seven highly trained panelists from the Hill's Pet Nutrition Center, Topeka, KS, analyzed the five feline formulas for aroma and appearance characteristics. Each of the seven panelists contributed to the development of a 16-attribute Lexicon for dry kibbles. A Lexicon is a set of pre-determined attributes developed by highly trained panelists for describing the sensory attributes present in a product. Prior to testing, the trained panelists evaluate a calibration standard sample to standardize their responses using the modified consensus method when evaluating the test samples. The panelists evaluated each of the five experimental formulas (n=5; PBPM, CM, DC, FC, and FCPM). A list of attributes used from the developed lexicon was utilized to identify the sensory notes present in each of the samples (Table 14). Aroma intensity and physical appearance attributes were quantified using a 0-15 hedonic scale featuring 0.5 increments where 0 = none and 15 = very high. Appearance was also analyzed for color uniformity, size and shape using a 0-15 hedonic scale featuring 0.5 increments where 0 = none and 15 = very high including lexicon references (Table 14). Red Jade (Pleasant Hill, CA, USA) software was used to collect data for the descriptive panel. Each of the experimental formula samples were presented to the panelists in 5.5 oz glass brandy snifter glasses covered with a watch glass lid cover. Each glass contained approximately 20 grams of the sample. Each sample variant was assigned to a designated three-digit randomized sample number and was prepared less than three hours prior to the start of testing. Each panelist was provided with one glass containing each sample. The study took place in a well-lit room with neutral lighting, which was

quiet and free of any distracting outside variables. The list of aroma attributes that were evaluated included: overall aroma intensity, barnyard, smoky, cardboard, oxidized oil, fatty, fishy, grain, hay-like, vegetable complex, meaty, sour, pungent, sweet, spice brown, toasted, and earthy. The appearance attributes evaluated consisted of: lack of fine, lack of surface damage, lack of kibble speckles, color uniformity, shape uniformity, size uniformity, surface shine, fibrous, brown color and brown color Y/N ("Is this kibble brown?"). Quantitative Descriptive Analysis was used to determine the aroma attributes. The data from the Trained Descriptive panel was analyzed using the Red Jade software. A statistical significance was defined as $P < 0.05$. Data was analyzed using Analysis of Variance (ANOVA) as well as the statistical post-hoc Duncan's Multiple Range Test (DMRT) to determine which specific group means differ significantly.

Consumer Acceptance Sensory Analysis

All human sensory research was approved by the Institutional Review Board for Protection of Human Subjects (IRB #10608) at Kansas State University. A Consumer Study was conducted with the Sensory Analysis Center at Kansas State University-Olathe, Olathe, KS, to analyze feline owners' acceptance of the five experimental formulas. The study included 109 consumers (feline owners) who were familiar with dry feline food products. These participants were recruited from the Olathe, Kansas, area. Recruitment was conducted through the Sensory Analysis Center database used at Kansas State University-Olathe. Participants must have met predefined standards, and we pre-evaluated by a pre-test screening. Consumers must be at least 18 years old, own at least one cat, and must be the sole person or share at least 50% or more purchasing responsibility for dry cat food. Demographics were measured using the Check-All-That-Apply (CATA) method. CATA percentages may not equal 100%.

Table 4.1: CATA Demographics Summary (n=109)

Feline Age	
Kitten (0-12 months)	10%
Adult (1-8 years)	67%
Senior (9 years and older)	50%
DRY Feline Food Brands	
Hill's Prescription Formula	5%
Blue Buffalo	5%
Meow Mix	6%
Purina Pro Plan	14%
Friskies	6%
Hill's Science Formula	16%
Fancy Feast	1%
Purina Cat Chow	18%
Purina Kitten Chow	1%
Iams	14%
Other Brand (specify)	15%
Change Brands	
Once a month	1%
Once every 2 to 6 months	9%
Once a year	8%
Less than once a year	37%
I never change cat food brands	45%
Primary Shopper	
I do all of the purchasing	81%
I do more than half the purchasing	17%
I do half the purchasing	1%
I do less than half the purchasing	1%
I do not do any of the purchasing	0%
Most Important Factors (PI)	
Nutrition	75%
Ingredient Statement	52%
Flavor	40%
Brand	29%
Vet Recommended	38%
Label	17%
Claims	9%

Marketing	2%
Life Stage	60%
Cat Size	20%
Cat Activity Level	20%
Other (please specify)	12%
Sustainability	
Environmentally Friendly	56%
Organic	12%
Biodegradable	17%
Efficient	19%
Recyclable	21%
Green	24%
Imperishable	6%
Feasible	15%
Continuous	17%
Maintain Over Time	49%
Other (please specify)	1%
None of the above	0%

Using a tablet, each consumer provided quantitative data by completing questionnaires that were administered to each participant through Compusense at Hand software (Compusense Inc., Guelph, Ontario, Canada). The questionnaire may be referenced in Appendix B. A total of four sessions took place, with approximately 27 consumers or participants for each session, totaling 109 participants. 20 males and 89 females participated in the study. The samples were provided to the consumers individually in a randomized order with each formula labeled with a corresponding randomized three-digit code. The samples were contained in translucent 4-ounce recyclable, BPA-Free, Food Grade Condiment Container cups with fastened snap-on lids made of the same material. Consumers were instructed to remove the lid and evaluate the aroma first, then they were to evaluate the appearance of the kibble. A 9-point hedonic scale was used to determine liking/acceptance questions where 1 = dislike extremely and 9 = like extremely. Participants were asked to rank the kibble samples in order from 1 = most liked to 5 = least liked.

Consumers were asked to keep each sample after receipt and evaluation so that the five samples may be ranked according to preference; first = most preferred to fifth = least preferred. Consumers performed two rankings. After the initial ranking, the chicken protein variables used in each of the kibble samples were disclosed to the participants (PBPM, CM, DC, FC, FCPM), and they were asked to re-rank the samples for a second time. This data was analyzed using XLSTAT software (version 2025.2.0.1432, Addinsoft, New York, NY, USA). Consumer liking data were evaluated via Analysis of Variance (ANOVA), and mean separations were determined using Tukey's Honestly Significant Difference (HSD) post-hoc test on least squares (LS) means ($p < 0.05$). Consumer ranking data were analyzed using the non-parametric Friedman test, followed by Nemenyi's two-tailed procedure for multiple pairwise comparisons ($p < 0.05$) to assess ranking differences based on rank sums, means, and significance groups. Products with the lowest sum of ranks and means of ranks were designated as the most preferred. For Check-All-That-Apply (CATA) questions, counts were summarized as frequency tables and evaluated.

Extraction of Volatile Compounds Through Gas Chromatography-Mass Spectrometry

Headspace-solid phase microextraction (HS-SPME) was used to sample volatile compounds across the five dry feline formulas, following similar method as described in *Characterization of the Key Aroma Compounds in Dog Foods by Gas Chromatography-Mass Spectrometry, Acceptance Test, and Preference Test*. For each formula, 2.0 g of kibble was weighed into a 20 mL autosampler vial (Wheaton, DWK Life Sciences, Millville, NJ, USA) and sealed with a screw-cap septa. All samples were analyzed in triplicate. An internal standard consisting of 50µL of thujone in methanol (Sigma-Aldrich, St. Louis, MO, USA) was added to achieve a final concentration of 5.007µg/mL of aqueous thujone solution. The vials were

incubated at 50 °C for 25 minutes with agitation at 250 rpm using an automated sample preparation system (MPS Robotic Pro, Gerstel, Linthicum Heights, MD, USA). Following incubation, a 2 cm 50/30µm divinylbenzene/carboxen/PDMS fiber (Supelco Analytical, Bellefonte, PA, USA) was exposed to the sample headspace for 30 minutes at 50 °C. Following extraction, analytes were eluted into the GC injection port at 250 °C for 6 minutes in splitless mode. Chromatographic separation and tentative identification of volatile compounds were conducted using an Agilent 7890A gas chromatograph paired with an Agilent 5977 mass spectrometer (Agilent Technologies, Santa Clara, CA, USA). Separation was performed on a DB-WAXetr column (Agilent Technologies, Inc., Santa Clara, CA, USA; 30 m x 0.25 mm x 0.25 µm film thickness). The initial oven temperature was held at 35 °C for 1 minute, increased to 230 °C at a rate of 6 °C/min, and held for 5 minutes. Compounds were tentatively identified by comparing mass spectra against the NIST 2017 library (Agilent MassHunter Qualitative Analysis). Only compounds with a spectral match probability greater than 75% and high relative intensity were selected for further analysis. Peak areas were normalized using the internal standard (Thujone), and the mean corrected intensity was calculated for each formula.

Gas Chromatography-Mass Spectrometry

The intensity of the volatile compounds was evaluated using analysis of variance (ANOVA), with Fisher's Protected Least Significant Difference (LSD) post-hoc mean separation applied to establish significant differences between samples ($p<0.05$). Partial least squares regression (PSLR) was conducted to correlate chromatographic instrumental data (X-matrix) with descriptive sensory attributes (Y-matrix). All statistical modeling, including ANOVA and PLSR, was completed using XLSTAT software (Addinsoft, New York, NY, USA). While similar volatile compounds were identified at different intensities, it remains unclear whether

these compounds contributed to the kibble aroma or influenced feline preference for the specific chicken protein ingredients.

Results

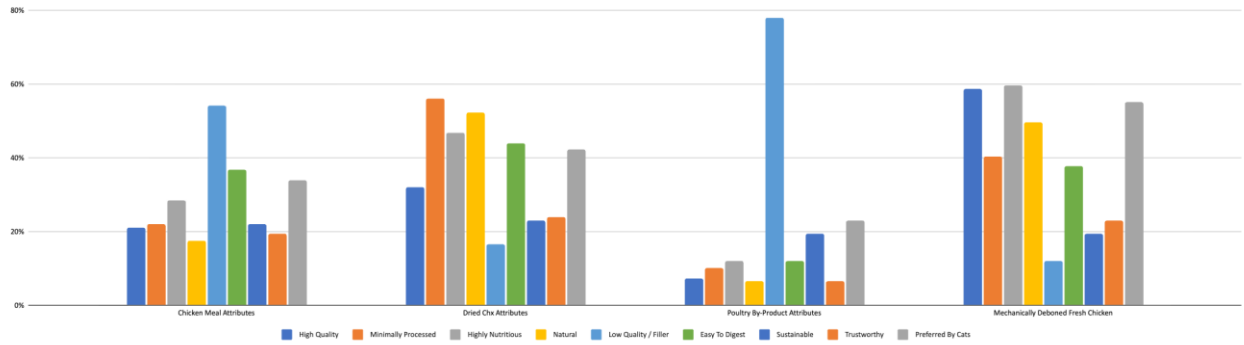
CATA Summary

The CATA summary showed a larger percentage of consumers recognized CM (54%) and PBPM (78%) as 'Low Quality or Filler.' FC was scored as 'High Quality' by 59% of consumers. 47% of consumers recognized DC as 'Highly Nutritious' as well as 'Natural' (52%). 55% of consumers stated that FC was most preferred by cats, and PBPM was least preferred by cats (23%). Scores for 'Sustainability' showed the least amount of variation. Consumers recorded their overall perception of the protein variables for 'Trustworthiness' with 24% recognizing DC as most trustworthy and PBPM the least trustworthy at 6%. Overall, consumers seem to be relatively skeptical of all four ingredients. These results directly support results from *Does quantity equal quality? Source of protein influences American dog owner purchasing decisions more than the quantity of protein in the absence of marketing claims,* which found that by-product meals are poorly perceived by consumers due to the correlated belief that by-product meals are recognized as "filler" or cheap ingredients.

Table 4.2: CATA Summary

n=109	High Quality	Minimally Processed	Highly Nutritious	Natural	Low Quality / Filler	Easy To Digest	Sustainable	Trustworthy	Preferred By Cats
CM	21%	22%	28%	17%	54%	37%	22%	19%	34%
DC	32%	56%	47%	52%	17%	44%	23%	24%	42%
PBPM	7%	10%	12%	6%	78%	12%	19%	6%	23%
FC	59%	40%	60%	50%	12%	38%	19%	23%	55%

Figure 4.1: CATA Summary Chart



Liking Results

The liking results (Table 9) show that the CM formula was most liked in a*ppearance*, *texture*, *overall* (OA) *cat liking*, and *OA liking* categories. However, the PBPM formula was most liked in *appearance*. This aligns with Sheild's (et al. 2013) where consumers also ranked dry canine kibble using chicken by-product meal as the highest in *appearance* above all other chicken protein variables. In addition, this study found that CM was the most liked for *aroma, appearance,* and *overall liking.* This supports that consumers prefer the appearance of their pet kibble to be richer and darker in color as opposed to the two FC formulas which were the lightest and lowest ranking for *appearance*. The two FC formulas (FC and FCPM) scored the lowest rating for all categories except for the 'Aroma' category in where the DC formula was recognized as the least liked.

Table 4.3: Liking Summary (LS means) Tukey (HSD) (n=109)

Category	Aroma Liking	Appearance Liking	Texture Liking	OA Cat Liking	OA LIKING
Poultry By-Product Meal	6.174 a	6.954 a	6.550 a	6.596 a	6.661 a
Chicken Meal	6.083 a	6.899 a	6.560 a	6.697 a	6.743 a
Dried Chicken	5.073 b	5.661 b	6.119 ab	5.560 b	5.550 b
Fresh Chicken at Moderate Inclusion	5.284 b	4.615 c	5.881 b	5.165 b	5.018 b
Fresh Chicken at High Inclusion	5.651 ab	4.954 c	6.064 ab	5.486 b	5.294 b
Pr > F(Model)	<0.0001	<0.0001	0.004	<0.0001	<0.0001
Significant	Yes	Yes	Yes	Yes	Yes

***Values with no shared letters represent statistical significance.*

The ranking evaluation revealed an ingredient bias amongst consumers. Prior to the ingredient disclosure to the participants, they ranked the poultry by-product meal formula first in terms of likeness followed by CM, DC, FCPM, and FC. After the ingredients were disclosed, consumers inverted their original rankings. The second round of rankings resulting in a #1 ranking of the FCPM formula above all other formulas, PBPM ranked #5 **(Table 10-11)**. When asked if disclosure of ingredient information influenced how much they liked or disliked the feline food kibbles they evaluated, 90% of participants concluded that their ranking was influenced. These results align with results seen in Shield's (et al. 2013) research on pre and post-ingredient disclosure rankings for canine kibble, which supports the poor customer's perception of meat meals and by-products consumers maintain supported by Singh's research (et al. 2026).

Table 4.4: Pre-Ingredient Disclosure Ranking

Sample	Frequency	Sum of ranks	Mean of ranks	Groups		
612 -- Poultry By-Product Meal	109	206.000	1.890	A		
417 -- Chicken Meal	109	220.000	2.018	A		
288 -- Dried Chicken	109	346.000	3.174		B	
158 -- Fresh Chicken at High Inclusion	109	421.000	3.862			C
853 -- Fresh Chicken at Moderate Inclusion	109	442.000	4.055			C

Table 4.5: Post-Ingredient Disclosure Ranking

Sample	Frequency	Sum of ranks	Mean of ranks	Groups		
158 -- Fresh Chicken at High Inclusion	109	239.000	2.193	A		
288 -- Dried Chicken	109	276.000	2.532	A		
853 -- Fresh Chicken at Moderate Inclusion	109	280.000	2.569	A		
417 -- Chicken Meal	109	356.000	3.266		B	
612 -- Poultry By-Product Meal	109	484.000	4.440			C

Descriptive Analysis

The descriptive panel identified aroma attributes; barnyard, cardboard, oxidized oil, fatty, grain, hay-like, meaty, sour, pungent, sweet, spice brown, toasted, earthy, and overall aroma intensity. The DC formula scored the highest in ‘overall’ aroma and ‘oxidized oil’ aroma. There were no significant differences between the formulas for the rest of the aroma categories. DC was also scored with the highest amount of kibble speckles out of the five formulas. CM and PBPM were scored as the darkest in color of all five formulas. There were no significant differences amongst the formulas for the rest of the physical aesthetic attributes.

Table 4.6: Mean Scores of Individual Aroma Attributes

Attribute	Overall	Barnyard	Smoky	Cardboard	Oxidized Oil	Fatty	Fishy	Grain	Hay-like	Vegetable Complex	Meaty	Sour	Pungent	Spice Sweet	Spice Brown	Spice Toasted	Spice Earthy
FCPM	**5.21bc**	0.00a	0.00a	2.36a	**0.21b**	0.64a	0.00a	1.86a	0.00a	0.00a	0.64a	0.00a	0.00a	0.07a	0.00a	1.43a	0.29a
FC	**4.14c**	0.00a	0.00a	2.71a	**0.36b**	0.57a	0.00a	1.64a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	1.50a	0.00a
CM	**6.71ab**	0.43a	0.00a	2.14a	**0.64b**	0.36a	0.00a	2.07a	0.14a	0.00a	0.71a	0.07a	0.00a	0.00a	0.36a	2.29a	0.57a
PBPM	**6.14b**	0.14a	0.00a	1.79a	**0.57b**	1.07a	0.00a	2.00a	0.43a	0.00a	0.43a	0.00a	0.00a	0.00a	0.14a	1.71a	0.29a
DC	**8.21a**	0.00a	0.00a	3.21a	**2.71a**	0.50a	0.00a	2.07a	0.57a	0.00a	0.64a	0.29a	0.64a	0.00a	0.00a	1.86a	0.14a

*** [a]Means with the same letter are not significantly different at a 95% confidence interval between products**

Figure 4.2: Kibble Aroma Attributes

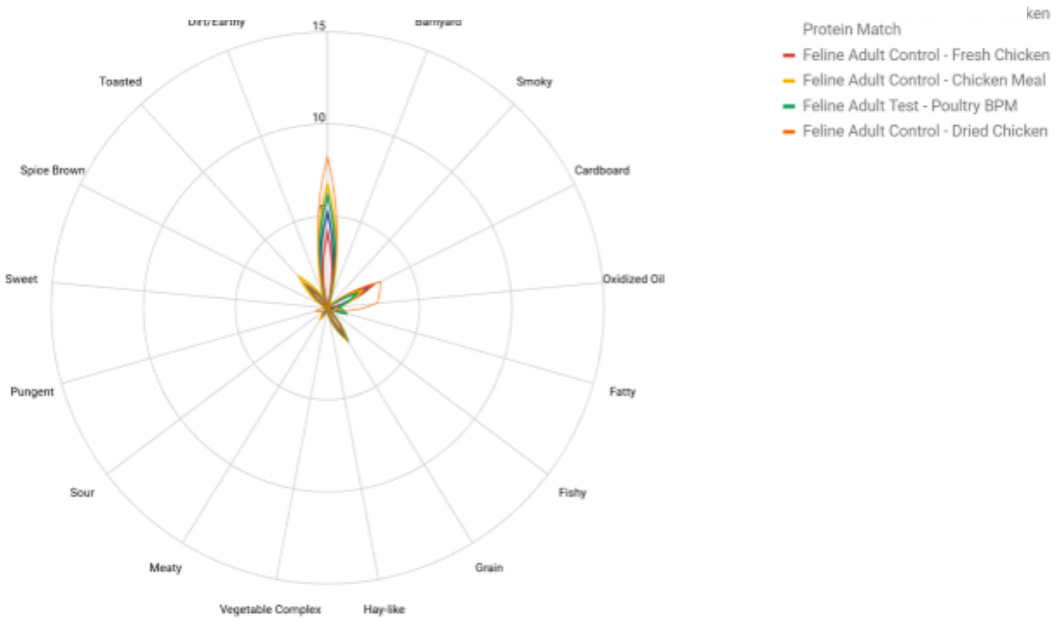


Table 4.7: Mean Scores of Kibble Physical Aesthetic Attribute

Attribute	Lack of Fines	Lack of Surface Damage	Lack of Broken Kibbles	Lack of Kibble Speckles	Color Uniformity	Shape Uniformity	Size Uniformity	Surface Shine	Fibrous	Brown Color	Brown Color Y/N
FCPM	14.43[a]	14.36[a]	14.71[a]	**14.29[a]**	14.07[a]	12.29[a]	12.79[a]	4.64[a]	14.86[a]	**1.92[b]**	100% yes
FC	14.43[a]	14.36[a]	14.86[a]	**14.43[a]**	13.86[a]	12.36[a]	12.50[a]	4.57[a]	14.93[a]	**2.29[b]**	100% yes
CM	14.50[a]	14.43[a]	14.86[a]	**13.64[ab]**	13.86[a]	12.64[a]	12.86[a]	5.57[a]	14.79[a]	**4.75[a]**	100% yes
PBPM	14.57[a]	14.21[a]	14.71[a]	**14.07[a]**	14.00[a]	12.86[a]	13.00[a]	5.71[a]	14.93[a]	**4.86[a]**	100% yes
FC	14.36[a]	14.14[a]	14.64[a]	**12.50[b]**	13.64[a]	13.00[a]	12.93[a]	4.50[a]	14.86[a]	**3.08[b]**	100% yes

*** [a]Means with the same letter are not significantly different at a 95% confidence interval between products**

Figure 4.3: Kibble Physical Aesthetic Attributes

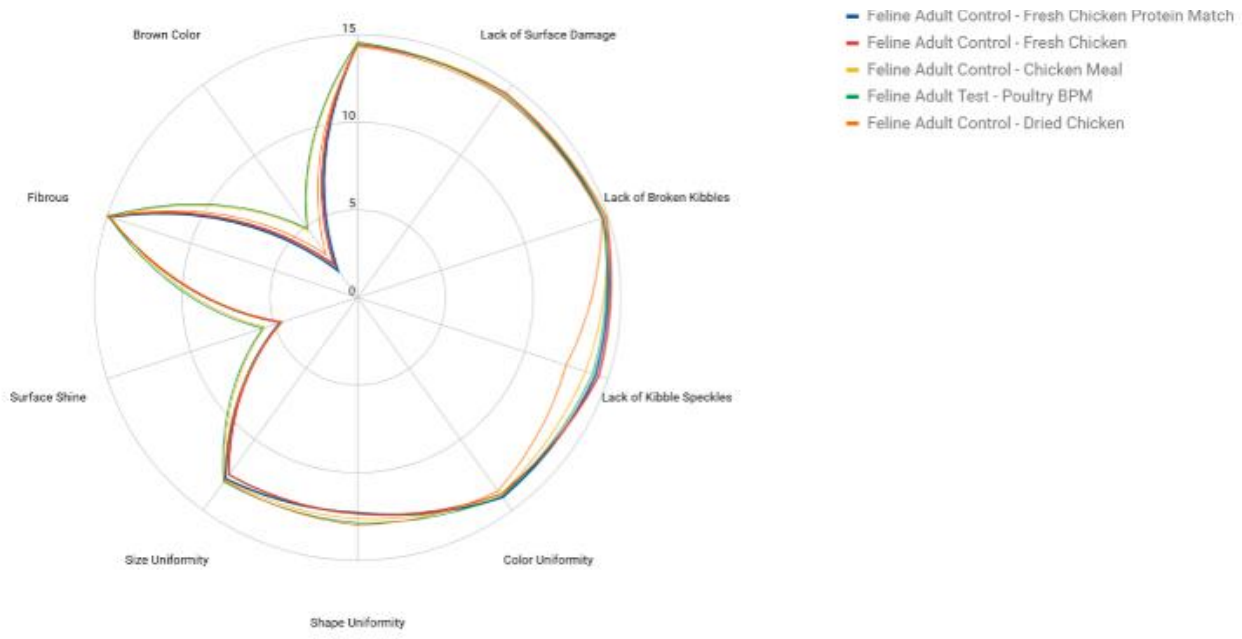


Table 4.8: Sensory Descriptive Panel Aesthetic Reference Standards

Aromas		
Attribute	**Definition**	**Reference and Intensity**
Overall	Cumulative initial aroma impression of the sample	N/A

Barnyard	Aromas associated with the smell of live animals, fecal or sweaty notes	Chicken Fat + white pepper = 10
Smoky	Aromas associated with smokey burnt or ashy notes	Wright's liquid smoke- Hickory = 13
Cardboard	Aromas associated with wet cardboard or paper	2 in cardboard = 4
Oxidized Oil	The aromatic associated with aged or highly used oil and fat	Cooked vegetable oil = 6
Fatty	Aromas associated with animal fat	Morrell Snow cap lard = 5
Fishy	Aromas associated with characteristic odors of fish and seafood	M2215 Menhaden Fish Meal = 12
Grain	Aromas associated with raw grains	Rice Chex, Wheaties, Quaker Quick Oats = 3
Hay-like	Aromatics associated with dry grasses, hay, dry parsley	Parsley = 11
Vegetable Complex	A general term to describe a combination of cooked vegetable aromatics that may include celery, carrot, potato or other vegetables	Vegetable broth = 6
Meaty	Aromas associated with gamey poultry, pork or beef products	Beef broth = 8
Sour	Aromas associated with sour substances	Buttermilk = 7
Pungent	The sharp physically penetrating sensation in the nasal cavity	Orange Essential Oil = 8
Sweet	Aromas associated with caramel, brown sugar, molasses, honey, vanilla, malt, or cocoa	Turbinado sugar = 5
Spice Brown	The aromatics commonly associated with brown spices	Allspice, clove, nutmeg, cinnamon, ginger = 14
Toasted	Aromas associated with warmed grain products	Toasted Whole Wheat Bread = 7
Earthy	Musty, aromatics associated with decaying vegetative matter and damp black soil	Potting soil = 4
Appearance		
Lack of Fines	Grains or fines on the surface.	Sour patch = 0 Ritz = 9
Lack of Surface Damage	Damage or holes on the surface.	Cheerios=7.5
Lack of Broken Kibbles	Number of kibbles which appear to be fractured	Kix = 15
Lack of Kibble Speckles	Presence of internal speckles. Speckles could be inclusions or spots in the kibble.	Goldfish = 8 Baby cheese puffs = 13
Color Uniformity	Evenness of distribution of the color, not blotchy.	Cheerios = 7 Kix = 14
Shape Uniformity	Irregular shaped pieces in a given sample.	Honeycomb = 5 Baby puffs = 12

Size Uniformity	The extent to which the kibbles in the sample have equally sized pieces. Wedge cuts and cut length differences in kibbles are examples of deficiencies in this category.	Cheetos = 2 Ritz = 15
Surface Shine	Amount of light reflected from the product's surface.	4 = 2 3 = 6 1 = 8 2 = 11 Flat = 1, Peanut = 2.5, Gloss = 13
Fibrous	The perception of visible fibers and filaments on the product	Post shredded wheat = 3
Brown Color - Y/N	Is the kibble brown ? Y- then rate brown color N- then name color	
Brown Color	Light to dark evaluation of brown color of product.	Paint samples Paint 1 = 12.0 Paint 2 = 6.0
Name color	If not brown	

Gas Chromatography-Mass Spectrometry

The identification of shared compound results was analyzed using set intersection analysis. The compounds present in at least three of the five formulas; Acetophenone, Benzaldehyde, and Propanoic acid. Compounds present in at least four of the five formulas; 1-Octanol, 1-Penten-3-ol (capitalized as 1-penten-3-ol in some tables), 2,4-di-tert-butylphenol, Decane, Dodecane, Furfural, Hexane, 1-nitro-, and Isopropyl Alcohol. Compounds present in all five of the formulas; 1-Hexanol, 1-Pentanol, 2,3-pentanedione, 2-Butanone, 2-Heptanone, 2-pentyl furan, 3-methyl butanal, 3-Octen-2-one, Acetic acid, Benzyl alcohol, Dimethyl Disulfide, Heptanal, Hexanal, Pentanal, and Thujone. The compounds found present in all five experimental formulas consisted mainly of alcohols and ketones. The compounds were sorted with a two-part verification process which included frequency grouping analysis through Python followed by an additional manual verification process. Acetophenone (ketone) and Benzaldehyde (aldehyde) were only shared amongst the formulas that excluded the FC

ingredient. These two compounds typically present sweet, fruity, almond-like notes (Liu et al., 2022). It's possible that these two compounds are responsible for those notes from the PBPM, CM, and DC that are not present in the FC ingredient.

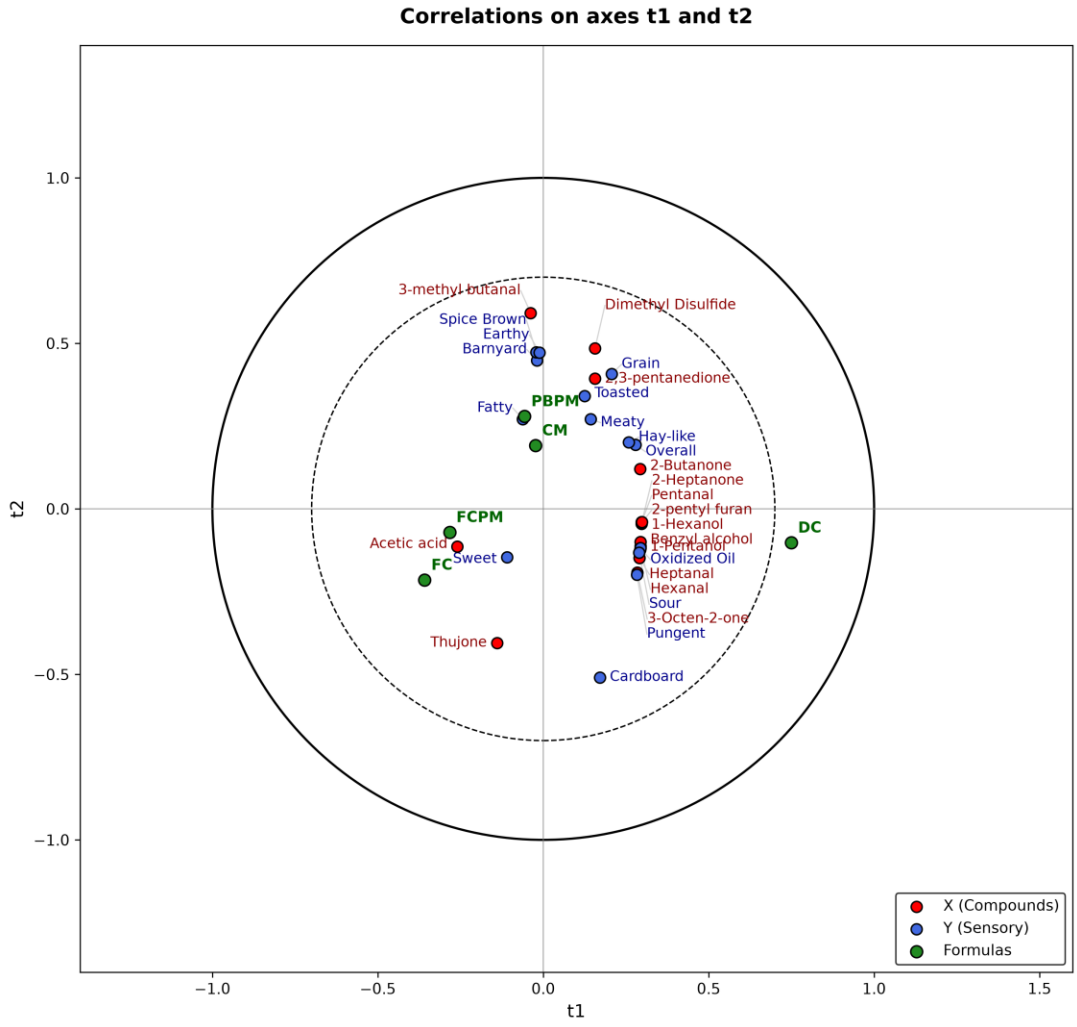
Table 4.9: Thujone Adjusted Abundance/Intensity of Compounds Detected in Experimental Formulas

Sample Formula	**PBPM**	**CM**	**DC**	**FC**	**FCPM**
Compound					
Aldehydes					
3-methyl butanal	1.2572	0.7065	0.1218	0.1244	0.2002
Organosulfurs					
Dimethyl Disulfide	0.2205	0.2590	0.2137	0.1197	0.1406
Hexanal	12.0667	10.9112	44.9132	6.1088	8.4835
Pentanal	4.4500	3.6476	12.4039	1.6145	2.1927
Alcohols					
1-Hexanol	0.1854	0.2169	0.4741	0.1054	0.1649
1-Pentanol	1.3392	1.3191	6.8385	0.5445	0.8761
Benzyl alcohol	0.1274	0.1335	0.1584	0.1243	0.1270
Heptanal	0.5046	0.5036	2.3002	0.3563	0.3572
Carboxylic Acids					
Acetic acid	8.4727	9.0248	4.4161	11.0645	14.8613
Furans					
2-pentyl furan	2.1304	3.0937	7.0669	1.1340	1.5323
Ketones					
2,3-pentanedione	1.8261	0.5850	1.2282	0.2059	0.2301
2-Butanone	1.0623	1.2028	2.1579	0.3203	0.4810
2-Heptanone	0.3233	0.4986	1.4160	0.0852	0.1436
3-Octen-2-one	0.4468	0.3458	9.6067	0.3038	0.3115
Internal Standard					
Thujone	1.0000	1.0000	1.0000	1.0000	1.0000

As mentioned in *Associations of volatile compounds with sensory aroma and flavor: the complex nature of flavor,* the main drawback of GC-MS is that no information regarding aroma of specific compounds is collected which can lead to false conclusions as chemicals change over the course of time. The FC and FCPM formulas resulted in higher levels of compounds

associated with lipid oxidization like Heptanone, 2-pentyl furan, Pentanal, 1-Hexanol, and Hexanal. These compounds can be attributed directly to the source of FC. When PBPM was compared directly with FC during the feline palatability study, PBPM was preferred by the felines. It's possible that this FC loss was due to the dense presence of compounds associated with lipid oxidation.

Figure 4.9: Partial Least Squares Regression: Dependent variable (Y): Descriptive Panel Aroma Scores, Explanatory variable (X): GC-MS Data Results. Observations: Dry Kibble Samples



Partial least squares regression (PLSR) was performed to determine the existence of a correlation between the sensory aroma attributes from the Descriptive Panel and the instrumental

data regarding compounds from the GC-MS analysis (Figure 18). Volatile compound data variation explained 74.2% of descriptive aroma data variation. The data from this analysis can be separated into two areas. The first area presented Oxidized Oil (0.293), Sour (0.290), and Pungent (0.283) with the highest positive numbers, while the volatile compound outputs 2-Heptanone (0.298), 2-pentyl furan (0.297), Pentanal (0.297), 1-Hexanol (0.297), and Hexanal (0.294) all share very similar values. It can be concluded that oxidized oil, sour, and pungent aromas can be linked to 2-Heptanone, 2-pentyl furan, Pentanal, 1-Hexanol, and Hexanal. In addition, Koppel (2013) also reported correlations between hexanal and oxidized oil aromatics in dry dog foods. These compounds (especially aldehydes like Hexanal and Pentanal and ketones like 2-Heptanone) are heavy drivers for the Oxidized Oil, Sour, and Pungent aroma attributes in the kibble samples (Koppel et al., 2013). The second area consisted of Spice Brown (0.473), Earthy (0.472), Barnyard (0.448), Grain (0.408), and Toasted (0.342) are positive. The closest plotted volatiles; 3-methyl butanal (0.592), Dimethyl Disulfide (0.485), and 2,3-pentanedione (0.394) strongly correlate with these sensory aroma attributes. 3-methyl butanal (nutty, caramelized and savory notes) and Dimethyl Disulfide (savory/meaty notes) are heavily driving the Toasted, Earthy, Spice Brown, and Barnyard sensory profiles of the kibble. (Chen et al., 2025).

Conclusion

Consumers' opinions are significantly impacted by their perception of ingredient quality and nutrition, and not necessarily the true impact an ingredient has on palatability or nutrition. When considering the results from the Pre-Ingredient Disclosure Ranking and Post-Ingredient Disclosure Ranking, it was clear that consumers retained a bias against meat by-products and meals. Given the inverted scores after revealing the ingredient variables, FC and DC rose to the

top two rankings while the products formulated with CM and PBPM dropped to the bottom two rankings. These results align with results seen in *Effects of different chicken protein sources on palatability in dry adult dog food* —as meat meals have notoriously been poorly perceived by consumers for several years (Singh 2026). Based on the CATA responses, the consumers believed that FC was most preferred by cats (55%), and PBPM was least preferred by cats (23%). However, the feline palatability results in Chapter 3 proved that the PBPM formula was most preferred by cats, while the FC formula lost to the PBPM formula when directly tested head-to-head. The DC formula scored the highest in 'overall' aroma, and 'oxidized oil' aroma. This is likely due to processing factors of the DC ingredient.

The natural volatile compounds (esters and ketones) and amino-sugar complexes that are lost during high-heat rendering processes typically used to produce chicken meal or poultry by-product meal still remain present in dried chicken due to the lower processing temperatures (AAFCO, 2026; MDPI Molecules, 2021). Since the internal cellular fat structure is maintained during dehydration, dried chicken would contain a higher concentration of reactive lipids (Kemin Nutrisurance, 2022). Due to the presence of these lipids, a higher likelihood of oxidative rancidity is possible. Oxidative rancidity is a chemical reaction where the exposure to oxygen during the extrusion process breaks down lipids into aldehydes and ketones which can present stale, metallic, and cardboard notes in a finished product (Journal of Animal Science, 2019). Due to the nature of dried chicken, additional antioxidants are required to slow down the reactions that lead to oxidative rancidity in finished products. Kibbles that utilize rendered meals such as chicken meal or poultry by-product meal may require low levels of added antioxidants, if all other factors are held equal (MDPI Animals, 2020). Even with the added antioxidants in each formula tested, consumers and trained panelists alike were able to determine an odor difference.

DC scored the highest for *abundance of kibble speckles* out of the five formulas. A high abundance of kibble speckles does not indicate the formula is better. The abundance of kibble speckles in DC could have been caused by the processing of the DC ingredient compared to the rendered meal ingredients like CM and PBPM. During the extrusion process, larger and more fibrous particles in DC do not become fully homogenous with the rest of the ingredients which can lead to a finished product with visible proteins or darker flecks caused by Maillard browning (Tran et al., 2008). CM and PBPM were scored as the darkest in color of all five formulas. High-heat rendering (120-150°C) used in meat-meal processing trigger Maillard browning that darkens the ingredient prior to extrusion (Meeker & Hamilton, 2006; van Rooijen et al., 2020). Additionally, meals contain concentrated levels of minerals and iron-rich "heme" proteins which further oxidize and deepen their color during extrusion (Bazolli et al., 2019; AAFCO, 2026). These dark pigments are homogenous throughout the CM and PBPM kibbles because they are ground into a fine, uniform powder resulting in a dark, uniform kibble, unlike the DC formula which resulted in a mottled appearance or the very light appearance of the kibbles from the FC formulas (Tran et al., 2008). The lack of significant differences amongst the other physical aesthetic attributes is complementary to the uniformity of processing parameters and finished product results of production. Overall, consumers knowingly rejected formulas that contained meat meals in terms of ranking, likeness, and acceptability. However, when considering the results from consumers' blind rankings, they preferred PBPM and CM over the other three formulas. The descriptive panel was also able to identify a significantly darker color difference for CM and PBPM when compared to the rest of the formulas, due to the present rendered fat in the meat meal ingredients. Additionally, the trained descriptive panel was able to identify a

significant difference in a stronger overall aroma for the DC formula as well as rating it the highest in oxidized oil aroma due to a higher concentration of reactive lipids.

GC-MS data supports a relationship of prominent lipid oxidization in the FC and FCPM formulas compared to the other three formulas containing PBPM, CM, and DC. It is possible that this was a contributing factor to the PBPM palatability win over the FC formula. Lastly, as a result of the PLSR analysis, 74.2% of descriptive aroma data variation was explained in correlation with the volatile compound data from GC-MS analysis. There was a strong association between Oxidized Oil aroma and from the presence of select aldehydes and ketones.

Chapter 5 - Conclusion

Poultry by-product meal is the most palatable for felines out of the other chicken protein sources, but consumers found it the least acceptable out of all other protein sources. When compared to CM and FC, felines demonstrated a significant preference for the PBPM formula. The PBPM formula delivered the highest number of palatability wins out of the 5 different formula variations tested. When asked which chicken protein ingredient consumers assumed would be most palatable for their pet cat, FC received the highest number of votes while PBPM resulted in the lowest votes. In addition, the feline palatability results showed that PBPM was the most preferred of all five experimental formulas. It's apparent that consumers perceive PBPM and CM to have poor quality or filler ingredients, as these formulas were amongst the least preferred following the consumer acceptance panel in **Chapter 3**. Consumer acceptance is heavily driven by perception of ingredient quality and nutrition, which can often contrast with an ingredient's true palatability or nutritional performance. The results from the trained descriptive panel showed that processing methods of each chicken protein ingredient directly dictate each formula's physical and sensory characteristics. Ultimately, while consumers blindly favored the performance and physical traits of rendered meal formulas, their conscious bias led them to reject those exact products once the chicken protein ingredients were disclosed. GC-MS analysis revealed specific volatile compounds across the experimental formulas, dominated primarily by alcohols and ketones. Specifically, acetophenone and benzaldehyde were uniquely present in the PBPM, CM, and DC formulas, contributing sweet, fruity, and almond-like notes that the FC formulas lacked. High concentrations of lipid oxidation contributing compounds FC formulas likely explain why felines preferred PBPM over FC during palatability testing. PLSR confirmed that volatile compound variation accounted for nearly three-quarters of the descriptive aroma

data, directly linking compounds to sensory data. Aldehydes and ketones heavily drove oxidized oil, sour, and pungent aromas, whereas compounds like 3-methyl butanal and dimethyl disulfide correlated strongly with toasted, earthy, and savory notes. Ultimately, these findings demonstrate how specific processing-derived volatiles directly dictate the primary aroma traits and palatability of pet food formulations.

Overall, these findings exhibited that PBPM delivered the highest palatbility wins, highest optimal dry matter digestibility and was preferred when blinded from pet owners. However, the post-ingredient disclosure ranking inversion supported a consumer bias against PBPM, even after previously liking PBPM. This exhibits the clear discrepancy between sensory acceptance and consumer ingredient perception. Future beneficial steps to bridge consumer bias would include transparent sustainability and nutritional education to align consumer acceptance of PBPM with objective ingredient performance.

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Appendix A - Analytical Results for Each Experimental Formulas as a Finished Product

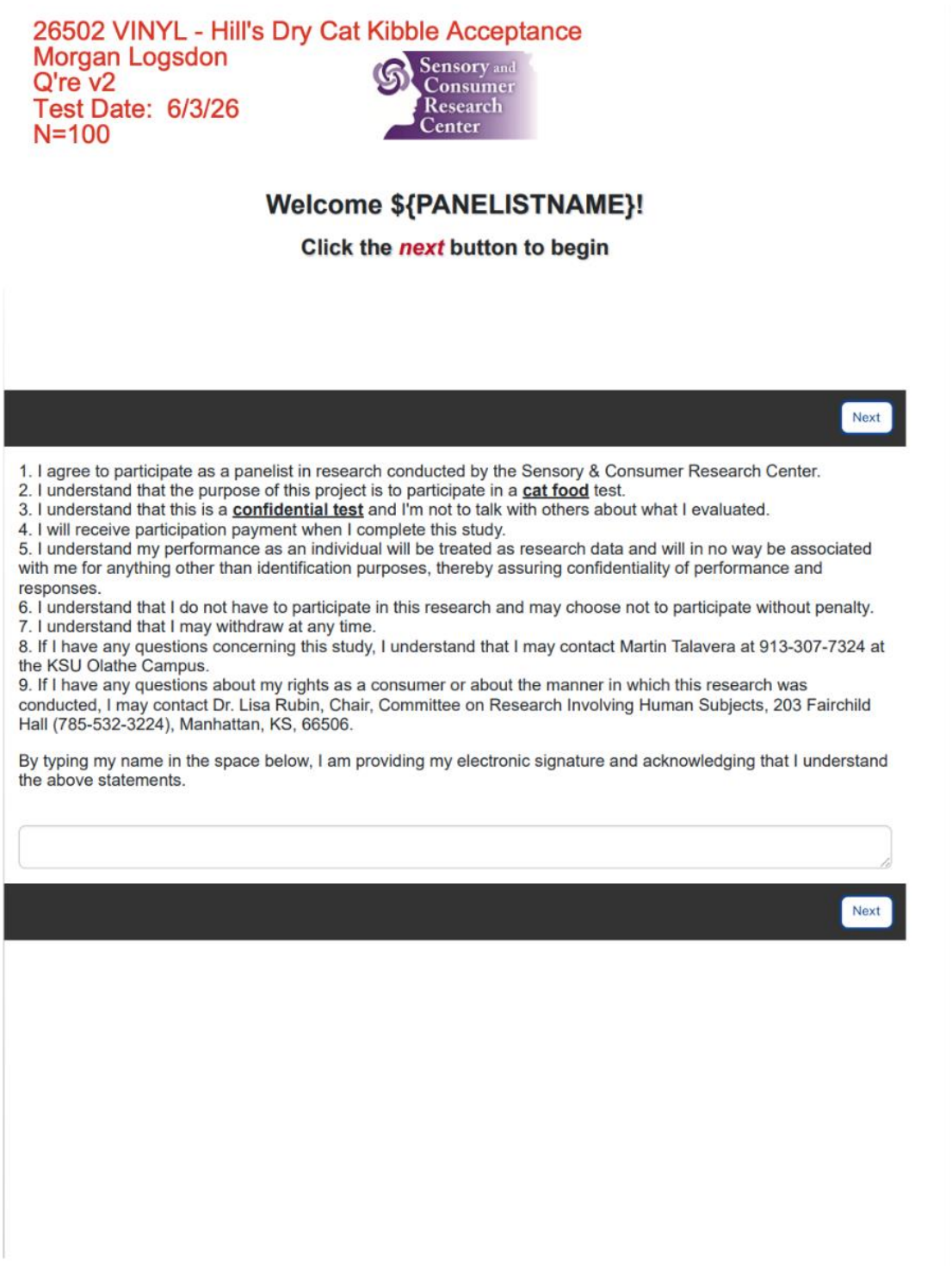
Analyte	Reported Unit	PBPM	CM	DC	FC	FCPM
Moisture	%	5.58	5.48	5.45	5.45	5.28
Crude Fat	%	10.34	10.57	10.43	11.18	12.93
Crude Protein	%	32.44	32.63	33.94	25.63	32.63
Ash	%	4.95	6.31	5.48	4.86	5
Crude Fiber	%	7.4	6.2	7.2	7.7	9.3
Fiber Insoluble	%	13.3	11.5	12.8	14	15
Fiber Total Dietary	%	14.2	12.2	13.2	15	15.6
Fiber Soluble	%	0.9	0.7	0.4	1	0.6
Total Fat as Triglycerides	%	9.8	9.63	9.36	10.37	11.98
Calories	kcal / lb	2110	2100	2130	2080	2160
Sulfur	%	0.41	0.4	0.44	0.37	0.48
Sodium	%	0.563	0.539	0.48	0.568	0.629
Calcium	%	0.725	1.32	1.07	0.63	0.748
Phosphorus	%	0.5	0.78	0.72	0.71	0.79
Potassium	%	0.82	0.8	0.75	0.79	0.69
Magnesium	%	0.071	0.08	0.079	0.066	0.055
Chloride	%	0.87	0.85	0.79	0.93	0.98
Fluoride	%	< 0.0015	0.0017	0.0021	0.0022	0.0025
Iron	%	0.0351	0.0294	0.0362	0.0137	0.0135
Zinc	ppm	904	771	903	135	141
Copper	ppm	67.8	56.9	65.3	10.4	10.5
Manganese	ppm	65.8	57.9	67.7	15.8	13.8
Selenium	ppm	0.38	0.37	0.39	0.33	0.36
Cobalt	ppm	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Tryptophan	%	0.4	0.37	0.45	0.34	0.45
Aspartic Acid	%	2.85	2.81	3.22	2.32	2.9
Threonine	%	1.19	1.17	1.38	0.9	1.16
Serine	%	1.5	1.45	1.6	1.22	1.58
Glutamic Acid	%	4.97	5.03	5.51	4.25	5.52

Glycine	%	2.05	2.22	1.83	1.22	1.6
Alanine	%	1.86	1.93	1.98	1.4	1.86
Valine	%	1.73	1.68	1.86	1.44	1.91
Isoleucine	%	1.32	1.3	1.52	1.06	1.38
Leucine	%	2.49	2.45	2.81	2.04	2.68
Tyrosine	%	0.9	1	0.94	0.66	0.98
Phenylalanine	%	1.51	1.51	1.68	1.29	1.68
Lysine	%	1.7	1.66	2.16	1.2	1.41
Histidine	%	0.73	0.72	0.88	0.62	0.79
Arginine	%	2.29	2.38	2.46	1.84	2.43
Proline	%	1.64	1.78	1.63	1.17	1.52
Cystine	%	0.45	0.4	0.46	0.39	0.5
Methionine	%	0.66	0.64	0.77	0.55	0.76
Taurine	%	0.19	0.17	0.12	0.14	0.14
Hydroxyproline	%	0.38	0.5	0.26	0.12	0.14
Choline	mg / 100 g	428	426	430	461	446
Vitamin A	IU / 100 g	4420	889	590	1860	2150
Vitamin B1 Mononitrate	ppm	148	42.9	37.1	85.7	85.4
Vitamin B2 - Riboflavin	ppm	32.5	8.7	7.5	15.9	16.4
Vitamin B5 - Pantothenic Acid	mg / 100 g	4.67	1.57	1.62	3.05	3.08
Vitamin B9 - Folic Acid	mg / 100 g	0.221	0.231	0.183	0.704	0.392
Vitamin B3 - Niacin	mg / 100 g	52.2	16.6	13.9	29.2	29.7
Vitamin B6 - Pyridoxine	mg / 100 g	2.7	0.7	0.8	1.6	1.7
Vitamin B7 - Biotin	µg / g	0.74	0.25	0.21	0.42	0.41
Vitamin B12 - Cobalamin	µg / 100 g	32.3	9.1	7.06	17.3	16.7
C08:0 Octanoic (Caprylic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C10:0 Decanoic (Capric)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C11:0 Undecanoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

C12:0 Dodecanoic (Lauric)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C14:0 Tetradecanoic (Myristic)	%	0.04	0.04	0.04	0.05	0.06
C14:1 n9c Tetradecenoic (Myristoleic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C15:0 Pentadecanoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C15:1 Pentadecenoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C16:0 Hexadecanoic (Palmitic)	%	1.61	1.63	1.5	1.75	2.17
C16:1 Hexadecenoic (Palmitoleic)	%	0.17	0.17	0.1	0.19	0.27
C16:2 Hexadecadienoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C16:3 Hexadecatrienoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C16:4 Hexadecatetraenoic	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C17:0 Heptadecanoic (Margaric)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C17:1 Heptadecenoic (Margaroleic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C18:0 Octadecanoic (Stearic)	%	0.49	0.48	0.49	0.47	0.55
C18:1 Octadecenoic (Oleic + isomers)	%	2.54	2.55	2.28	2.86	3.39
C18:2 Omega 6 (Linoleic)	%	3.84	3.68	3.82	3.96	4.36
C18:2 Octadecadienoic (Linoleic-all isomers)	%	3.86	3.71	3.85	4.02	4.4
C18:3 Octadecatrienoic (Linolenic-all isomers)	%	0.4	0.39	0.41	0.41	0.41
C18:3 Omega 3 (alpha-Linolenic)	%	0.39	0.39	0.4	0.4	0.4
C18:3 Omega 6 (gamma-Linolenic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

C18:4 Octadecatetraenoic Omega 3 (Stearidonic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:0 Eicosanoic (Arachidic)	%	0.03	0.03	0.03	0.03	0.03
C20:1 Eicosenoic (all isomers)	%	0.03	0.04	0.03	0.05	0.04
C20:2 Omega 6	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:3 Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:3 Omega 6 (homo-gamma-Linolenic)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:3 Eicosatrienoic (all isomers)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:4 Arachidonic (all isomers)	%	0.04	0.04	0.05	< 0.02	0.02
C20:4 Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C20:4 Omega 6	%	0.04	0.04	0.05	< 0.02	0.02
C20:5 EPA Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C21:5 Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:0 Docosanoic (Behenic Acid)	%	0.03	0.03	0.03	0.03	0.03
C22:1 Docosenoic (all isomers)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:2 Omega 6	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:3 Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:4 Omega 6 (Adrenic Acid)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:5 Docosapentaenoic (all isomers)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:5 DPA Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:5 Omega 6	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C22:6 DHA Omega 3	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
C24:0 Tetracosanoic	%	0.03	0.03	0.03	0.03	0.03
C24:1 Tetracosenoic (all isomers)	%	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Appendix B - Questionnaire for Consumer Acceptance Study



You will be evaluating 5 dry cat food samples today that provide balanced nutrition for your pet.

You will be evaluating the kibble, one sample at a time, based on their appearance, aroma and texture.

We are interested in what you think about these cat food samples, NOT what your cat might think, unless specified in the question.

Please read all instructions and questions carefully.

Click *next* to continue.

Next

Please wait for your **FIRST** Kibble sample.

DO NOT OPEN CONTAINER!



When you have received sample **${SAMPLEBC}**, click *next* to continue.

Please wait for your **SECOND** Kibble sample.

DO NOT OPEN CONTAINER!



When you have received sample **${SAMPLEBC}**, click *next* to continue.

Please wait for your **THIRD** Kibble sample.

DO NOT OPEN CONTAINER!



When you have received sample **${SAMPLEBC}**, click *next* to continue.

Please wait for your **FOURTH** Kibble sample.

DO NOT OPEN CONTAINER!



When you have received sample **${SAMPLEBC}**, click *next* to continue.

Please wait for your **LAST** Kibble sample.

DO NOT OPEN CONTAINER!



When you have received sample **${SAMPLEBC}**, click *next* to continue.

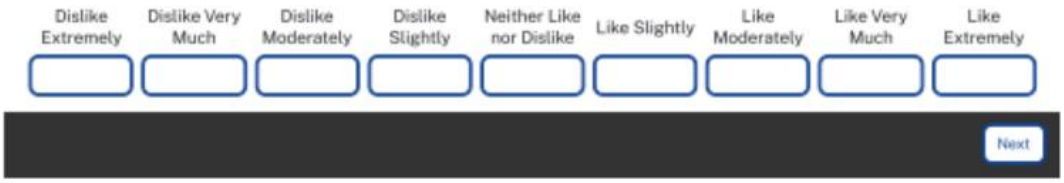
Next

Open the container now.

SNIFF the kibble before answering the following question.

Sample: BC1

How much do you like or dislike the **aroma** of this kibble?



Sample: BC1

How would you describe the **overall aroma** of this kibble?



Sample: BC1

How much do you like or dislike the **appearance** of this kibble?



Sample: BC1

How would you describe the **color** of this kibble?



Use your fingers to feel the cat kibble.

Sample: BC1

How much do you like or dislike the **texture** of this kibble?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Next

Sample: BC1

How would you describe the **texture** of this kibble?

Much Too Hard	A Little Too Hard	Just-About-Right	A Little Too Soft	Much Too Soft
☐	☐	☐	☐	☐

Next

Sample: BC1

Considering the **aroma**, **appearance**, and **texture**, how much do you like or dislike this kibble sample **overall**?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

How much do you think **your cat** would **like or dislike** this kibble?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Next

Using between 1 and 5 single terms or descriptors, please say what you **LIKED** about this product.

Sample: BC1

Using between 1 and 5 single terms or descriptors, please say what you **DISLIKED** about this product.

Sample: BC1

Next

Push your sample aside, making sure to keep them all in the same order as you receive them.



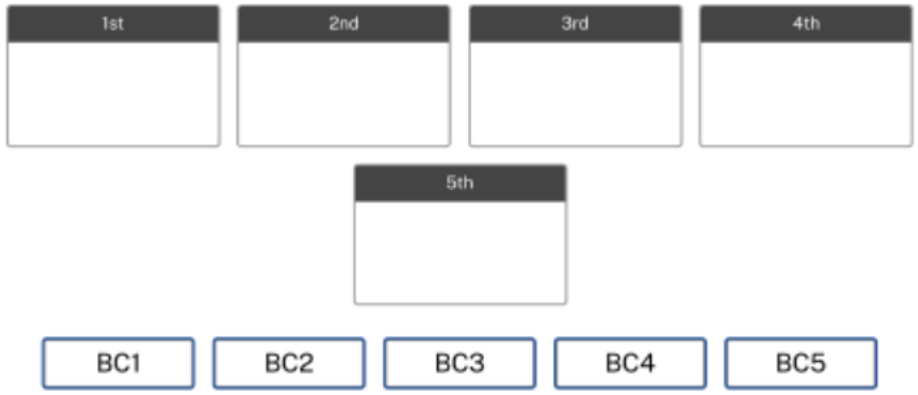
Click *"Next"*

Next

Thinking about the 5 dry cat food kibble samples you just reviewed, please RANK them in order of PREFERENCE.

- Click & drag the code of the MOST PREFERRED sample into the box labeled "1st".
- Click & drag the code of the SECOND MOST PREFERRED sample into the box labeled "2nd".
- Repeat for the THIRD MOST PREFERRED (3rd box) and FOURTH, and FIFTH samples

- Samples are listed from left to right in the order that they were served.



Next

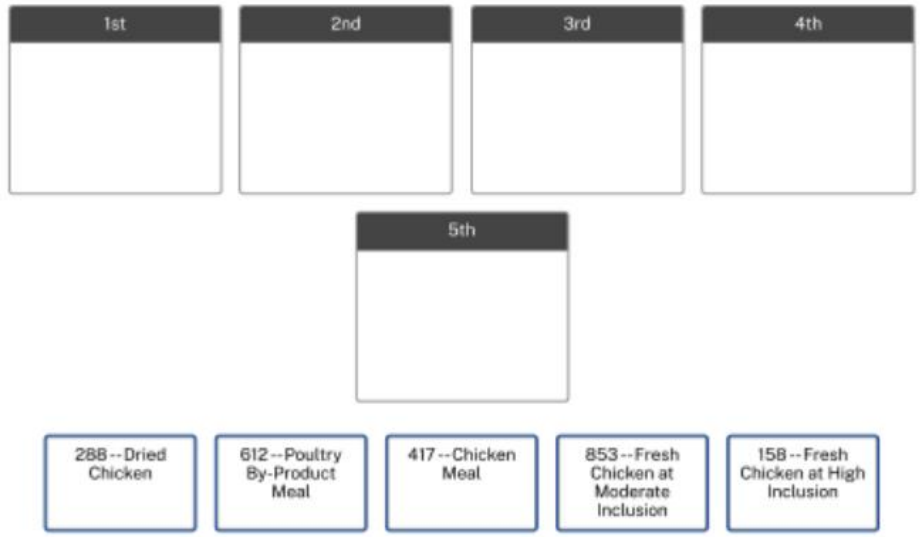
All 5 of the samples are foods that **provide the same nutrition to your cat** and are made using the same ingredients, with the **only difference being the protein source used**:

- **288 - Dried Chicken**
- **417 - Chicken Meal**
- **612 - Poultry By-Product Meal**
- **853 - Fresh Chicken at Moderate Inclusion**
- **158 - Fresh Chicken at High Inclusion**

Based on the Protein Ingredient information given above, along with the Aroma, Appearance, and Texture, please RANK the 5 kibble samples in order of PREFERENCE.

- Click & drag the code of the MOST PREFERRED sample into the box labeled "1st".
- Click & drag the code of the SECOND MOST PREFERRED sample into the box labeled "2nd".
- Repeat for the THIRD MOST PREFERRED (3rd box) and FOURTH, and FIFTH samples

- Samples are listed from left to right in the order that they were served.



Next

Did having the **ingredient information** change how much you **liked or disliked** the different dry cat food kibbles you evaluated?

Yes

No

If learning the protein ingredient in the dry cat kibble **changed your kibble ranking**, please explain why.

Next

Please select the attributes that you feel would be present in dry cat kibble containing the following protein products (chicken meal, dried chicken, poultry by-product meal, mechanically deboned fresh chicken).

Select all attributes that apply to each protein type.

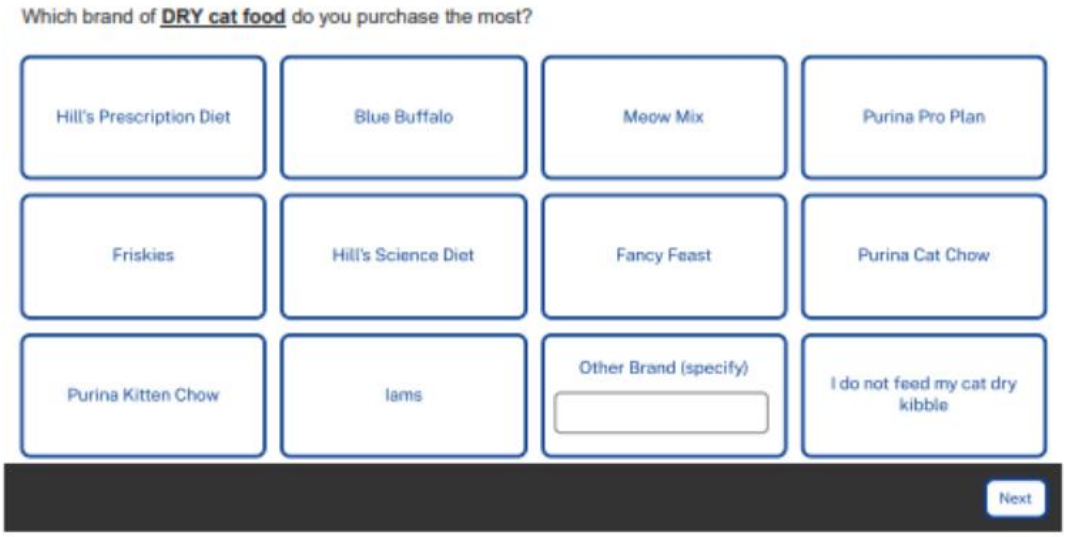
	Chicken Meal	Dried Chicken	Poultry By-Product Meal	Mechanically Deboned Fresh Chicken
High Quality				
Minimally Processed				
Highly Nutritious				
Natural				
Low Quality / Filler				
Easy to Digest				
Sustainable				
Trustworthy				
Preferred by Cats				

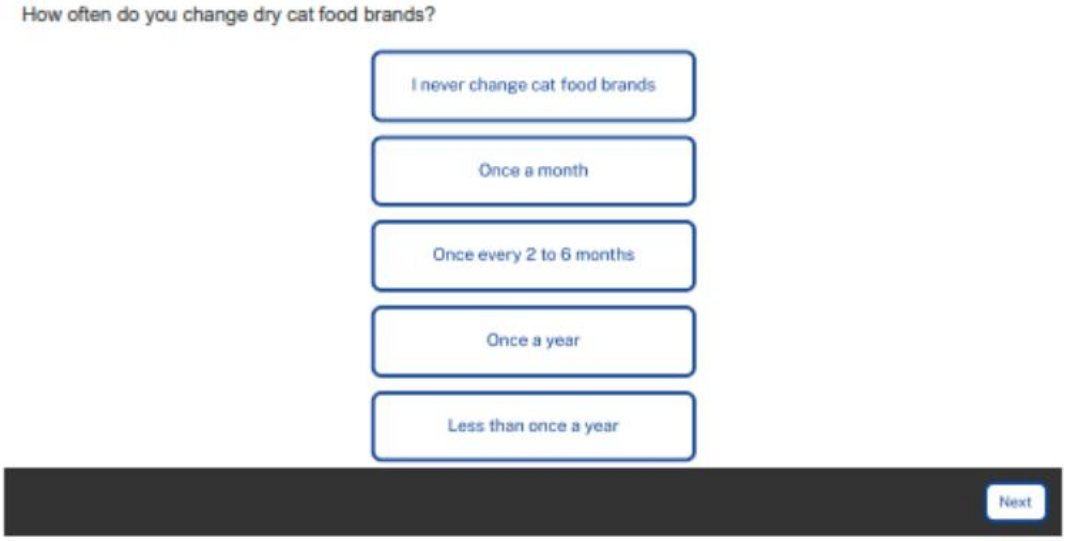
Next

What **age range** does your cat fall? (If you have multiple cats please check all that apply)

- Kitten (0-12 months)
- Adult (1-8 years)
- Senior (9 years and older)

Next


Which brand of DRY cat food do you purchase the most?
Hill's Prescription Diet
Blue Buffalo
Meow Mix
Purina Pro Plan
Friskies
Hill's Science Diet
Fancy Feast
Purina Cat Chow
Purina Kitten Chow
Iams
Other Brand (specify)
I do not feed my cat dry kibble
Next


How often do you change dry cat food brands?
I never change cat food brands
Once a month
Once every 2 to 6 months
Once a year
Less than once a year
Next

Which best describes **your role** in **purchasing** pet food, supplements and treats for your household/family?

- I do all of the purchasing
- I do more than half the purchasing
- I do half the purchasing
- I do less than half the purchasing
- I do not do any of the purchasing

Next

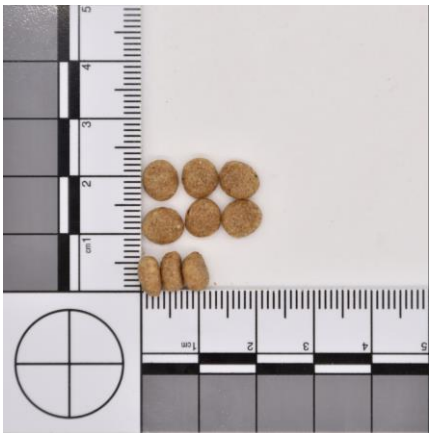
What **factors are most important** to you for purchasing a dry cat/kitten kibble product (check all that apply)

- Nutrition
- Ingredient Statement
- Flavor
- Brand
- Vet Recommended
- Label
- Claims
- Marketing
- Life Stage
- Cat Size
- Cat Activity Level
- Other (please specify)
- None of the above

Next

Appendix C - Physical Kibble Images

Figure C.1: Chicken Meal Formula (CM)



FigureC.2: Dried Chicken Formula (DC)

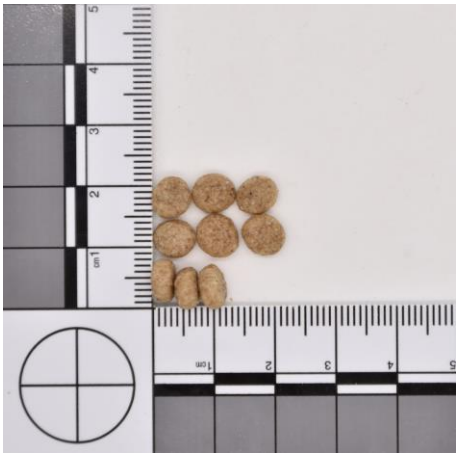


Figure C.3: Fresh Chicken Formula (FC)

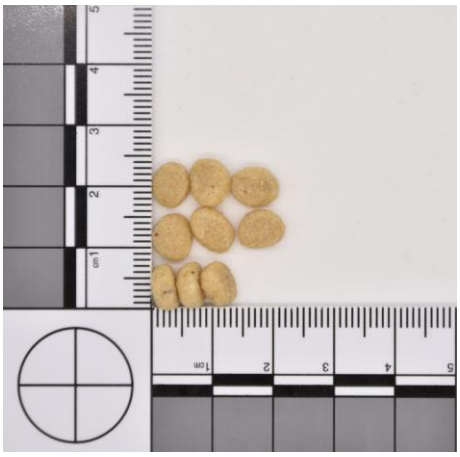


Figure C.4: Fresh Chicken Protein Match Formula (FCPM)



Figure C.5: Poultry By-Product Meal Formula (PBPM)



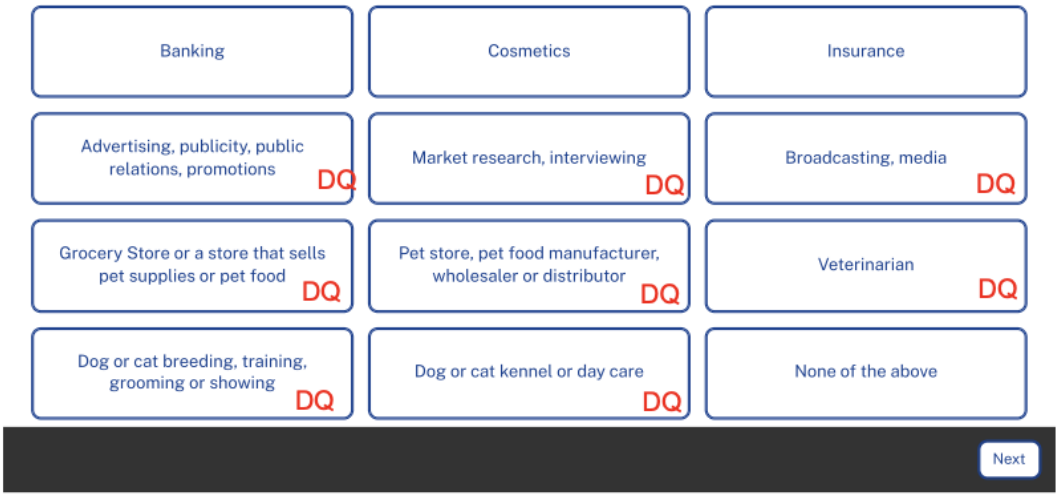
Appendix D - KSU Olathe Participant Screener



Which of the following best describes your age?



We are looking for people who work in certain occupations. Do you, or does any member of your family, work in or participate in any of the following businesses? (Check all that apply)



When was the last time, if ever, **you participated** in any type of market research for pets?

- In the last month — DQ
- In the last two months — DQ
- In the last three months — DQ
- In the last 4-6 months
- More than 6 months ago
- I have never participated in a consumer research study about pets or children.

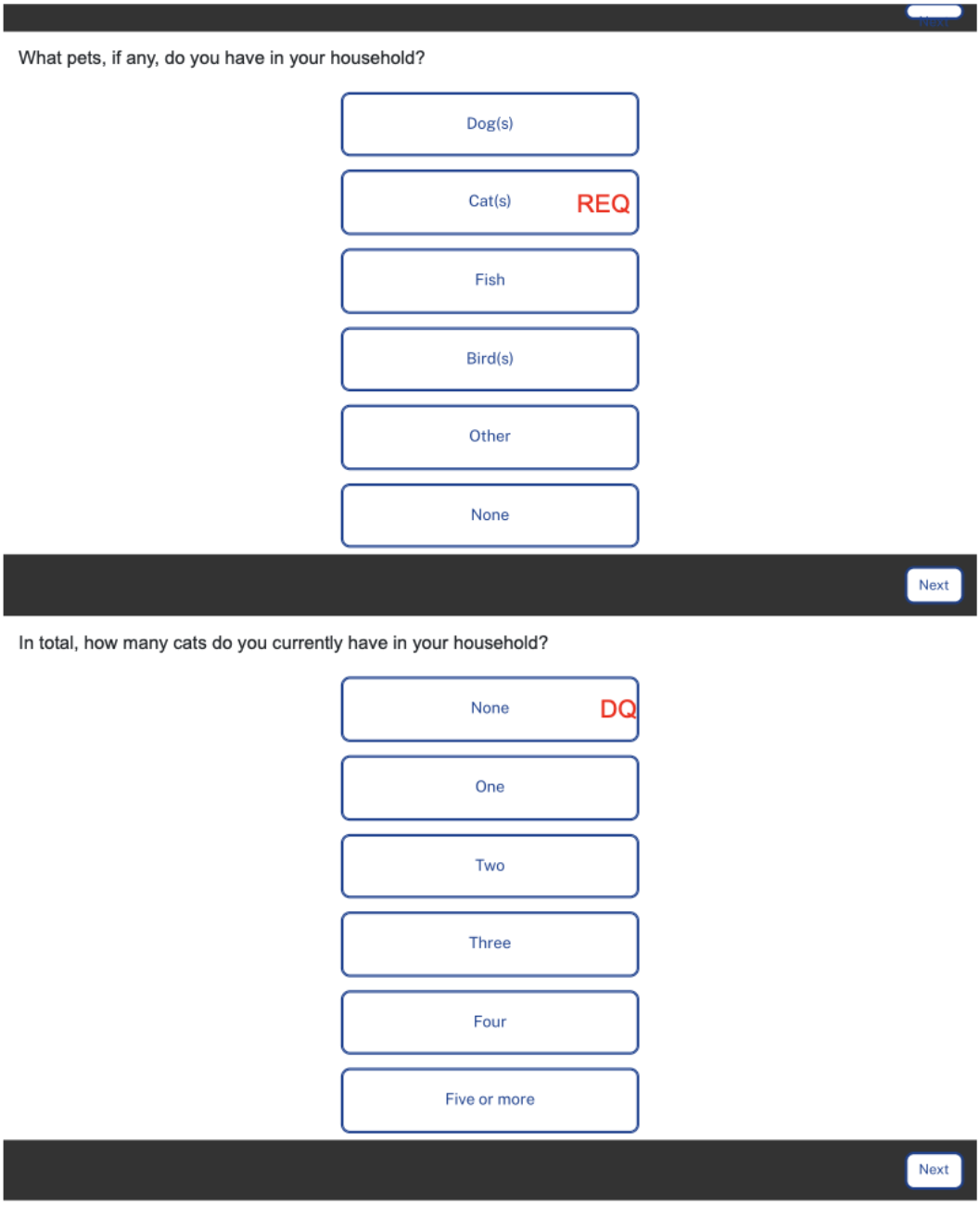
Are you **currently scheduled** to participate in a market research study or taste test?

- Yes — DQ
- No

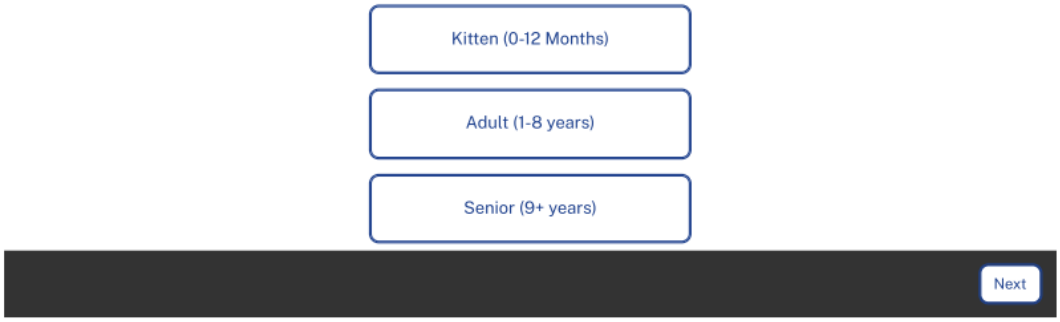
Next

Are you currently feeling sick, have a fever, or have any loss of taste or smell?

- Yes — DQ
- No


What pets, if any, do you have in your household?
Dog(s)
Cat(s)
REQ
Fish
Bird(s)
Other
None
Next
In total, how many cats do you currently have in your household?
None
DQ
One
Two
Three
Four
Five or more
Next

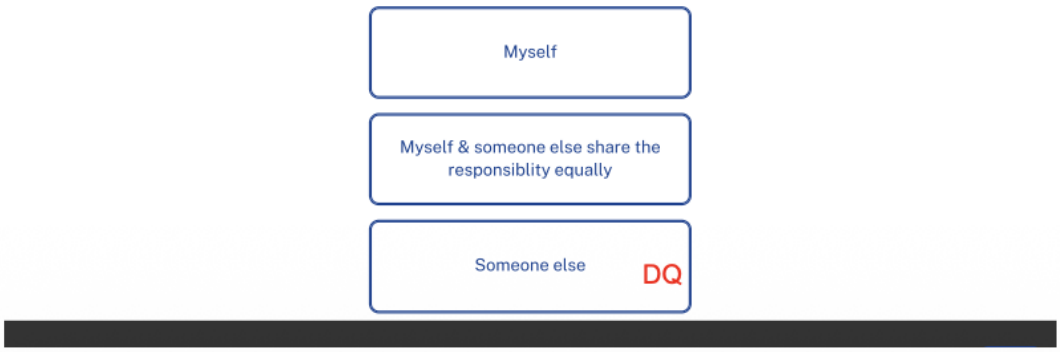
In what **age range** does your cat fall? (If you have multiple cats please check all that apply)



How much responsibility do you have for **purchasing food** for your cat(s)?



Who in your household is **most** responsible for **taking care** for your cat(s)?




Next
Which of the following statements best describes your involvement in feeding your cat(s)?
I feed the cat all of the time
I feed the cat most of the time
I feed the cat some of the time
DQ
I don't feed the cat but I supervise someone else who does
DQ
Someone else feeds the cat
DQ
Next
What type(s) of food do you feed your cat(s)? (check all that apply)
Dry Cat Food
REQ
Wet/Canned Cat Food
Homemade Food
Other (specify)
Next

You are being considered for a dry cat kibble study on Thursday, May 28th.

- **Please DO NOT wear any type of fragrance, body lotion or spray, or any other strong smelling products the day of the study.**
- Please **arrive 10 minutes before your session time.**
- You will need a **photo ID to check in.**
- If you need glasses for reading, please bring them with you to the session.
- **Please refrain from smoking or vaping for at least 1 hour before your session time and while you are on the K-State Olathe property.**
- If you have experienced **Covid-19 or fever or any flu-like symptoms** in the past 72 hours, please contact us to cancel your session and do not attend the study.
- **Children are not allowed at adult studies**. Please make prior childcare arrangements.

- **DO NOT bring your cat to the study!**

Do you agree to adhere to the requirements above?

(Note: You could be disqualified during check in if you have not met these requirements.)

Yes

No DQ

Next

You **MAY** have qualified to participate in a **Cat Food Study** on **Thursday, May 28.**

This study will NOT require you to bring your cat(s) to the test. Only you, the pet owner, will be participating in the study.

The study will take approximately 35 minutes, and you will be compensated $xx for your time. The study will take place at the Sensory & Consumer Research Center at the K-State Olathe campus.

Are you willing to participate?

Yes

No DQ

Next

IF YOU QUALIFY and meet all the QUOTAS, then you will see the Scheduler next and may schedule yourself for a time that works best.

Please type your CELL PHONE number in the space below, including the AREA CODE.

Click "next" after entering your cell number.

Next

Sensory and Consumer Research Center

Thanks for completing this test.

If you are viewing this screen, you did not qualify for this particular study.

We look forward to your participation in future studies.

Finished