Effect of dehydration time on physicochemical, textural, instrumental color, and sensory characteristics of jerky-style pet treats made with swine pluck

by

Hilary Gisselle Carrera Arcia

A thesis submitted to the Graduate Faculty of Auburn University in partial fulfillment of the requirements for the Degree of Master of Science

Auburn, Alabama
December 14, 2024

Keywords: Pet treats, co-products, physicochemical parameters, texture analysis, instrumental color, sensory characteristics

Approved by:

Dr. Jessica Starkey, Chair, Associate Professor of the Department of Poultry Science
Dr. Sungeun Cho, Assistant Professor, Department of Poultry Science
Dr. Charles Starkey, Vice President of Regulatory Affairs, NARA

Abstract

The current growth of pet ownership, coupled with the rise of pet humanization, has driven the integration of convenient materials repurposed into pet food products, particularly pet treats. Swine pluck (SP), a combination of heart, lungs, esophagus, and trachea offers a single-removal unit that can be effectively utilized to manufacture pet treats. However, pet food manufacturers continue to seek ways to improve the product's characteristics to satisfy both pet owners and their pets, influencing purchasing decisions. In this study, one experiment was conducted to assess the effect of dehydration time on physicochemical, textural, instrumental color changes post-production, and sensory attributes of jerky-style pet treats made with SP. Dehydration time impacted the characteristics of SP treats, with the lowest levels of moisture content and water activity observed after 7 h of dehydration. To achieve a water activity of 0.85, a minimum dehydration time of 5 h was required. Treats dehydrated for 7 h were found to be harder and stiffer, whereas those dehydrated for 3 and 4 h were the more flexible. Additionally, SP treats dehydrated for 6 and 7 h exhibited the highest firmness and toughness. Prolonged heat treatments also had a notable effect on the final color of SP treats. After 7 d of storage, SP samples dehydrated for 3 h were the lightest (L*), reddest (a*), and yellowest (b*) among treatments. Delta-E (ΔE) values were the highest between d 0 and 1 post-production, indicating color changes that were perceptible to the human eye. According to pet owners' liking scores, dehydration time impacted the color, texture, and intent of purchase. However, pet owners did not differentiate between the samples in terms of appearance and the overall liking. Variations in dehydration time impacted both instrumental and sensory characteristics. Overall, SP can be effectively used to produce jerky-style pet treats, resulting in a shelf-stable product that meets the quality standards of the pet food industry.

Acknowledgments

I would like to express my deepest gratitude to God for providing me with strength and unconditional love throughout this journey. I am thankful to my loving mom, dad, sister, and family members, who have been my constant source of motivation and encouragement. A special mention goes to my mom, Elizabeth, whose kind and wise words have constantly supported and lifted me up. To my friends, thank you for your companionship, care, and love. The memories we have created together will remain in my heart and you are truly the family I have chosen.

A huge thanks goes to Jorge Romero, whose endless support, love, and belief in me have shaped this journey. I am grateful to have you in my life, thank you for always caring about my future. Having you around motivates me to be the best version of myself and continue achieving my goals.

I would like to give special thanks to my advisors, Drs. Jessica and Charles Starkey, for giving me the opportunity to grow as both professional and a person. Your patience and support have helped me achieve goals I never thought possible. Thank you for teaching me the importance of hard work, challenging me to succeed, and supporting me throughout my research. I would also like to thank Dr. B.J. Bench, whose unwavering support and care have motivated me to follow his great example of leadership. Thank you for believing and trusting in my abilities.

Lastly, I would like to thank the Starkey Lab members. My journey wouldn’t have been the same without your company and dedication to research. I believe I have built strong friendships within this group and will carry these experiences and memories with me in the future.

Table of Contents

Abstract 2

Acknowledgments 3

Chapter I. Literature review 11

1.1 Introduction 12

1.2 Overview of the pet food industry 15

1.3 Uses of co-products in the pet food industry 16

1.4 Chemistry and uses of hydrocolloids in the pet food industry 18

1.5 Cooking methodologies 21

1.6 Intent of purchase among pet owners 23

1.7 Sensory evaluation in food products 25

1.8 Sensory evaluation in pet food 27

1.9 References 29

Chapter II. Effect of dehydration time on physicochemical and textural properties of jerky-style pet treats made with swine pluck 43

2.1 Abstract 44

2.2 Keywords: 45

2.3 Introduction 46

2.4 Materials and Methods 48

2.4.1 Raw materials and preparation of ingredients 48

2.4.2. Inclusion of the structure forming technology 49

2.4.3 Extrusion and dehydration of the samples 49

2.4.4 Moisture content 50

2.4.5 Water activity 50

2.4.6 Three-point bend 51

2.4.7 Shear force 51

2.4.8 Statistical analysis 51

2.5 Results and Discussion 52

2.5.1 Moisture content 52

2.5.2 Water activity 53

2.5.4. Three-point bend 53

2.5.5 Shear force 55

2.6 Conclusions 56

2.7 References 57

Chapter III. Effect of dehydration time on instrumental color characteristics of jerky-style pet treats using made with pluck 66

3.1 Abstract 67

3.2 Keywords 68

3.3 Introduction 69

3.4 Materials and Methods 70

3.4.1 Ingredients and raw material preparation 70

3.4.2. Addition of the structure forming technology 71

3.4.3. Sample extrusion and dehydration 71

3.4.4 Instrumental color 72

3.4.5 Delta E (ΔE) 72

3.4.6 Statistical analysis 73

3.5 Results and Discussion 73

3.5.1 Lightness (L*) 73

3.5.2 Redness (a*) 75

3.5.3 Yellowness (b*) 76

3.5.4 Delta-E (ΔE) 78

3.6 Conclusions 79

3.7 References 80

Chapter IV. Effect of dehydration time on sensory properties of jerky-style pet treats made with swine pluck among pet owners 89

4.1 Abstract 90

4.2 Keywords: 91

4.3 Introduction 92

4.4 Materials and Methods 94

4.4.1 Preparation of raw samples and ingredient composition 94

4.4.2. Structure forming technology inclusion ... 94
4.4.3. Sample extrusion and drying method ... 95
4.4.4 Demographics characteristics of pet owners ... 95
4.4.5. Sensory parameters in jerky-style pet treats ... 96
4.4.6 Comparison between overall liking and demographic characteristics ... 96
4.4.7. Statistical analysis ... 97
4.5 Results and Discussion ... 97
4.5.1. Demographic characteristics of pet owners ... 97
4.5.2 Sensory parameters evaluated in jerky-style pet treats ... 99
4.5.3 Comparison between overall liking and demographic characteristics ... 101
4.6 Conclusions ... 102
4.7 References ... 104

List of Tables

Chapter II.

Table 2.1 Effect of dehydration time on physicochemical characteristics of dehydrated jerky-style pet treats made with swine pluck. 63

Table 2.2 Effect of dehydration time on the three-point bend test of dehydrated jerky-style pet treats made with swine pluck. 64

Table 2.3 Effect of dehydration time on the shear force test of dehydrated jerky-style pet treats made with swine pluck. 65

Chapter III.

Table 3.1 Delta-E values range from 0 to 100. 73

Table 3.2 Effect of dehydration time and time post-production on Delta-E values of dehydrated jerky-style pet treats made with swine pluck. 88

Chapter IV.

Table 4.1 Demographic characteristics of pet owners evaluating jerky-style pet treats made with swine pluck. 108

Table 4.2 Pet ownership questionnaire evaluating jerky-style pet treats made with swine pluck. 109

Table 4.3 Effect of dehydration time on sensory parameters of jerky-style pet treats made with swine pluck. 110

Table 4.4 Comparison between overall liking and demographics of jerky-style pet treats made with swine pluck. 111

List of Figures

Chapter II.

Figure 2.1 Sample preparation of dehydrated jerky-style pet treats made with swine pluck (SP) mixed with 1% sodium alginate (SA) and 0.85% encapsulated calcium lactate (ECL). 62

Chapter III.

Figure 3.1 Effect of dehydration time on lightness (L*) values over time post-production of jerky-style pet treats made with swine pluck. 85

Figure 3.2 Effect of dehydration time on redness (a*) values over time post-production of jerky-style pet treats made with swine pluck. 86

Figure 3.3 Effect of dehydration time on yellowness (b*) values over time post-production of jerky-style pet treats made with swine pluck. 87

List of Abbreviations

3PB	Three-point bend
a*	Redness
ALGIN	Sodium alginate + encapsulated calcium lactate
aw	Water activity
b*	Yellowness
CAGR	Compound annual growth rate
d	Day
ECL	Encapsulated calcium lactate
g	Grams
h	Hour
kg	Kilogram
L*	Lightness
MC	Mositure content
mm	Milimiter
s	Second
SA	Sodium alginate
SF	Shear force
SP	Swine pluck

Chapter I. Literature review

Overview of the pet food industry, cooking methodologies, and sensory evaluation of pet food

1.1 Introduction

The rise in animal protein consumption over the years have led to a projected 14% increase in demand by 2030, influenced by population growth and rising income levels (Food and Drug Administration 2021). As a result, parts of the animal not destined for human consumption can be repurposed and transformed into valuable materials for the pet food industry, thus typically known as co-products (Aldrich, 2006). For instance, using these co-products can be considered as a sustainable practice while producing new ingredients and products for different purposes (Henchion et al., 2016). Co-products offer several nutritional benefits considering their content of protein, vitamins, and minerals (Mullen & Álvarez, 2016).

Co-products are widely used in the pet food industry (Lynch et al., 2018), influenced by growth in pet ownership, humanization of pets, and searching for premium ingredients for pet food production (Mullen et al., 2017). These materials can be exposed to high-temperature treatments to remove moisture, separate the protein from the fat, and eliminate microorganisms, making them safe for pet consumption (Meeker & Meisinger, 2015). While exposing this material cooking processes, the chemical composition of these materials changes, rendering them sources of protein, essential amino acids, fats, minerals, and vitamins (Aldrich, 2006).

Heat treatments can also affect other aspects of meat products, such as texture and color. Therefore, denaturation of the protein can be a result of exposing meat products to heat, ultimately affecting the structure of the protein (Tornberg, 2005). This denaturation can have an effect in the water-holding capacity and moisture content of the product (Zielbauer et al., 2016). Additionally, the myofibrillar proteins in meat shrink as a result of heat-induced denaturation (Ježek et al., 2019). Moreover, cooking processes can have a positive effect in meat products by increasing the shelf-life stability of the products at storage (Vinnikova et al., 2019).

As an indicator of shelf-life in dried products, water activity (a_w) can help determine chemical reactions and microorganism associated with spoilage (Barbosa-Cánovas et al., 2020). Similarly, moisture content can be also measured in these products, which can be considered as a quality indicator (Collell et al., 2012). Texture is another quality parameter in meat-derived products. During cooking or drying methods, a product builds a less permeable membrane that can limit moisture removal, thus causing a harder texture in the product (Gou et al., 2005). Additionally, meat products exposed to heated treatments can experienced changes in flavor, and fluctuations in nutritional properties including vitamins and amino acids (Doymaz et al., 2016).

With increases in the pet food market and the demand of high-quality pet food products, this industry is exploring alternatives to enhance some properties in the product such as texture (Koppel, 2014). The use of hydrocolloids in pet food products can potentially improve structural and binding properties for these products as well as increase their shelf-life and improve quality (Dainton et al., 2021). Hydrocolloids is a polysaccharide with multiple functions in products including thickening, coating, gelling, and others (Phillips & Williams, 2009). In terms of properties, hydrocolloids can impact the rheological and sensory properties that can influence consumer's perception (Jayakody et al., 2023), the viscosity of the product (Varela & Fiszman, 2011), emulsification properties (Tan & McClements, 2021), and thickening agents (Lu et al., 2021).

To meet the market standards for pet food, manufacturers must consider quality parameters that can drive purchasing decisions among pet owners. According to literature, various parameters can influence these decisions, such as the level of involvement, effort and interest of owners during pet food selection (Morelli et al., 2021), nutritional benefits for their pets (Rogues et al., 2022), processing methods involved in the manufacturing process (Rombach

& Dean, 2021a), and cultural eating behaviors driven by pet owners (Vinassa et al., 2020). Another aspect that can influence the intent of purchase in pet food are the ingredients and the price (Schleicher et al., 2019), therefore among all parameters influencing purchasing decisions, pet owners will emphasize on the composition of the food, including food manufactured with natural ingredients, amount of protein, and containing vitamins and minerals that will be beneficial to their pets health (Vinassa et al., 2020).

While determining the quality of a pet food product, a sensory evaluation which is a technique developed to evaluate the product's attributes using human senses can be employed in this market (Ruiz-Capillas & Herrero, 2021). Different types of sensory tests can be used to determine food product characteristics, including affective, discriminative, and descriptive tests. The selection of the appropriate test depends on factors like product type, panel size, target audience, and relevant statistical parameters (Meilgaard et al., 2016).

A sensory evaluation performed in pet food can be used to determine changes in the formulation, inclusion of a new ingredient, and improvements in the processing methods (Koppel et al., 2015). Conducting sensory studies in pet food products can be challenging since pet owners, not pets, are the ones purchasing the products. Thus, sensory tests must assess characteristics appealing to owners while ensuring satisfaction for their pets (Rogues et al., 2022). Pet food characteristics such as appearance, texture, flavor, and aroma can be assess by either humans or instruments, while preference tests or consumption are conducted using the pets themselves (Koppel, 2014). Ultimately, sensory evaluation and palatability tests provide valuable insights into the acceptability of pet food products for both owners and their pets (Di Donfrancesco, 2016).

1.2 Overview of the pet food industry

Globally, the pet food industry has been undergoing significant growth, according to recent data reports. In 2023, the market revenue reached $120.87 billion, with projections for 2024 rising to $126.66 billion. Furthermore, the industry is expected to continue its expansion, with revenues projected to reach $195.63 billion by 2032. The expansion of the middle class in certain regions has also driven substantial growth in pet ownership across Latin America, Asia Pacific, Middle East, Africa, and Eastern Europe (Fortune Business Insights 2024).

Over the past 5 years, the pet food industry in the United States has experienced substantial growth. The American Pet Products Association (APPA) report spanning from 2018 to 2023 indicates a 43.8% in total U.S. expenditures within the pet food sector (APPA, 2023). According to the same data, the projected sales for 2024 amount to $150.6 billion, with $66.9 billion allocated for pet food and treats in the U.S. market. This projection represents 44.4% of total sales.

The pet food market is anticipated to exhibit a Compound Annual Growth Rate (CAGR) of 5.77% between 2024 and 2028, with projected revenues in the U.S. reaching $58.42 billion in 2024 (Statista, 2024). In addition to revenue growth, the increase of pet ownership significantly contributes to the expansion of the pet food market, with 82 million households owning a pet. When categorizing pet ownership by species, 58 million households have a dog, and 40 million households have a cat, making them the most prevalent pets in the U.S (APPA, 2024).

Data on pet ownership across generations holds significance for pet food manufacturers and retailers. In this context, millennials comprise 32% of pet ownership, followed by 27% for Generation X, and 24% for baby boomers (APPA, 2024). Conversely, Generation Z owners are distinguished by their inclination to have a varied array of pets, and propensity to spend more on specialized pet food products, including birthday cakes for their pets (Megna, 2024). Pet owners consider their pets as members of their family; in fact, 63% of American owners affectionally labeled their companions as their “fur kids” (Rauktis et al., 2017). Align with this findings, 77% of dog and cat owners perceived their companion animals as family members (Mcconnell et al., 2019). This bound between pet owners and pets is another factor leading the pet food market growth (Kumcu & Woolverton, 2015).

Pet humanization is another factor that can influence the growth of the pet food market and the importance of ingredients in pet food products (Fortune Business Insights 2024). As pets become increasingly humanized, owners tend to align their own lifestyle trends with those of their pets, seeking similar nutritional options for their companion animals (Schleicher et al., 2019). In fact, many pet owners are willing to make significant financial and personal sacrifices to ensure the well-being of their pets (Kylkilahti et al., 2016).

A study performed in dog owners revealed that individuals who prioritize healthy eating for themselves are more likely to provide nutritious food for their dogs (Jyrinki & Leipamaa-Leskinen, 2006). Consequently, the pet food industry is responding by developing products that prioritize pet health and nutrition to align with the current market demand (Carter et al., 2014).

1.3 Uses of co-products in the pet food industry

The current demand in the pet food industry has led to the seek for animal-based protein alternatives to be used in the manufacturing of pet food products (Aldrich, 2006). Co-products are the most common products used in pet food formulation, based on their high-quality, environmental friendly, and affordable ingredient not desired for human consumption (Meeker &

Meisinger, 2015). These co-products can include fat, abdominal and intestinal contents, skin, organs, feet, bone, and blood from different animals such as chicken, beef, pigs, and lambs (Jayathilakan et al., 2012).

Transforming those co-products into higher-value alternatives could result in the creation of a sustainable and profitable ingredient with potential applications across various industries, including pet food and animal feed (Toldrá et al., 2021). These animal processing co-products are not only cost-effective but also richer in essential nutrients, such as amino acids and proteins, when compared to traditional meat products (Álvarez et al., 2018). As highlighted by Anzani et al., 2020, co-products like heart, kidney, liver, thymus, tripe, and brain have the leading amount of consumption among other co-products for human consumption (Anzani et al., 2020).

Co-products, also known as offal, are defined by the United Nations as any part of the animal that is not classified as red or white muscle meat (Nations, 2015). During animal processing, in terms of live weight, 59% of the cattle weight, 44% of the pigs weight, and 47% of the chickens weight is not intended for human consumption (Aldrich, 2006). These non-meat components, produced during the meat processing, are known as co-products, which large quantities can be generated in a daily basis (Lynch et al., 2018).

Alternatives processes like rendering have been employed to repurpose non-edible materials from meat processing, thereby reducing the landfill usage, carbon emissions, food waste, and significantly cutting greenhouse gas (GHC) emissions (Wilkinson & Meeker, 2021). Rendering is widely recognized as a recycling practice that adds value by converting these materials into new and useful products (Meeker & Meisinger, 2015). Rendering systems are designed to cook the product, causing a separation of fat and protein. After cooking, the product is dried to reduce moisture content (Meeker, 2009).

Maintaining control over microbial load through proper temperature and timing during the rendering process can be crucial to ensure the pets' health during consumption. The recommended temperature range for effective microbial control during rendering is between 115 and 146 °C (Vidyarthi et al., 2021). However, studies have shown that some pet owners perceived negatively the taste and texture of ingredients derived from offal (Henchion et al., 2016). On the other hand, once the product's appearance and physical form are modified, owners tend to recognize its benefits and characteristics more positively (Mullen et al., 2017).

As previously stated, various co-products from different species can be redirected to be used in rendering for pet food. In particular, the combination of heart, lungs, esophagus, and trachea (excluding the thyroid gland) can be efficiently utilized in the production of pet treats, due to the simplicity of single-step removal during swine processing. In recent years, the FDA has expressed concerns regarding the presence of thyroid hormones in pet food, as outlined in their official communications with members of the pet food industry (Rotstein et al., 2021).

Certain product recalls have highlighted the issue, including a 2018 voluntary recall by Dave's Pet Food due to elevated levels of thyroid gland in premium beef cans (FDA, 2020). Similarly, J.M. Smucker issued a recall in 2018 after thyroid gland contamination was discovered in Milo's Kitchen pet treats, causing health concerns among pet owners (FDA, 2018). In conclusion, transforming animal co-products into high-value ingredients through processes like rendering offers a sustainable and cost-effective solution for the pet food industry.

1.4 Chemistry and uses of hydrocolloids in the pet food industry

The increasing demand of pet food products in the pet food industry has driven efforts to enhance the texture of products by incorporating various ingredients to optimize the final texture

(Koppel et al., 2015). The inclusion of hydrocolloids in the system could improve the structural and binding properties of the pet food products (Dainton et al., 2021). Hydrocolloids are commonly used in food products to enhance quality and extend shelf-life. Therefore, it is essential to understand how they interact with other components, such as meat products, when developing new pet food formulations (Saha & Bhattacharya, 2010).

Hydrocolloid is a Greek terminology with hydro meaning 'water' and colloid meaning 'glue' (Wüstenberg, 2015). It is known as a long-chain of polymers with a particular property of being dispersed in water (Milani & Maleki, 2012). This can be attributed to chemical properties of hydrocolloids, which contains a large amount of hydroxyl groups, providing greater binding properties with water (Li & Nie, 2016). Hydrocolloids is define as a variety of polysaccharides and proteins with functional properties such as thickening, coating, gelling, emulsifying, and stabilization (Phillips & Williams, 2009). Plants and seaweeds are commonly used for extracting hydrocolloids, some examples of hydrocolloids are locust bean gum, guar gum, carrageenan, and agar (Goff & Guo, 2019).

Hydrocolloids modify the rheological and sensory properties of food thus ultimately impacting consumer perception (Jayakody et al., 2023). A proper selection of hydrocolloids can be influence by their functional properties and processing methods of food items (Seisun & Zalesny, 2021). Viscosity, in relation to these characteristics, can be described as the resistance to flow (Bourne, 2002). Furthermore, the effectiveness of hydrocolloids in terms of viscosity can be attributed to both their concentration and the specific type used (Varela & Fiszman, 2011).

Another functional attribute of hydrocolloids is gelation, which occurs through the formation of a polymer chain network, leading to the creation of a three-dimensional structure (Saha & Bhattacharya, 2010). This structure is formed by the aggregation of primary interchain connection, which culminates in the creation of junction zones essential for network development (Banerjee & Bhattacharya, 2012). Typically, these junction zones incorporate various non-covalent bonds including ionic bonding, hydrogen bonding, van der Waals attraction, and hydrophobic interactions (Nishinari et al., 2000). The configuration of junction zones can be influenced by different factors, such as the presence of ions, inherent structure, and temperature (Burey et al., 2008).

Hydrocolloids can additionally offer emulsifying attributes to food items. An emulsion is described as the mixture of two immiscible phases, this includes continuous and disperse phases (Tan & McClements, 2021). In food products, restructured food products are identified as co-products that undergone processing to transform into a new product with enhanced characteristics, including texture and appearance (Moreno et al., 2016). In restructured meat products, myofibrillar proteins, particularly actin and myosin, play an important role in gelation and binding during exposure to heat treatments (Ramírez et al., 2011).

Certain ingredients, such as thickening agents, can be added into the formulation of restructured foods, specifically hydrocolloids (Lu et al., 2021). The addition of hydrocolloids, particularly to restructured meat like duck skin can enhance cohesiveness, and reduce the cooking loss (Saengsuk et al., 2022). Restructured products currently in the market include those intended for human consumption, along with those utilized in animal feed and pet food (Nordgård & Draget, 2021). Furthermore, understanding the influence of the pet food industry is crucial for determining the appropriate hydrocolloid to be utilized as an ingredient in pet food products.

1.5 Cooking methodologies

Cooking methods play a crucial role in meat processing, as it help control microbial growth by eliminating pathogens while enhancing meat quality (Pathare & Roskilly, 2016). The digestibility and edibility of meat products also improve through cooking (Białobrzewski et al., 2010). Additionally, different cooking techniques can positively impact the texture and flavor of meat, making it essential to choose a method that optimizes these quality parameters (King & Whyte, 2006). Exposing meat products to high temperature during cooking can denature proteins, resulting in structural changes within the product (Tornberg, 2005).

Protein denaturation affect the main components of the muscle such as myosin, sarcoplasmic protein, collagen, and actin depending on thermal exposition (Ishiwatari et al., 2013). During the cooking process, the native structure of proteins can undergo changes, affecting the texture of the meat. Moreover, when meat is exposed to high cooking temperatures, water loss occurs, which influences its water-holding capacity. Consequently, the denaturation of proteins can have either a positive or negative on the product's moisture content (Zielbauer et al., 2016).

Another effect that meat products undergo during the cooking process is the shrinkage of the myofibrillar proteins due to denaturation (Ježek et al., 2019). In food products, water can be categorized as free, entrapped, or bound. Specifically, the water content in meat muscles is mostly in free state, while a smaller amount of water remains in connective tissues. During heat processing, the bound water of a meat tissue is not entirely removed from the muscle fiber (Ahmad et al., 2018). Furthermore, exposing meat samples to heat not only improves flavor and taste, but also extends shelf stability during storage (Vinnikova et al., 2019).

In terms of meat cooking, several measurements can be used as indicators of the product's shelf life. Moreover, water activity (a_w) serves as an indicator of microbial and chemical processes associated with spoilage, that are unpleasant in food items (Beňo et al., 2023). In other words, a_w helps determine a product's stability, microbial reactions, and which microorganisms may be present depending on the water activity level (Barbosa-Cánovas et al., 2020). Moisture content is also a critical indicator of quality in meat products. Some companies have adopted fast detection methods to control and monitor food products (Collell et al., 2012).

At the time of dehydration and cooking processes, meat products can build a crust on their surface, resulting in differences in moisture and water activity values between the surface and the inner sections of the meat. (Serra et al., 2005). This crust generate changes in the sensory characteristics of the product, providing a harder texture and creating a less permeable membrane layer that prevents moisture removal (Gou et al., 2005). In meat processing, different heating methodologies, such as oven cooking and dehydration, can affect a meat product characteristic depending on the setting and parameters used.

Oven cooking is commonly used in food products, especially within food service establishments and industrial food production (Mora et al., 2011). During oven cooking, the meat can be heated up to 250 °C (Alfaifi et al., 2023). At this temperature, microbial and quality parameters can be subjected to changes (Goñi & Salvadori, 2010). While cooking in ovens, critical parameters such as temperature, time, and food composition must be carefully controlled (Pathare & Roskilly, 2016). For instance, exposing meat to higher temperature rates can reduce cooking time and improve color and flavor parameters. Nonetheless, it may compromise other quality parameters, resulting in less tender and juicy meat samples (Rinaldi et al., 2010).

Another heating method used in meat processing is dehydration, which involves removing moisture using continuous hot air flow. Due to the exposure to high temperature, drying can inactivate microorganisms and chemical components that can contribute to spoilage. Drying is commonly used in the food industry, including method such as hot air, freeze drying, and others (Elmas et al., 2020). Innovations in drying techniques, such as improvements in mechanical drying has largely replaced traditional sun-dry techniques (Moses et al., 2014).

In meat products, conventional drying can increase the shelf life by lowering water activity values. Moreover, another advantage of this process is during transportation, considering the final product is reduced in weight and volume. However, some disadvantages include changes in color, flavor, as well as decreasing nutritional properties such as vitamins and amino acids present in food products (Doymaz et al., 2016). Therefore, selecting the appropriate methodology for drying meat products is crucial to maintaining the integrity of the final product. These characteristics can play a crucial role by influencing purchasing decisions of meat products, particularly those produced for companion animals.

1.6 Intent of purchase among pet owners

Pet owners involvement in purchasing pet food influences the level of effort and interest they invest in the process (Morelli et al., 2021). When selecting pet food, owners base their decisions on various product characteristics, with one of the main parameters being the nutritional aspect that ensures their pet's health (Rogues et al., 2022). Another important parameter evaluated by pet owners regarding food items are associated with the production and processing methods (Rombach & Dean, 2021a). Furthermore, eating behaviors based on social and cultural practices among pet owners can also impact the pet owner's selection and purchasing decisions for pet food (Vinassa et al., 2020).

Pet owners knowledge regarding ingredient safety, nutritional requirements, and reliable information resources also plays a role in influencing their decisions (Michel et al., 2008). Pet food characteristics including ingredients, price, and quality have a great importance for pet owners (Schleicher et al., 2019). Several studies have supported the importance of ingredients in pet food among pet owners as the main factor influencing their decisions (Boya et al., 2015; Simonsen et al., 2014). The relationships between owners and their pets, including the trend of pet humanization, has led to a transfer of human feeding to preferences for pet food products (Chen et al., 2012). Emphasizing in this human-animal bond, owners are having strong relationships with their pets, this resulting in purchasing specialized and premium food for their pets (Bontempo, 2005). Furthermore, owners who prioritize healthy food for themselves are more likely to purchase healthier food for their pets (Jyrinki & Leipamaa-Leskinen, 2006).

Commercial brands and price are also crucial factors when selecting pet food products. One study found that owners who were loyal to brands and responsive to price changes in their own food tend to follow a similar behavior when selecting food items for their companion animals (Chen et al., 2012). A growing trend of caring for pet food are influencing purchasing decisions, with owners prioritizing quality over than price (Boya et al., 2015). When determining the quality of pet food, owners pay close attention to the composition of the food. For instance, owners search for products made with natural ingredients, provide health benefits, are organic, have high protein content, and have other beneficial information for their pets (Vinassa et al., 2020).

According to studies evaluating socio-demographic characteristics and its influence on purchasing decisions among pet owners shown mixed results. Some studies have found that factors including gender, age, income did not affect purchasing choices, while others observed that these factors directly influenced the selection of pet food and other items for pets (Rombach & Dean, 2021b). When selecting pet food items, various characteristics must be considered, and some parameters may be more critical than others, depending on the personal choices of pet owners.

1.7 Sensory evaluation in food products

Sensory evaluation is technique used to assess a product's attributes, such as texture, color, appearance, aroma, and more, as distinguished through the 5 human senses: sight, smell, touch, taste, and hearing (Ruiz-Capillas & Herrero, 2021). In descriptive analysis during sensory evaluation, human subjects are considered instruments, however, they can vary over time, among individuals, and highly susceptible to bias. To obtain reliable and trustworthy results, subjects must undergo training, validation, calibration, and screening process (Meilgaard et al., 2016). Since instruments cannot provide the emotional and psychological responses that humans can, sensory evaluation is valuable for understanding the characteristics of food products (Singh-Ackbarali & Maharaj, 2014).

In terms of sensory evaluation, 3 main types of tests are mainly used to evaluate food items, including affective, discriminative, and descriptive analysis. In affective tests, studies aim to determine the level of liking or disliking that consumers have for a particular product. During sensory evaluation, consumers' scores on liking and preferences can influence the outcomes (Torrico et al., 2018). Additionally, an effective test can evaluate the intent of purchase and product acceptance using a hedonic scale. This scale measures participants' perception of a product by assigning numerical values to their responses, where 1 represents "extremely dislike" and 9 represents "extremely like". These values provide useful feedback for product development. When evaluating intent of purchase using this type of test, over 100 participants are normally recruited to evaluate the product (Ruiz-Capillas & Herrero, 2021).

Discriminative tests in sensory evaluation are performed to detect variations among products. This testing technique is employed to identify minor modifications in the formulation or changes during processing methods (Vivek et al., 2020). Typically, the most common discrimination tests in sensory include the triangle test, duo-trio test, paired comparison test and ranking test (Torrico et al., 2018). For discrimination tests, panelists should not be experts on the products, and the number of participants is smaller compared to hedonic tests (Rousseau, 2015).

Moreover, descriptive tests in sensory analysis are used to evaluate in detail a product's characteristics in detail, such as aroma, color, texture, flavor, appearance, and more, by describing both quantitative and qualitative properties. In terms of quantitative properties, the intensity of each characteristic can be measured by using an intensity rating scale (Vivek et al., 2020). When conducting descriptive tests, panelists must be trained and have some level of sensory accuracy (de Cássia dos Santos Navarro da Silva et al., 2012). Training typically requires developing a specific descriptive language that panelist can apply when scoring a food item (Ray, 2021). The introduction of faster evaluation techniques in descriptive test has made this analysis more flexible, customizable, and efficient (Marques et al., 2022).

In the sensory evaluation of food products, a variety of tests can be use depending on the aim of the study to determine differences or similarities between products (Ruiz-Capillas & Herrero, 2021). When selecting the appropriate test to evaluate sensory characteristics, factors such as type of product, target audience, sensory attributes of the product, panel size, and relevant statistical parameters need to be considered to choose the correct sensory analysis (Meilgaard et al., 2016). Additionally, sensory evaluation is a powerful tool used in the food industry to assess quality parameters and identify improvements in the processes to potentially increase efficiency (Świąder & Marczewska, 2021).

1.8 Sensory evaluation in pet food

Sensory characteristics evaluated in pet food can have an effect on the formulation ingredients, the use of palatants, and the selection of appropriate processing methods (Koppel et al., 2015). Since the final consumer of pet food is not the purchaser, pet food parameters must appeal to the owner to encourage repeat purchases. Likewise, pet owners seek to strength the human-pet bond by providing a sensory experience that satisfy their pets during consumption (Rogues et al., 2022).

Pet owners act as intermediaries between pet food and their pets, evaluating the acceptability of the product. If certain characteristics of the pet food do not meet the owners' standards, they are unlikely to offer it to their pets (Chanadang et al., 2016). Sensory attributes such as appearance, texture, and aroma are essential factors that influence the acceptability of pet food for both pets and owners. By analyzing this sensory information, manufacturers can identify consumer preferences and develop pet food products that appeal to both pets and their owners' expectations (Koppel, 2014).

Sensory evaluation of pet food can be evaluated using either humans or animals, depending on the objective of the project. When evaluating pet food parameters such as appearance, texture, flavor, and aroma, both humans and instruments can be used. However, for consumption or preference tests, these analyses are performed with animals (Koppel, 2014). Various instruments used to evaluate sensory characteristics in pet food include gas chromatography, mass spectrophotometry, high-performance liquid chromatography, electronic nose and tongue systems, and instrumental texture analysis (Koppel, 2014). A descriptive test can be conducted using human panelists, and although human sensory perceptions may differ from those of pets, this data can be valuable to understand owner's acceptability of a pet food product (Di Donfrancesco, 2016).

Regarding pet owners' sensory evaluation of pet food, studies have been conducted to determine factors influencing liking scores and purchasing decisions (Di Donfrancesco et al., 2012; Gomez Baquero et al., 2018; Pickering, 2009). Another common test performed in pet food research is the palatability test, which refers to the sensory response produced during consumption. Based on a previous study, palatability can be influenced by previous exposure to a product (Bradshaw, 2006). In palatability test, feed intake is commonly measured to assess acceptability and preference among pet food products, commonly through 1-bowl test and 2-bowl test (Di Donfrancesco, 2016).

A one-bowl test involves measuring food intake over a set period to assess product acceptance, by comparing the initial weigh of food provided to the animal with the leftover amount in the bowl. When conducting this test, normal feeding parameters can be monitored daily or over a 5-day period, either in a home-used test or a kennel setting (Aldrich & Koppel, 2015). Additionally, a two-bowl test is performed by offering the animal two options simultaneously for a specified time, and then measuring the consumption from each bowl to determine preference (Di Donfrancesco, 2016). It is recommended to conduct the test using 20 animals over a period of 2 to 4 d to obtain more accurate results, and animals should be adapted to the environment conditions (Aldrich & Koppel, 2015).

1.9 References

1. (APPA), A. P. P. A. (2023). Industry trends and stats. American Pet Products Association. Retrieved Feb 13, 2024 from https://www.americanpetproducts.org/research-insights/industry-trends-and-stats

2. (APPA), A. P. P. A. (2024). Industry Trends and Stats. American Pet Products Association. Retrieved Sept 3, 2024 from https://www.americanpetproducts.org/research-insights/industry-trends-and-stats

3. (FDA), F. a. D. A. (2018). FDA Alerts Pet Owners about the Presence of Thyroid Hormones in Certain Milo's Kitchen Pet Treats https://public4.pagefreezer.com/content/FDA/08-02-2022T03:01/https://www.fda.gov/animal-veterinary/outbreaks-and-advisories/fda-alerts-pet-owners-about-presence-thyroid-hormones-certain-milos-kitchen-pet-treats

4. (FDA), F. a. D. A. (2020). Dave's Pet Food Voluntarily Recalls 95% Premium Beef Canned Dog Food Due to Potentially Elevated Levels of Thyroid Hormone https://www.fda.gov/safety/recalls-market-withdrawals-safety-alerts/daves-pet-food-voluntarily-recalls-95-premium-beef-canned-dog-food-due-potentially-elevated-levels

5. Ahmad, R. S., Imran, A., & Hussain, M. B. (2018). Nutritional composition of meat. Meat science and nutrition, 61(10.5772), 61-75.

6. Aldrich, G. (2006). Rendered products in pet food. Essential rendering, 159-178.

7. Aldrich, G., & Koppel, K. (2015). Pet Food Palatability Evaluation: A Review of Standard Assay Techniques and Interpretation of Results with a Primary Focus on Limitations. Animals, 5(1), 43-55. https://doi.org/10.3390/ani5010043

8. Alfaifi, B. M., Al-Ghamdi, S., Othman, M. B., Hobani, A. I., & Suliman, G. M. (2023). Advanced Red Meat Cooking Technologies and Their Effect on Engineering and Quality Properties: A Review. Foods, 12(13), 2564. https://doi.org/10.3390/foods12132564

9. Álvarez, C., Drummond, L., & Mullen, A. M. (2018). Protein recovered from meat co-products and processing streams as pork meat replacers in Irish breakfast sausages formulations. LWT, 96, 679-685.

10. Anzani, C., Boukid, F., Drummond, L., Mullen, A. M., & Álvarez, C. (2020). Optimising the use of proteins from rich meat co-products and non-meat alternatives: Nutritional,

technological and allergenicity challenges. Food Research International, 137, 109575. https://doi.org/https://doi.org/10.1016/j.foodres.2020.109575

11. Banerjee, S., & Bhattacharya, S. (2012). Food gels: gelling process and new applications. Critical reviews in food science and nutrition, 52(4), 334-346.

12. Barbosa-Cánovas, G. V., Fontana Jr, A. J., Schmidt, S. J., & Labuza, T. P. (2020). Water activity in foods: fundamentals and applications. John Wiley & Sons.

13. Beňo, F., Kostlán, J., Pivoňka, J., Pohůnek, V., & Ševčík, R. (2023). Water activity of Czech dry-cured meat products: Influence of sampling point and sample preparation method. Czech Journal of Food Sciences, 41(5), 340-347. https://doi.org/10.17221/99/2023-cjfs

14. Białobrzewski, I., Danowska-Oziewicz, M., Karpińska-Tymoszczyk, M., Nalepa, B., Markowski, M., & Myhan, R. (2010). Turkey breast roasting–Process optimization. Journal of Food Engineering, 96(3), 394-400.

15. Bontempo, V. (2005). Nutrition and health of dogs and cats: evolution of petfood. Veterinary research communications, 29, 45-50.

16. Bourne, M. (2002). Food texture and viscosity: concept and measurement. Elsevier.

17. Boya, U. O., Dotson, M. J., & Hyatt, E. M. (2015). A comparison of dog food choice criteria across dog owner segments: an exploratory study. International Journal of Consumer Studies, 39(1).

18. Bradshaw, J. W. (2006). The evolutionary basis for the feeding behavior of domestic dogs (Canis familiaris) and cats (Felis catus). The Journal of nutrition, 136(7), 1927S-1931S.

19. Burey, P., Bhandari, B., Howes, T., & Gidley, M. (2008). Hydrocolloid gel particles: formation, characterization, and application. Critical reviews in food science and nutrition, 48(5), 361-377.

20. Carter, R. A., Bauer, J. E., Kersey, J. H., & Buff, P. R. (2014). Awareness and evaluation of natural pet food products in the United States. Journal of the American Veterinary Medical Association, 245(11), 1241-1248.

21. Chanadang, S., Koppel, K., & Aldrich, G. (2016). The Impact of Rendered Protein Meal Oxidation Level on Shelf-Life, Sensory Characteristics, and Acceptability in Extruded Pet Food. Animals, 6(8), 44. https://doi.org/10.3390/ani6080044

22. Chen, A., Hung, K.-p., & Peng, N. (2012). A cluster analysis examination of pet owners' consumption values and behavior–segmenting owners strategically. Journal of Targeting, Measurement and Analysis for Marketing, 20, 117-132.

23. Collell, C., Gou, P., Arnau, J., Muñoz, I., & Comaposada, J. (2012). NIR technology for on-line determination of superficial aw and moisture content during the drying process of fermented sausages. Food Chemistry, 135(3), 1750-1755. https://doi.org/https://doi.org/10.1016/j.foodchem.2012.06.036

24. Dainton, A. N., Dogan, H., & Aldrich, C. G. (2021). The Effects of Select Hydrocolloids on the Processing of Pâté-Style Canned Pet Food. Foods, 10(10), 2506. https://doi.org/10.3390/foods10102506

25. de Cássia dos Santos Navarro da Silva, R., Minim, V. P. R., Simiqueli, A. A., da Silva Moraes, L. E., Gomide, A. I., & Minim, L. A. (2012). Optimized Descriptive Profile: A rapid methodology for sensory description. Food Quality and Preference, 24(1), 190-200. https://doi.org/https://doi.org/10.1016/j.foodqual.2011.10.014

26. Di Donfrancesco, B. (2016). Sensory analysis and acceptability of pet food (Publication Number 10244020) [Ph.D., Kansas State University]. ProQuest Dissertations & Theses Global. United States -- Kansas.

http://spot.lib.auburn.edu/login?url=https://www.proquest.com/dissertations-theses/sensory-analysis-acceptability-pet-food/docview/1872364352/se-2?accountid=8421.

27. Di Donfrancesco, B., Koppel, K., & Chambers, E. (2012). An Initial Lexicon for Sensory Properties of Dry Dog Food. Journal of Sensory Studies, 27(6), 498-510. https://doi.org/10.1111/joss.12017

28. Doymaz, İ., Karasu, S., & Baslar, M. (2016). Effects of infrared heating on drying kinetics, antioxidant activity, phenolic content, and color of jujube fruit. Journal of Food Measurement and Characterization, 10(2), 283-291. https://doi.org/10.1007/s11694-016-9305-4

29. Elmas, F., Bodruk, A., Köprüalan, Ö., Arıkaya, Ş., Koca, N., Serdaroğlu, F. M., Kaymak-Ertekin, F., & Koç, M. (2020). Drying kinetics behavior of turkey breast meat in different drying methods. Journal of Food Process Engineering, 43(10). https://doi.org/10.1111/jfpe.13487

30. Food and Drug Administration (2021). OECD-FAO Agricultural Outlook 2021-2030. Food and Drug Administration Retrieved from https://openknowledge.fao.org/server/api/core/bitstreams/09e88a46-b005-4d65-8753-9714506afc38/content

31. Fortune Business Insights (2024). Pet Food Market Size, Share & Industry Analysis By Animal Type (Dogs, Cats, and Others), By Form (Dry Pet Food, Wet Pet Food, and Snacks & Treats), By Distribution Channel (Supermarket/Hypermarket, Specialty Stores, Online Channel, and Others), By Source (Animal and Plant), and Regional Forecast, 2024-2032 https://www.fortunebusinessinsights.com/industry-reports/pet-food-market-100554

32. Goff, H. D., & Guo, Q. (2019). The Role of Hydrocolloids in the Development of Food Structure. In F. Spyropoulos, A. Lazidis, & I. Norton (Eds.), Handbook of Food Structure

Development (pp. 0). The Royal Society of Chemistry. https://doi.org/10.1039/9781788016155-00001

33. Gomez Baquero, D., Koppel, K., Chambers, D., Hołda, K., Głogowski, R., & Chambers, E. (2018). Acceptability of Dry Dog Food Visual Characteristics by Consumer Segments Based on Overall Liking: a Case Study in Poland. Animals, 8(6), 79. https://doi.org/10.3390/ani8060079

34. Goñi, S. M., & Salvadori, V. O. (2010). Prediction of cooking times and weight losses during meat roasting. Journal of Food Engineering, 100(1), 1-11.

35. Gou, P., Comaposada, J., Arnau, J., & Pakowski, Z. (2005). On-Line Determination of Water Activity at the Lean Surface of Meat Products During Drying and Its Relationship with the Crusting Development. Drying Technology, 23(8), 1641-1652. https://doi.org/10.1081/drt-200065033

36. Henchion, M., McCarthy, M., & O'Callaghan, J. (2016). Transforming Beef By-products into Valuable Ingredients: Which Spell/Recipe to Use? Frontiers in Nutrition, 3. https://doi.org/10.3389/fnut.2016.00053

37. Ishiwatari, N., Fukuoka, M., & Sakai, N. (2013). Effect of protein denaturation degree on texture and water state of cooked meat. Journal of Food Engineering, 117(3), 361-369. https://doi.org/https://doi.org/10.1016/j.jfoodeng.2013.03.013

38. Jayakody, M. M., Kaushani, K. G., Vanniarachchy, M. P. G., & Wijesekara, I. (2023). Hydrocolloid and water soluble polymers used in the food industry and their functional properties: a review. Polymer Bulletin, 80(4), 3585-3610. https://doi.org/10.1007/s00289-022-04264-5

39. Jayathilakan, K., Sultana, K., Radhakrishna, K., & Bawa, A. S. (2012). Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. Journal of Food Science and Technology, 49(3), 278-293. https://doi.org/10.1007/s13197-011-0290-7

40. Ježek, F., Kameník, J., Macharáčková, B., Bogdanovičová, K., & Bednář, J. (2019). Cooking of meat: effect on texture, cooking loss and microbiological quality – a review. Acta Veterinaria Brno, 88(4), 487-496. https://doi.org/10.2754/avb201988040487

41. Jyrinki, H., & Leipamaa-Leskinen, H. (2006). Pets as extended self in the context of pet food consumption. European Advances in Consumer Research, 7, 543-549.

42. King, N. J., & Whyte, R. (2006). Does it look cooked? A review of factors that influence cooked meat color. Journal of Food Science, 71(4), R31-R40.

43. Koppel, K. (2014). Sensory analysis of pet foods. Journal of the Science of Food and Agriculture, 94(11), 2148-2153. https://doi.org/10.1002/jsfa.6597

44. Koppel, K., Monti, M., Gibson, M., Alavi, S., Donfrancesco, B., & Carciofi, A. (2015). The Effects of Fiber Inclusion on Pet Food Sensory Characteristics and Palatability. Animals, 5(1), 110-125. https://doi.org/10.3390/ani5010110

45. Kumcu, A., & Woolverton, A. E. (2015). Feeding Fido: Changing Consumer Food Preferences Bring Pets to the Table. Journal of Food Products Marketing, 21(2), 213-230. https://doi.org/10.1080/10454446.2012.715575

46. Kylkilahti, E., Syrjälä, H., Autio, J., Kuismin, A., & Autio, M. (2016). Understanding co-consumption between consumers and their pets. International Journal of Consumer Studies, 40(1), 125-131. https://doi.org/10.1111/ijcs.12230

47. Li, J.-M., & Nie, S.-P. (2016). The functional and nutritional aspects of hydrocolloids in foods. Food Hydrocolloids, 53, 46-61.

48. Lu, W., Li, X., & Fang, Y. (2021). Introduction to Food Hydrocolloids. In (pp. 1-28). Springer Singapore. https://doi.org/10.1007/978-981-16-0320-4_1

49. Lynch, S. A., Mullen, A. M., O'Neill, E., Drummond, L., & Álvarez, C. (2018). Opportunities and perspectives for utilisation of co-products in the meat industry. Meat Science, 144, 62-73. https://doi.org/https://doi.org/10.1016/j.meatsci.2018.06.019

50. Marques, C., Correia, E., Dinis, L.-T., & Vilela, A. (2022). An Overview of Sensory Characterization Techniques: From Classical Descriptive Analysis to the Emergence of Novel Profiling Methods. Foods, 11(3), 255. https://doi.org/10.3390/foods11030255

51. Mcconnell, A. R., Paige Lloyd, E., & Humphrey, B. T. (2019). We Are Family: Viewing Pets as Family Members Improves Wellbeing. Anthrozoös, 32(4), 459-470. https://doi.org/10.1080/08927936.2019.1621516

52. Meeker, D. L. (2009). North American Rendering: processing high quality protein and fats for feed. Revista Brasileira de Zootecnia, 38(spe), 432-440. https://doi.org/10.1590/s1516-35982009001300043

53. Meeker, D. L., & Meisinger, J. L. (2015). COMPANION ANIMALS SYMPOSIUM: Rendered ingredients significantly influence sustainability, quality, and safety of pet food. Journal of Animal Science, 93(3), 835. https://doi.org/10.2527/jas.2014-8524

54. Megna, M. (2024). Pet ownership statisitcs 2024. Forbes Advisor. Retrieved Feb 13, 2024 from https://www.forbes.com/advisor/pet-insurance/pet-ownership-statistics/

55. Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2016). Sensory evaluation tecniques (Fifth Edition ed.).

56. Michel, K. E., Willoughby, K. N., Abood, S. K., Fascetti, A. J., Fleeman, L. M., Freeman, L. M., Laflamme, D. P., Bauer, C., Kemp, B. L., & Van Doren, J. R. (2008). Attitudes of pet owners toward pet foods and feeding management of cats and dogs. Journal of the American Veterinary Medical Association, 233(11), 1699-1703.

57. Milani, J., & Maleki, G. (2012). Hydrocolloids in food industry. Food industrial processes–Methods and equipment, 2, 2-37.

58. Mora, B., Curti, E., Vittadini, E., & Barbanti, D. (2011). Effect of different air/steam convection cooking methods on turkey breast meat:Physical characterization, water status and sensory properties. Meat Science, 88(3), 489-497. https://doi.org/https://doi.org/10.1016/j.meatsci.2011.01.033

59. Morelli, G., Stefanutti, D., & Ricci, R. (2021). A Survey among Dog and Cat Owners on Pet Food Storage and Preservation in the Households. Animals, 11(2), 273. https://doi.org/10.3390/ani11020273

60. Moreno, H. M., Herranz, B., Pérez-Mateos, M., Sánchez-Alonso, I., & Borderías, J. A. (2016). New alternatives in seafood restructured products. Critical reviews in food science and nutrition, 56(2), 237-248.

61. Moses, J. A., Norton, T., Alagusundaram, K., & Tiwari, B. K. (2014). Novel Drying Techniques for the Food Industry. Food Engineering Reviews, 6(3), 43-55. https://doi.org/10.1007/s12393-014-9078-7

62. Mullen, A. M., & Álvarez, C. (2016). Offal: Types and Composition. In B. Caballero, P. M. Finglas, & F. Toldrá (Eds.), Encyclopedia of Food and Health (pp. 152-157). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-384947-2.00501-8

63. Mullen, A. M., Álvarez, C., Zeugolis, D. I., Henchion, M., O'Neill, E., & Drummond, L. (2017). Alternative uses for co-products: Harnessing the potential of valuable compounds from meat processing chains. Meat Science, 132, 90-98.

64. Nations, U. (2015). UNECE Standard Edible Meat Co-Products. In: UN Geneva, Switzerland.

65. Nishinari, K., Zhang, H., & Ikeda, S. (2000). Hydrocolloid gels of polysaccharides and proteins. Current Opinion in Colloid & Interface Science, 5(3), 195-201. https://doi.org/https://doi.org/10.1016/S1359-0294(00)00053-4

66. Nordgård, C. T., & Draget, K. I. (2021). Chapter 26 - Alginates. In G. O. Phillips & P. A. Williams (Eds.), Handbook of Hydrocolloids (Third Edition) (pp. 805-829). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-12-820104-6.00007-3

67. Pathare, P. B., & Roskilly, A. P. (2016). Quality and energy evaluation in meat cooking. Food Engineering Reviews, 8, 435-447.

68. Phillips, G. O., & Williams, P. A. (2009). Handbook of hydrocolloids. Elsevier.

69. Pickering, G. J. (2009). Optimizing the sensory characteristics and acceptance of canned cat food: use of a human taste panel. Journal of Animal Physiology and Animal Nutrition, 93(1), 52-60. https://doi.org/10.1111/j.1439-0396.2007.00778.x

70. Ramírez, J. A., Uresti, R. M., Velazquez, G., & Vázquez, M. (2011). Food hydrocolloids as additives to improve the mechanical and functional properties of fish products: A review. Food Hydrocolloids, 25(8), 1842-1852. https://doi.org/https://doi.org/10.1016/j.foodhyd.2011.05.009

71. Rauktis, M. E., Rose, L., Chen, Q., Martone, R., & Martello, A. (2017). “Their Pets Are Loved Members of Their Family”: Animal Ownership, Food Insecurity, and the Value of Having

Pet Food Available in Food Banks. Anthrozoös, 30(4), 581-593. https://doi.org/10.1080/08927936.2017.1370225

72. Ray, S. (2021). Sensory properties of foods and their measurement methods. Techniques to Measure Food Safety and Quality: Microbial, Chemical, and Sensory, 345-381.

73. Rinaldi, M., Chiavaro, E., & Massini, R. (2010). Apparent thermal diffusivity estimation for the heat transfer modelling of pork loin under air/steam cooking treatments. International Journal of Food Science & Technology, 45(9), 1909-1917.

74. Rogues, J., Csoltova, E., Larose-Forges, C., & Mehinagic, E. (2022). Sensory evaluation of pet food products. In Nonfood Sensory Practices (pp. 313-329). Elsevier.

75. Rombach, M., & Dean, D. L. (2021a). It Keeps the Good Boy Healthy from Nose to Tail: Understanding Pet Food Attribute Preferences of US Consumers. Animals, 11(11), 3301. https://www.mdpi.com/2076-2615/11/11/3301

76. Rombach, M., & Dean, D. L. (2021b). Just Love Me, Feed Me, Never Leave Me: Understanding Pet Food Anxiety, Feeding and Shopping Behavior of US Pet Owners in Covidian Times. Animals, 11(11), 3101. https://doi.org/10.3390/ani11113101

77. Rotstein, D., Jones, J. L., Buchweitz, J., Refsal, K. R., Wilson, R., Yanes, E. G., Heitkemper, D., Edwards, E., Post, L., Palmer, L. A., Carey, L., Wolf, K., Burkholder, W., Ceric, O., Glover, M., Hodges, A., Kemppainen, R. J., Lambkin, S., Lovell, R., . . . Reimschuessel, R. (2021). Pet Food-Associated Dietary Exogenous Thyrotoxicosis: Retrospective Study (2016-2018) and Clinical Considerations. Topics in Companion Animal Medicine, 43, 100521. https://doi.org/https://doi.org/10.1016/j.tcam.2021.100521

78. Rousseau, B. (2015). Sensory discrimination testing and consumer relevance. Food Quality and Preference, 43, 122-125. https://doi.org/https://doi.org/10.1016/j.foodqual.2015.03.001

79. Ruiz-Capillas, C., & Herrero, A. M. (2021). Sensory Analysis and Consumer Research in New Product Development. Foods, 10(3), 582. https://doi.org/10.3390/foods10030582

80. Saengsuk, N., Laohakunjit, N., Sanporkha, P., Kaisangsri, N., Selamassakul, O., Ratanakhanokchai, K., Uthairatanakij, A., & Waeonukul, R. (2022). Comparative physicochemical characteristics and in vitro protein digestibility of alginate/calcium salt restructured pork steak hydrolyzed with bromelain and addition of various hydrocolloids (low acyl gellan, low methoxy pectin and κ-carrageenan). Food Chemistry, 393, 133315. https://doi.org/https://doi.org/10.1016/j.foodchem.2022.133315

81. Saha, D., & Bhattacharya, S. (2010). Hydrocolloids as thickening and gelling agents in food: a critical review. Journal of Food Science and Technology, 47(6), 587-597. https://doi.org/10.1007/s13197-010-0162-6

82. Schleicher, M., Cash, S. B., & Freeman, L. M. (2019). Determinants of pet food purchasing decisions. The Canadian Veterinary Journal, 60(6), 644.

83. Seisun, D., & Zalesny, N. (2021). Strides in food texture and hydrocolloids. Food Hydrocolloids, 117, 106575. https://doi.org/https://doi.org/10.1016/j.foodhyd.2020.106575

84. Serra, X., Ruiz-Ramírez, J., Arnau, J., & Gou, P. (2005). Texture parameters of dry-cured ham m. biceps femoris samples dried at different levels as a function of water activity and water content. Meat Science, 69(2), 249-254. https://doi.org/https://doi.org/10.1016/j.meatsci.2004.07.004

85. Simonsen, J. E., Fasenko, G. M., & Lillywhite, J. M. (2014). The value-added dog food market: do dog owners prefer natural or organic dog foods? Journal of Agricultural Science, 6(6), 86.

86. Singh-Ackbarali, D., & Maharaj, R. (2014). Sensory evaluation as a tool in determining acceptability of innovative products developed by undergraduate students in food science and technology at the University of Trinidad and Tobago. Journal of Curriculum and Teaching, 3(1), 10-27.

87. Statista. (2024, Jun, 2024). Pet Food - United States. Statista Market Insights. Retrieved Jan 9, 2024 from https://www.statista.com/outlook/cmo/food/pet-food/worldwide

88. Świąder, K., & Marczewska, M. (2021). Trends of Using Sensory Evaluation in New Product Development in the Food Industry in Countries That Belong to the EIT Regional Innovation Scheme. Foods, 10(2), 446. https://doi.org/10.3390/foods10020446

89. Tan, C., & McClements, D. J. (2021). Application of Advanced Emulsion Technology in the Food Industry: A Review and Critical Evaluation. Foods, 10(4), 812. https://www.mdpi.com/2304-8158/10/4/812

90. Toldrá, F., Reig, M., & Mora, L. (2021). Management of meat by- and co-products for an improved meat processing sustainability. Meat Science, 181, 108608. https://doi.org/https://doi.org/10.1016/j.meatsci.2021.108608

91. Tornberg, E. (2005). Effects of heat on meat proteins–Implications on structure and quality of meat products. Meat Science, 70(3), 493-508.

92. Torrico, D. D., Hutchings, S. C., Ha, M., Bittner, E. P., Fuentes, S., Warner, R. D., & Dunshea, F. R. (2018). Novel techniques to understand consumer responses towards food products: A review with a focus on meat. Meat Science, 144, 30-42.

93. Varela, P., & Fiszman, S. M. (2011). Hydrocolloids in fried foods. A review. Food Hydrocolloids, 25(8), 1801-1812. https://doi.org/https://doi.org/10.1016/j.foodhyd.2011.01.016

94. Vidyarthi, S., Vaddella, V., Cao, N., Kuppu, S., & Pandey, P. (2021). Pathogens in animal carcasses and the efficacy of rendering for pathogen inactivation in rendered products: A review. Future Foods, 3, 100010.

95. Vinassa, M., Vergnano, D., Valle, E., Giribaldi, M., Nery, J., Prola, L., Bergero, D., & Schiavone, A. (2020). Profiling Italian cat and dog owners' perceptions of pet food quality traits. BMC Veterinary Research, 16(1). https://doi.org/10.1186/s12917-020-02357-9

96. Vinnikova, L., Synytsia, O., & Kyshenia, A. (2019). THE PROBLEMS OF MEAT PRODUCTS THERMAL TREATMENT. Food Science & Technology (2073-8684), 13(2).

97. Vivek, K., Subbarao, K. V., Routray, W., Kamini, N. R., & Dash, K. K. (2020). Application of Fuzzy Logic in Sensory Evaluation of Food Products: a Comprehensive Study. Food and Bioprocess Technology, 13(1), 1-29. https://doi.org/10.1007/s11947-019-02337-4

98. Wilkinson, A. D., & Meeker, D. L. (2021). How agricultural rendering supports sustainability and assists livestock's ability to contribute more than just food. Animal Frontiers, 11(2), 24-34. https://doi.org/10.1093/af/vfab002

99. Wüstenberg, T. (2015). General overview of food hydrocolloids. Cellulose and Cellulose Derivatives in the Food industry Fundamentals and Applications; Wüstenberg, T., Ed, 1-68.

100. Zielbauer, B. I., Franz, J., Viezens, B., & Vilgis, T. A. (2016). Physical Aspects of Meat Cooking: Time Dependent Thermal Protein Denaturation and Water Loss. Food Biophysics, 11(1), 34-42. https://doi.org/10.1007/s11483-015-9410-7

Chapter II. Effect of dehydration time on physicochemical and textural properties of jerky-style pet treats made with swine pluck

2.1 Abstract

With the increasing humanization of pets and their roles as integral family members, the pet food and treat market continues to expand annually, with a compound annual growth rate (CAGR) of 5.26% from 2024 to 2029. Meat animal processing co-products are often sold at a low value for the rendering process. On average, 44% of the pig's live weight is considered offal, often undervalued animal processing co-products. The pet food industry utilizes these co-products as a rich protein source for pet food and treats. Consequently, swine pluck (SP), a combination of heart, lungs, esophagus, and trachea (without the thyroid gland), can be included as a protein source in pet food and treats due to its convenient single-unit removal during processing. Sensory parameters such as texture and color can play a major role in the purchasing decisions of pet owners. Therefore, quantitative data on sensory parameters can be used to assess the suitability of a new product for the market when combined with pet owner preference information. The aim of the study was to determine the effect of dehydration time on various organoleptic characteristics, such as physicochemical, textural, and color parameters, on jerky-style treats made with SP. For sample preparation, raw SP was ground using a 4.76-mm grinder plate, mixed with sodium alginate (1%) and encapsulated calcium lactate (0.85%), extruded into jerky strips, and refrigerated for 16 h at 4 ºC to allow product gelation. Then, 76.2-mm jerky strip samples were dehydrated at 68 ºC for five different dehydration times (3, 4, 5, 6, and 7 h). For data collection, $n \geq 8$ samples were used in each analysis. The AOAC 950.46 moisture content method was used to determine moisture content (MC). Water activity (a_w) was measured using an Aqualab 4TE water activity meter. A TA-HD plus C texture analyzer was used to conduct a 3-point-bend (3PB) test using a TA-43R probe and a shear force (SF) test using a TA-42 45° angle chisel blade probe. Data were analyzed as a 1-way ANOVA for texture and physicochemical parameters using the GLIMMIX procedure of SAS ver. 9.4 with means separated at $P \leq 0.05$. As expected, MC and a_w decreased linearly as dehydration time increased and were lowest in the 7 h treats ($P < 0.0001$). Based on 3PB parameters, samples dehydrated for 7 h were the hardest ($P < 0.0001$) and stiffest ($P < 0.0001$). Meanwhile, based on SF, the SP product flexibility was greatest following 3 or 4 h of dehydration ($P < 0.0465$). The 6 and 7 h SP samples were firmer ($P < 0.0001$) and tougher ($P < 0.0001$) than their 3 and 4 h counterparts. Overall, SP can generate shelf-stable jerky-style pet treats with varying textural characteristics depending on dehydration time, providing value to the meat and pet food industries. Future work will assess pet owners' preference for SP treats with different textural characteristics.

2.2 Keywords: Moisture content, water activity, three-point bend, shear force, pet treats, co-products

2.3 Introduction

Globally, the United States has been considered the third largest consumer and producer of pork. Nonetheless, in recent times, the U.S. has ascended to become the second-largest pork meat exporter (USDA, 2024). During pork processing, only around 56% of a pig's live weight is intended for human consumption. The remainder processing co-products are typically not used by the meat industry and are often redirected to the rendering industry. Rendering involves converting various animal processing co-products into animal protein meals through chemical and physical processes (Aldrich, 2006). These co-products are considered a rich source of protein, lipids, vitamins, and minerals (Mullen et al., 2017).

Swine pluck (SP), a co-product of pig processing, can be removed from the carcass as a single unit, offering a convenient method for processing plants. Swine pluck combines the lungs, heart, esophagus, and trachea, excluding the thyroid gland. The FDA has raised concerns about the safety of thyroid hormones in pet food, as highlighted in official communications to pet food industry members (Rotstein et al., 2021). Transforming co-products, such as SP, into more valuable products could reduce waste generation, making the meat industry more profitable and sustainable (Toldrá et al., 2021).

Some organs can be utilized for pet food and rendering; numerous non-edible co-products can be further explored for use in pet food (Shirsath & Henchion, 2021). The pet food industry is under continuous changes due to market trends. Increase in pet ownership combined with the humanization of pets, has led to a rise in the production of pet food and treats resulting in owners spending more time with their pets, and buying more pet food (IBISWorld, 2023).

As reported by the Association of Pet Products (APPA), 66% of households in the U.S., or approximately 89.1 million homes, owned a pet in 2023 ((APPA), 2023). The pet food and treat market has expanded annually, with a compounds annual growth rate (CAGR) of 5.26% from 2024 to 2029. Various market trends can influence purchasing decisions. One trend among pet owners is the emphasis on pet food's nutritional aspects, driven by their perception of themselves as pet parents. Incorporating specialized and innovative ingredients in the production process can be vital for the pet food industry (Watson et al., 2023). A study conducted with pet owners found that 43.6% were willing to buy healthier food for their pets than for themselves, indicating that owners prioritize their pets' health (Schleicher et al., 2019).

Pet owners are constantly seeking ways to strengthen their bond with their pets. Offering treats not only enhances their emotional connection but also facilitates the mutual expression of affection (Nielson et al., 2024). Approximately 77 to 94% of pet owners regularly provide treats to their pets. Given this high demand, manufacturers often employ thermal treatments to enhance production factors such as shelf life and texture (Oba et al., 2022). Drying preserves a product by reducing its water activity and moisture content, thus enhancing its stability. However, in meat, this process causes protein shrinkage, forming moisture channels for evaporation, leading to dryness and smaller size. Prolonged drying can also increase meat hardness (Lim et al., 2012; Shi et al., 2021).

Controlling water activity during the dehydration process is essential for maintaining product stability. For jerky products, a_w should be 0.85 or below to avoid microorganism growth and enhance stability (Juneja et al., 2016). The moisture content of jerky also plays a role in growth of microorganisms (Ku et al., 2013). The drying temperature and speed greatly influence the texture of a product. Elevated temperatures and rapid drying can lead to more pronounced changes, such as increased hardness due to more water being eliminated. Conversely, if the product does not shrink, the surface will have a porous and smoother texture (Guiné, 2018). Hydrocolloids, are commonly employed to improve the appearance and texture of food products. In restructured products, selecting the appropriate hydrocolloids and the inclusion rate is essential to achieving the desired physicochemical properties (Presume et al., 2022).

The texture of pet food is a significant factor influencing pet owners' perception of their pet's meals. A study has found that appearance can affect owners' preferences (Di Donfrancesco et al., 2014). Shear force is generally used in texture analysis to determine the meat tenderness in a product (Baldassini et al., 2021). On the other hand, a 3PB test measures the bending or flexibility properties of a product, by measuring the hardness to break or fractures during the breaking process (Stable Micro Systems, 2024).

Despite pet food not being meant for human consumption, pet owners made the initial approach and acceptance of the product (Delime et al., 2020). However, data on quantitative parameters in pet treats is limited and typically reserved for internal use by the manufacturer. This study aims to analyze the effects of dehydration time on the physicochemical and textural properties of jerky-style pet treats made with swine pluck.

2.4 Materials and Methods

2.4.1 Raw materials and preparation of ingredients

Swine pluck (SP) was the primary ingredient in formulating jerky-style pet treats for this study. SP combines the trachea, heart, lungs, and esophagus removed as a single unit during processing. The thyroid gland was removed from each SP used for this experiment. Raw SP was collected in the Lambert-Powells Meats Lab at Auburn University, and the product was stored at

-20 °C to prevent deterioration. SP was thawed at 4 °C for 48 h prior to grinding through a 4.76-mm-diameter plate using a commercial mixer 20 Qt meat grinder (Avantco equipment, China).

2.4.2. Inclusion of the structure forming technology

A combination of 1% sodium alginate (SA; Tilley Distribution, Waldo, ME, United States) and 0.85% encapsulated calcium lactate (ECL; Balchem, 52 Sunrise Park Rd, New Hampton, NY, United States) were mixed with the total amount of ground raw SP. The mixture of SA and ECL was referred to as ALGIN. According to the Food and Drug Administration (FDA), 1% of SA is considered the highest permissible level of SA inclusion in meat products for human consumption (FDA, 2023). For the sample mixture, half of the SA was added and mixed at a low speed for 30 s, then increased to a fast speed for another 30 s. Subsequently, the second half of the SA was added, following the same mixing process. Similarly, ECL was added following the previous mixing process.

2.4.3 Extrusion and dehydration of the samples

Ground SP mixture was extruded into jerky strips using a 38.1-mm wide single-strip nozzle probe, then covered with plastic wrapped to prevent moisture from being loss and refrigerated at 4 °C for 16 h to allow product gelation. The long jerky strips were cut into shorter pieces of the desired length (approximately 76.2 mm). For the dehydration process, the dehydrator oven (KWASYO Food Dehydrator Machine, China) was pre-heated to its maximum temperature (90 °C) for 8 min. Jerky-style strips were transferred to metal racks and placed into the pre-heated dehydrator. The temperature of the dehydrator oven decreased to 68.3 °C, and samples were collected hourly (3 to7 h) until dehydration was completed. After samples accomplished 7 h of dehydration, water activity (a_w) equal to or less than 0.85 was achieved.

2.4.4 Moisture content

The jerky-style pet treats' moisture content (MC) was calculated using the gravimetric moisture determination method. The AOAC 950.46 methodology was employed to measure the MC of the samples (AOAC official method 950.46). For this method, a total of 8 samples per dehydration time were weighed and placed in metal trays. After recording the weight of each sample, the samples were placed in a pre-heated convection oven at 125 °C for 2 h. This was followed by a cooling step, where the samples were placed into plastic desiccators containing desiccants for 1 hour. Subsequently, each dehydrated sample was weighted, and the moisture content was determined using the following formula:

$$MC = \frac{w - d}{w} \times 100$$

In the previous formula, w indicates the weight of the jerky-style pet treat before the drying process, and d indicates the weight of the jerky-style pet treats after the drying process.

2.4.5 Water activity

Water activity (a_w) was measured on dehydrated jerky-style samples to ensure the appropriate reduction of free and non-bound water in the product and to inhibit microbial growth in the samples using an AQUALAB 4TE water activity meter (Pullman, WA, United States). For this test, a_w cups were filled with approximately 3.5 to 5.0 g of chopped product until it covered the bottom of the cup. The temperature of the samples was < 25 °C to ensure appropriate water activity readings. The equipment was calibrated using saline standards of 0.760 to 0.920 a_w. A total of 8 samples per dehydration time were analyzed for water activity.

2.4.6 Three-point bend

A three-point bend test (3PB) was conducted using a TA-HD Plus C texture analyzer, which was equipped with a 50-kg load cell and a TA-43 round blade (Stable Micro Systems, Lammas Rd, Godalming, United Kingdom). The test was performed with the following settings: test speed set to 1 mm per s, trigger force was set to 12 g, and the distance between the pillars was set to 22 mm. All parameters were measured in a single-cycle compression. A total of 24 samples per dehydration time were evaluated for 3PB test. The test measures hardness (g), denoted as the maximum force required to break the sample, flexibility (mm), defined as the distance covered by the sample before it fractures, and stiffness (g per mm), represents the sample's resistance to bending.

2.4.7 Shear force

Shear force test (SF) was performed using a TA-HD Plus C texture analyzer, equipped with a 50-kg load cell and TA-45° chisel blade probe (Stable Micro Systems, Lammas Rd, Godalming, United Kingdom). Shear force test was conducted with the following settings test speed set to 2 mm per s, each sample was compressed to 93% of the initial height of the jerky strip and the trigger force was set to 3 g. A total of 32 samples per dehydration time were analyzed for SF test. The parameters measured in this test include firmness (g), representing the maximum force required to shear the sample, and toughness (g per s), defined as the greater cutting force over a determined distance.

2.4.8 Statistical analysis

Data were analyzed as a 1-way ANOVA for physicochemical parameters and texture. The analyses were conducted using a generalized linear mixed model (GLIMMIX) procedure in the

Statistical Analysis Software (SAS) version 9.4 (SAS Institute Inc., Cary, NC, USA). Dehydration time was the main effect evaluated for each parameter. Each jerky-style pet treat unit served as the experimental unit. Least square means were separated using the PDIFF option of SAS to perform a complete pairwise mean comparison analysis. The Satterthwaite adjustment was applied to correct the degrees of freedom. Significant differences between means were declared at $P \leq 0.05$.

2.5 Results and Discussion

2.5.1 Moisture content

Results for physicochemical parameters, specifically MC of dehydrated jerky-style pet treats, are shown in Table 2.1. As dehydration time increased, the MC of the samples decreased linearly ($P < 0.0001$). The samples dehydrated for 3 h had the highest MC value of 49.20%, while those dehydrated for 7 h had the lowest MC value of 17.26%. According to a previous study, the moisture content of pork jerky samples decreased as dehydration time increased (Yang et al., 2012). Similarly to these results, when binding ingredients were added into the matrix of the dried product, the moisture content was lower in the samples dehydrated the longest (Choi et al., 2015). This pattern is consistent with our findings.

Based on data reported by Konieczny et al. (2007), the moisture content of beef jerky samples decreased as drying time increased. Samples with no heat exposure had the highest moisture content, whereas those dehydrated for 7 h had the lowest moisture content compared to all treatments (Konieczny et al., 2007). Similar results were observed in a study where sodium alginate and calcium chloride were used as gelling agents in dried scallops, leading to lower moisture content values in samples containing gelling agents compared with the control (Shi et al., 2019). This outcome can be attributed to the chemical properties of sodium alginate, since it is primarily composed of polysaccharides and their high polarity results in a lower moisture barrier property (Shi et al., 2019).

2.5.2 Water activity

Results for water activity (a_w) of dehydrated SP jerky-style pet treats are presented in Table 2.1. The lowest water activity was observed in samples dehydrated for 7 h ($P < 0.0001$). Samples reached a water activity of 0.85 after 5 h of dehydration and decreased to 0.81 and 0.80 after 6 and 7 h of dehydration, respectively. Water activity in SP jerky-style pet treats decreased linearly as dehydration time increased ($P < 0.0001$). However, Ramírez-Cárdenas (2015) observed different results in dehydrated beef jerky samples during 4, 5, and 6 h, where all treatments achieved a water activity of 0.85, and no differences were found among the treatments (Ramírez-Cárdenas, 2015). In contrast, Kim et al. (2018) reported that the water activity of semi-dried restructured jerky decreased with longer dehydration periods, which could be associated to the reduction of free water in the food matrix at a constant rate (Kim et al., 2018). Based on both studies, a linear decrease in water activity was observed in the reconstituted product compared to whole muscle.

2.5.4. Three-point bend

Table 2.2 includes the results for three-point bend (3PB) test of dehydrated SP jerky-style samples. As dehydration time increased, hardness of the samples increased ($P < 0.0001$), with samples dehydrated for 7 h requiring the maximum force to deform the treats. Opposite results were found for flexibility measurements, samples dehydrated for 3 and 4 h were the most flexible ($P < 0.0001$), thus requiring a greater distance before fracturing. However, samples dehydrated for 4 h were statistically similar as those dehydrated for 5, 6, and 7 h. Furthermore, jerky-style samples dehydrated for 7 h had the highest stiffness values compared to other treatments (*P* < 0.0001), thus having the greater resistance to bending. Samples dehydrated for 3 and 4 h had the lowest stiffness values, while samples dehydrated for 5 and 6 h were intermediate.

The hardness and stiffness results differ from those observed by Konieczny et al. (2007) in beef jerky, where the hardness of dehydrated samples decreased as drying time increased, resulting in the lowest hardness values in samples dehydrated for 7 h. According to the same study, the stiffness values of beef jerky samples also decreased as dehydration time increased, with samples dehydrated for 5, 6, and 7 h having the lowest resistance to bending. For flexibility, similar results to this study were found, with samples dehydrated for 3 h being the most flexible compared to other treatments (Konieczny et al., 2007).

The differences in results between the studies could be explained by the composition of the jerky-style strips. One product was made with SP and gelling agents, and the other with beef short loin. According to findings reported on ostrich jerky samples, the hardness and stiffness values differ from those found in our study, where significant differences among temperature exposure were observed on dehydrated samples, thus associated with the moisture content. Samples dehydrated at 50 °C with the highest MC value (24%) required the lowest force to deform the sample and were the least resistance to bending compared to other treatments. Regarding flexibility, similar results were observed with those samples dehydrated at the lowest temperature, requiring the greater distance before fracturing, being the most flexible (Lee & Kang, 2003). Differences between studies could be attributed to the product matrix, experimental design, and the different ingredients used in the sample preparation for each product.

2.5.5 Shear force

Results for shear force (SF) test of dehydrated SP jerky-style pet treats are shown in Table 2.3. For firmness, samples dehydrated for 6 and 7 h required a higher amount of force to be sheared. However, samples dehydrated for 7 h were expressed similar firmness attributes to those dehydrated for 5 h. Additionally, the samples dehydrated for 3 h had the lowest firmness values ($P < 0.0001$). Toughness of samples dehydrated for 6 and 7 h were statistically similar, both having the greatest cutting force over a determined distance compared to all other treatments. Moreover, the samples dehydrated for 3 h had the lowest toughness values ($P < 0.0001$).

Similar results were found in jerky samples made from chicken breast; samples dehydrated for an extended period exhibited greater shear force values, indicating that shear force increased with longer dehydration times (Li et al., 2014). Similarly, a study on pork jerky samples reported that those dehydrated for 1.5 h and roasted at 150 °C for 5 minutes had a lower shear force values compared to samples roasted at 200 °C for 5 minutes (Chen et al., 2004). This suggests that samples with greater heat exposure were firmer and tougher. Another study on beef jerky samples reported differences in samples dehydrated under confined conditions, finding that shear force increased as moisture content of the samples decreased (He et al., 2023).

According to data from Kim et al. (2021), the moisture content of the samples can be associated to the texture of restructured pork. Samples subjected to drying method became harder and tougher due to the formation of a surface layer while dehydrating, which prevents the release of internal moisture, resulting in product shrinkage (Kim et al., 2021). Regarding the inclusion of hydrocolloids in the samples, a study conducted on canned cat food found similar findings on firmness and toughness values. However, shear force values increased with higher hydrocolloids inclusion. This can be attributed to the structure of hydrocolloids, as the amount of hydrocolloids increases, more hydroxyl groups are generated, ultimately resulting in stronger bonds with water (Dainton et al., 2021).

2.6 Conclusions

Dehydration time can play a crucial role in physicochemical characteristics of jerky-style pet treats made with SP. Specifically, as dehydration time increases, the moisture content and water activity of the pet treats decreased, with the lowest levels observed in treats dehydrated for 7 h. However, to achieve a water activity level of 0.85 and be deemed shelf-stable, SP treats must be dehydrated for a minimum of 5 h. Consequently, jerky-style pet treats dehydrated for 7 h were the hardest and stiffest, while those dehydrated for 3 and 4 h were the most flexible. Furthermore, samples dehydrated for 6 and 7 h were firmer and tougher compared to those dehydrated for 3 and 4 h.

Pet owners find dry pet food convenient due to its extended shelf-life (Le Guillas et al., 2024). According to a previous study, understanding pet and owners' characteristics regarding pet food can be one of the major factors influencing purchasing decisions (Schleicher et al., 2019). Therefore, swine pluck can be used to generate shelf-stable, jerky-style pet treats with varying textural and organoleptic characteristics dependent upon dehydration time, thus providing value for both the meat and the pet food industries.

2.7 References

1. (APPA), A. P. P. A. (2023). *Industry trends and stats*. American Pet Products Association. Retrieved Feb 13, 2024 from https://www.americanpetproducts.org/research-insights/industry-trends-and-stats

2. Aldrich, G. (2006). Rendered products in pet food. *Essential rendering*, 159-178.

3. Baldassini, W. A., Machado Neto, O. R., Fernandes, T. T., De Paula Ament, H., Luz, M. G., Santiago, B. M., Curi, R. A., & Chardulo, L. A. L. (2021). Testing different devices to assess the meat tenderness: preliminary results. *Journal of Food Science and Technology*, *58*(6), 2441-2446. https://doi.org/10.1007/s13197-020-04941-1

4. Chen, W. S., Liu, D. C., & Chen, M. T. (2004). Determination of Quality Changes throughout Processing Steps in Chinese-style Pork Jerky. *Asian-Australasian Journal of Animal Sciences*, *17*(5), 700-704. https://doi.org/10.5713/ajas.2004.700

5. Choi, Y.-S., Ku, S.-K., Park, J.-D., Kim, H.-J., Jang, A., & Kim, Y.-B. (2015). Effects of Drying Condition and Binding Agent on the Quality Characteristics of Ground Dried-Pork Meat Products. *Korean Journal for Food Science of Animal Resources*, *35*(5), 597-603. https://doi.org/10.5851/kosfa.2015.35.5.597

6. Dainton, A. N., Dogan, H., & Aldrich, C. G. (2021). The Effects of Select Hydrocolloids on the Processing of Pâté-Style Canned Pet Food. *Foods*, *10*(10), 2506. https://doi.org/10.3390/foods10102506

7. Delime, P., Koppel, K., Pachot, P., & De Ratuld, A. (2020). How the odor of pet food influences pet owners' emotions: A cross cultural study. *Food Quality and Preference*, *79*, 103772. https://doi.org/https://doi.org/10.1016/j.foodqual.2019.103772

8. Di Donfrancesco, B., Koppel, K., Swaney-Stueve, M., & Chambers, E. (2014). Consumer Acceptance of Dry Dog Food Variations. *Animals*, *4*(2), 313-330. https://doi.org/10.3390/ani4020313

9. CFR - Code of Federal Regulations Title 21, (2023). https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=184.1724

10. Guiné, R. P. F. (2018). The Drying of Foods and Its Effect on the Physical-Chemical, Sensorial and Nutritional Properties. *ETP International Journal of Food Engineering*, 93-100. https://doi.org/10.18178/ijfe.4.2.93-100

11. He, J., Jia, W., Lin, Z., Zhang, Y., Zhao, Y., & Fang, Y. (2023). Improving the quality and processing efficiency of beef jerky via drying in confined conditions of pre-stretching. *Food Research International*, *172*, 113171.

12. IBISWorld. (2023). *Pet Food Production in the US - Market Size, Industry Analysis, Trends and Forecasts (2024-2029)* https://www.ibisworld.com/united-states/market-research-reports/pet-food-production-industry/#IndustryStatisticsAndTrends

13. Juneja, V. K., Valenzuela-Melendres, M., Heperkan, D., Bautista, D., Anderson, D., Hwang, C.-A., Peña-Ramos, A., Camou, J. P., & Torrentera-Olivera, N. (2016). Development of a predictive model for Salmonella spp. reduction in meat jerky product with temperature, potassium sorbate, pH, and water activity as controlling factors. *International Journal of Food Microbiology*, *236*, 1-8.

14. Kim, S.-M., Kim, T.-K., Kim, H.-W., Jung, S., Yong, H. I., & Choi, Y.-S. (2021). Quality Characteristics of Semi-Dried Restructured Jerky Processed Using Super-Heated Steam. *Foods*, *10*(4), 762. https://doi.org/10.3390/foods10040762

15. Kim, T.-K., Shim, J.-Y., Hwang, K.-E., Kim, Y.-B., Sung, J.-M., Paik, H.-D., & Choi, Y.-S. (2018). Effect of hydrocolloids on the quality of restructured hams with duck skin. *Poultry Science*, *97*(12), 4442-4449. https://doi.org/https://doi.org/10.3382/ps/pey309

16. Konieczny, P., Stangierski, J., & Kijowski, J. (2007). Physical and chemical characteristics and acceptability of home style beef jerky. *Meat Science*, *76*(2), 253-257.

17. Ku, S. K., Park, J. D., Lee, N. H., Kim, H. J., & Kim, Y. B. (2013). Physicochemical and Sensory Properties of Restructured Jerky with Four Additives. *Korean Journal for Food Science of Animal Resources*, *33*(5), 572-580. https://doi.org/10.5851/kosfa.2013.33.5.572

18. Le Guillas, G., Vanacker, P., Salles, C., & Labouré, H. (2024). Insights to Study, Understand and Manage Extruded Dry Pet Food Palatability. *Animals*, *14*(7), 1095.

19. Lee, S. W., & Kang, C. S. (2003). Effects of moisture content and drying temperature on the physicochemical properties of ostrich jerky. *Food / Nahrung*, *47*(5), 330-333. https://doi.org/10.1002/food.200390076

20. Li, M., Wang, H., Zhao, G., Qiao, M., Li, M., Sun, L., Gao, X., & Zhang, J. (2014). Determining the drying degree and quality of chicken jerky by LF-NMR. *Journal of Food Engineering*, *139*, 43-49.

21. Lim, D.-G., Lee, S.-S., Seo, K.-S., & Nam, K.-C. (2012). Effects of Different Drying Methods on Quality Traits of Hanwoo Beef Jerky from Low-Valued Cuts during Storage. *Korean Journal for Food Science of Animal Resources*, *32*(5), 531-539. https://doi.org/10.5851/kosfa.2012.32.5.531

22. Mullen, A. M., Álvarez, C., Zeugolis, D. I., Henchion, M., O'Neill, E., & Drummond, L. (2017). Alternative uses for co-products: Harnessing the potential of valuable compounds from meat processing chains. *Meat Science*, *132*, 90-98.

23. Nielson, S. A., Khosa, D. K., Verbrugghe, A., & Clow, K. M. (2024). Talking treats: A qualitative study to understand the importance of treats in the pet-caregiver relationship. *Preventive Veterinary Medicine*, *226*, 106163. https://doi.org/https://doi.org/10.1016/j.prevetmed.2024.106163

24. Oba, P. M., Hwisa, N., Huang, X., Cadwallader, K. R., & Swanson, K. S. (2022). Nutrient and Maillard reaction product concentrations of commercially available pet foods and treats. *Journal of Animal Science*, *100*(11). https://doi.org/10.1093/jas/skac305

25. Presume, M. R., Soler, R. F., Chilenje, M. E., Sandoval, J. L., Avila, L. P., Garner, L. J., Mason, R. P., Altom, E. K., & Starkey, C. W. (2022). Physicochemical Parameters of Raw Pet Food and Dehydrated Pet Treats Developed from Beef Processing Co-Products. *Animals*, *12*(3), 278. https://doi.org/10.3390/ani12030278

26. Ramírez-Cárdenas, L. (2015). Effect of drying time and different beef muscles cuts on physicochemical and sensory characteristics of dried meat (Jerky). *Av. Cienc. Ing.(Quito)*, *7*, C31-C38.

27. Rotstein, D., Jones, J. L., Buchweitz, J., Refsal, K. R., Wilson, R., Yanes, E. G., Heitkemper, D., Edwards, E., Post, L., Palmer, L. A., Carey, L., Wolf, K., Burkholder, W., Ceric, O., Glover, M., Hodges, A., Kemppainen, R. J., Lambkin, S., Lovell, R., . . . Reimschuessel, R. (2021). Pet Food-Associated Dietary Exogenous Thyrotoxicosis: Retrospective Study (2016-2018) and Clinical Considerations. *Topics in Companion Animal Medicine*, *43*, 100521. https://doi.org/https://doi.org/10.1016/j.tcam.2021.100521

28. Schleicher, M., Cash, S. B., & Freeman, L. M. (2019). Determinants of pet food purchasing decisions. *The Canadian Veterinary Journal*, *60*(6), 644.

29. Shi, Q., Tian, Y., Zhu, L., & Zhao, Y. (2019). Effects of sodium alginate-based coating pretreatment on drying characteristics and quality of heat pump dried scallop adductors. *Journal of the Science of Food and Agriculture*, *99*(10), 4781-4792. https://doi.org/10.1002/jsfa.9728

30. Shi, S., Feng, J., An, G., Kong, B., Wang, H., Pan, N., & Xia, X. (2021). Dynamics of heat transfer and moisture in beef jerky during hot air drying. *Meat Science*, *182*, 108638.

31. Shirsath, A. P., & Henchion, M. M. (2021). Bovine and ovine meat co-products valorisation opportunities: A systematic literature review. *Trends in Food Science & Technology*, *118*, 57-70. https://doi.org/https://doi.org/10.1016/j.tifs.2021.08.015

32. Stable Micro Systems (2024). *Fracture/Bending Tests*. Stable Micro Systems. Retrieved Sep 23 from https://www.stablemicrosystems.com/fracture-and-bend-testing.html

33. Toldrá, F., Reig, M., & Mora, L. (2021). Management of meat by- and co-products for an improved meat processing sustainability. *Meat Science*, *181*, 108608. https://doi.org/https://doi.org/10.1016/j.meatsci.2021.108608

34. USDA. (2024). *Hogs & Pork*. USDA: USDA Retrieved from https://www.ers.usda.gov/topics/animal-products/hogs-pork/

35. Watson, P. E., Thomas, D. G., Bermingham, E. N., Schreurs, N. M., & Parker, M. E. (2023). Drivers of Palatability for Cats and Dogs—What It Means for Pet Food Development. *Animals*, *13*(7), 1134. https://doi.org/10.3390/ani13071134

36. Yang, H.-S., Kang, S.-W., Joo, S.-T., & Choi, S.-G. (2012). Effects of salt concentration and drying time on the quality characteristics of pork jerky during dehydration. *Korean J. Food Sci. An*, *32*, 285-292.

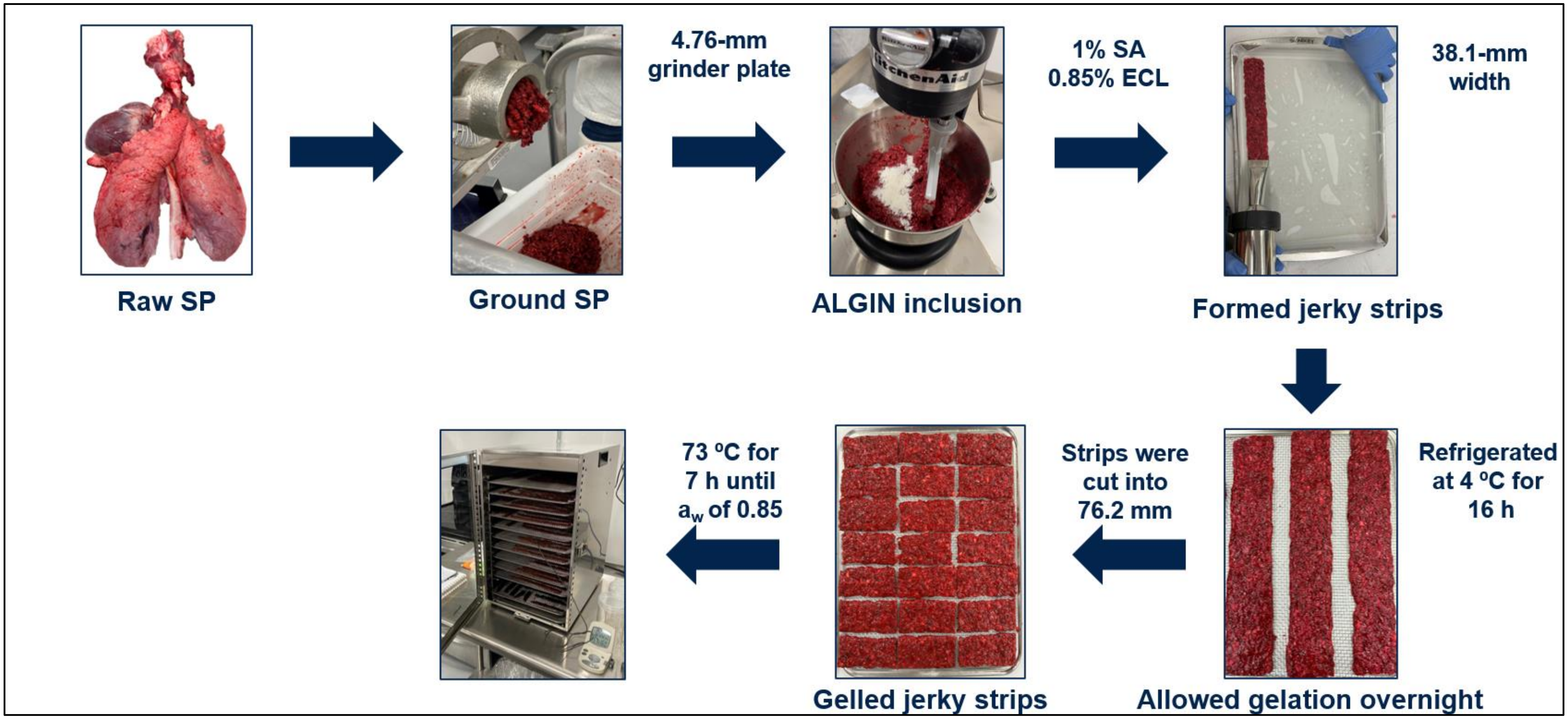

Figure 2.1 Sample preparation of dehydrated jerky-style pet treats made with swine pluck (SP) mixed with 1% sodium alginate (SA) and 0.85% encapsulated calcium lactate (ECL).

Table 2.1 Effect of dehydration time on physicochemical characteristics of dehydrated jerky-style pet treats made with swine pluck.

	Physicochemical characteristics of dehydrated SP jerky-style pet treats[1]						
	Dehydration time (h)[2]						
Variable	3	4	5	6	7	SEM[3]	*P* - value
Moisture content, %	49.20[a]	35.91[b]	29.73[c]	23.39[d]	17.26[e]	1.14	< 0.0001*
Water activity, a_w	0.94[a]	0.90[b]	0.86[c]	0.81[d]	0.80[e]	0.14	< 0.0001*

[1] The dehydration of jerky-style pet treats took place in a dehydrator set at 68.3 °C until each dehydration time was reached.
[2] Dehydration time was collected during five different periods including 3, 4, 5, 6, and 7 h.
[3] SEM = highest standard error of the LS means.
[a-e] Means within a row with different superscripts differ at $P < 0.05$.

Table 2.2 Effect of dehydration time on the three-point bend test of dehydrated jerky-style pet treats made with swine pluck.

	Three-point bend[1] of dehydrated jerky-style pet treats[2]						
	Dehydration time (h)[3]						
Variable	3	4	5	6	7	SEM[4]	*P* - value
Hardness, g	307.96[e]	580.89[d]	950.26[c]	1,376.86[b]	1,658.5[a]	93.00	< 0.0001*
Flexibility, mm	5.31[a]	4.78[ab]	4.59[b]	4.53[b]	4.32[b]	0.25	< 0.0001*
Stiffness, g per mm	60.91[c]	142.78[c]	233.39[b]	276.46[b]	438.03[a]	35.55	< 0.0001*

[1] Three-point bend test was conducted using a TA-43 round probe.

[2] The dehydration of jerky-style pet treats took place in a dehydrator set at 68.3 °C until each dehydration time was reached.

[3] Dehydration time was collected during five different periods including 3, 4, 5, 6, and 7 h.

[4] SEM = highest standard error of the LS means.

[a-e] Means within a row with different superscripts differ at $P < 0.05$.

Table 2.3 Effect of dehydration time on the shear force test of dehydrated jerky-style pet treats made with swine pluck.

	Shear force[1] of dehydrated jerky-style pet treats[2]						
	Dehydration time (h)[3]						
Variable	3	4	5	6	7	SEM[4]	*P* - value
Firmness, g	6,739.29[d]	10,340[c]	15,306[b]	17,859[a]	16,805[ab]	696.92	< 0.0001*
Toughness, g per s	3,989.35[d]	6,842.11[c]	10,790[b]	12,936[a]	13,867[a]	496.40	< 0.0001*

[1] Shear force test was done using a TA-43 45° chisel blade probe.

[2] The dehydration of jerky-style pet treats took place in a dehydrator set at 68.3 °C until each dehydration time was reached.

[3] Dehydration time was collected during five different periods including 3, 4, 5, 6, and 7 h.

[4] SEM = highest standard error of the LS means.

[a-e] Means within a row with different superscripts differ at $P < 0.05$.

Chapter III. Effect of dehydration time on instrumental color characteristics of jerky-style pet treats using made with pluck

3.1 Abstract

Color changes in meat products, influenced by factors such as heating exposure, heating time, and myoglobin content, are crucial in shaping pet owners' preferences, particularly in pet food products. During the dehydration process, the meat protein can denature, thus altering the appearance and color quality of meat products. The color of pet treats has been associated with pet owners' overall liking and purchasing decisions for pet food items. Therefore, the study aims to determine the effect of dehydration time on instrumental color and Delta-E on jerky-style pet treats made with swine pluck. For sample preparation, swine pluck (SP) was ground using a 4.76-mm-diameter grinder plate, mixed with 1% of sodium alginate and 0.85% of encapsulated calcium lactate, and then formed into jerky strips. These strips were refrigerated at 4 °C for 16 h to allow for proper gelation. Subsequently, 76.2-mm jerky strips were dehydrated at 68.3 °C for 3, 4, 5, 6, and 7 h. Regarding data collection, n = 8 samples per treatment were used for each analysis. Instrumental color was assessed on d 0, 1, 3, 5, 7 post-production time points using a Hunter Lab Mini Scan EZ colorimeter 4500 spectrophotometer in D65 illuminant mode with a 10° observer angle, and a 0.5-mm-diameter aperture, on the CIE color space: lightness (L*), redness (a*), and yellowness (b*). Delta-E values (ΔE) were calculated to determine visual perception of color differences by the human eye. Data were analyzed as a 2-way ANOVA for instrumental color, with dehydration time and d post-production as the fixed effects. The analysis was performed using the GLIMMIX procedure of SAS ver. 9.4 with means separated at $P \leq 0.05$. After samples were stored under the same conditions for 7 d, instrumental color revealed that SP samples dehydrated for 3 h were the lightest ($P < 0.0007$), reddest ($P < 0.0001$), and yellowest ($P < 0.0001$). Delta-E values were greatest between d 0 and 1 within all dehydration times, indicating that differences in color were perceptible at a glance ($2 \leq \Delta E \leq 10$). However, when

comparing days 0 to 7, SP treats dehydrated for 3 and 4 h had the most stable color, and the changes observed were not perceptible to human eyes ($\Delta E \leq 1.0$). Overall, the greatest color changes occurred between d 0 and 1 post-production, but as storage time progressed, ΔE values were either not perceptible by the human eye or changes were perceptible upon close observation.

3.2 Keywords: instrumental color, lightness, redness, yellowness, Delta-E, jerky pet treats.

3.3 Introduction

In the U.S. the pet food industry has been increasing sales in recent years. Of the $147 billion spent on pets in 2023, $64.4 billion was allocated to pet food and treats ((APPA), 2024). Similarly, the growing trend of pet humanization has influenced pet owners preferences, driving demand for more appealing and attractive options for their pets, while still prioritizing nutritional values (White, 2022).

In fact, meat animal processing co-products have been widely utilized in the pet food industry, considering their low value in the market and high-quality nutritional content (Toldrá et al., 2021). Therefore, swine pluck, a combination of heart, lungs, esophagus, and trachea (excluding the thyroid gland) due to concerns of the presence of thyroid hormones in pet food, the combination of those products has potential for developing pet treats. However, changes in organoleptic properties, such as a color, can influence pet owners perception of the quality and appeal of pet food (Di Donfrancesco et al., 2014).

Color changes in meat products can be influenced by factors such as heating exposure, heating time, and the content of hemoglobin and myoglobin (García-Segovia et al., 2007). In pet food, certain attributes, like aroma, color, and appearance can affect pet owners' overall preferences (Samant et al., 2021). Among these, color plays a particularly crucial role in shaping these preferences, as highlighted by Di Donfrancesco et al. 2014, who found that color has a more substantial influence than aroma (Di Donfrancesco et al., 2014).

Heat treatments can cause both chemical and physical alterations in the color of meat products, with changes in myoglobin closely linked to these color variations. The duration and temperature of heat treatments can influence myoglobin denaturation in meat products, which directly impacts the color outcome (Vinnikova et al., 2019). The dehydration process, which involves removing water content from a product through evaporation or sublimation (Agafonychev et al., 2021), is also associated with the product's temperature.

Higher temperatures during dehydration can alter the structure and appearance of the product. During cooking, water removal is drawn out from hydration cells, leading to protein denaturation, further affecting the product's color (Mishra et al., 2017). Dried meat has long been recognized as an ancient method of food preservation. In jerky production, dehydration can be prolonged by exposing the product to lower temperatures. As a result, the duration of dehydration is affected by several variables, such as temperature, airflow, external relative humidity, and the thickness of the meat slices (Bowser et al., 2009).

Certain factors, such as the color of dried products, can be impacted by heat exposure during dehydration (Hii et al., 2014). Consequently, the color of meat products is often measured instrumentally using spectrophotometers and colorimeters, which provide values for lightness (L*), redness (a*), and yellowness (b*; Tomasevic et al., 2019). Additionally, changes in color over a determined period can be calculated using the Delta-E formula, which incorporates these instrumental values to determine color differences as perceived by the human eye color (King et al., 2023). Therefore, the objective of this study was to evaluate the effect of dehydration time of instrumental color and Delta-E on jerky-style pet treats made with swine pluck.

3.4 Materials and Methods

3.4.1 Ingredients and raw material preparation

Swine pluck (SP) is the primary component in manufacturing jerky-style pet treats. This ingredient includes the trachea, heart, lungs, and esophagus (removing the thyroid gland), which are removed together as a single unit during processing and can provide a protein-rich source for pet treats. For this experiment, the thyroid gland was excluded from each SP. The raw SP was collected from the Lambert-Powells Meats Lab at Auburn University and stored at -20 °C to maintain quality. Before use, the SP was thawed at 4 °C for 48 h and then ground through a 4.76-mm-diameter plate using a commercial 20-quart meat grinder

3.4.2. Addition of the structure forming technology

A blend of 1% sodium alginate (SA) from Tilley Distribution in Waldo, ME, and 0.85% encapsulated calcium lactate (ECL) from Balchem in New Hampton, NY, was combined with the total amount of ground raw SP. This mixture of SA and ECL was termed ALGIN. As per the Food and Drug Administration (FDA), the maximum allowable level of sodium alginate in meat products for human consumption is 1% (FDA, 2023). For the sample mixture, half of the SA was first added and mixed at a low speed for 30 s, then at a high speed for another 30 s. The remaining SA was then added using the same mixing process. ECL was incorporated similarly, following the same mixing steps.

3.4.3. Sample extrusion and dehydration

The ground mixture (SP+ ALGIN) was extruded into jerky strips using a 38.1-mm wide single-strip nozzle probe. These strips were then covered with plastic wrap to retain moisture and refrigerated at 4 °C for 16 h to allow for gelation. The long jerky strips were cut into shorter pieces, approximately 76.2 mm. For dehydration, the dehydrator oven (KWASYO Food Dehydrator Machine) was pre-heated to its maximum temperature of 90 °C for 8 min. The jerky strips were placed on metal racks and transferred to the pre-heated dehydrator. The dehydrator oven temperature dropped to 68.3 °C, and samples were collected at 3, 4, 5, 6, and 7 h. After 7 hours of dehydration, the water activity (a_w) reached a value of 0.85 or lower.

3.4.4 Instrumental color

The instrumental color of jerky-style pet treats, each measuring 76.2 mm length, was evaluated using a Hunter Lab Mini Scan EZ 4000L Portable Spectrophotometer (Reston, VA, United States). Instrumental color data were collected in the CIELAB color space using parameters L*, a*, and b*, employing a D65 light source, a 10º observer angle, and a 12.7-mm aperture diameter. Measurements were collected from each sample (n = 8) over five post-production days, including days 0, 1, 3, 5, and 7. The samples were stored at 4 °C and covered with plastic wrap during data collection. The CIELAB color space operates in a three-axis system: L* represents lightness on a scale from 0 (black) to 100 (white), a* measures redness from -120 (green) to 120 (red), and b* quantifies yellowness from -120 (blue) to 120 (yellow). To ensure accuracy, the spectrophotometer was calibrated with a white calibration plate before each use. Three measurements per sample were taken, and the average was used to perform statistical analysis.

3.4.5 Delta E (ΔE)

Delta-E is an indicator of the human eye's visual perception of color differences. The color change can be perceptible at different ranges (see Table 3.1). The formula for calculating Delta-E from instrumental color data is shown below (King et al., 2023).

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

Delta-E values, as shown in Table 3.1. Lower Delta-E values indicate minimal differences between samples, while higher values represent more noticeable color variations between samples perceived by the human eye.

Table 3.1 Delta-E values range from 0 to 100.

Delta-E	Perception
≤ 1.0	Not perceptible by human eye
1 to 2	Perceptible under very close observation
2 to 10	Perceptible at a glance
11 to 49	Colors are more alike than opposite
100	Colors are exact opposites

3.4.6 Statistical analysis

Data were analyzed as a 2-way ANOVA for instrumental color. The analysis was conducted using a generalized linear mixed model (GLIMMIX) procedure in the Statistical Analysis Software (SAS) version 9.4 (SAS Institute Inc., Cary, NC, USA). A completely randomized block design experiment with a 5 × 5 factorial treatment structure was conducted for color analysis with dehydration time and d-post production as the fixed effects in the model statement. Each jerky-style pet treat unit served as an individual experiment unit. To conduct a comprehensive pairwise mean comparison analysis, least square means were separated using the PDIFF option of SAS. The Satterthwaite adjustment was utilized to correct the degrees of freedom. Significant differences between means were declared at $P \leq 0.05$.

3.5 Results and Discussion

3.5.1 Lightness (L*)

The color measurements of jerky-style pet treats were significantly influenced by dehydration time and time post-production, as shown in Figure 3.1 ($P < 0.0001$). After samples were stored under the same conditions for 7 d, the lightness of the samples was significantly greater for the samples dehydrated for 3 h than all other dehydration times *(P* < 0.0001). As time post-production increased, the lightness differences among various dehydration times became less pronounced but remained statistically significant.

On d 1 post-production, samples dehydrated for 4, 5, 6, and 7 h exhibit similar lightness measurements, but these differed from those dehydrated for 3 h ($P < 0.0001$). On d 3 post-production, lightness values for samples dehydrated for 5 h showed a noticeable reduction compared with the other dehydration times, except for samples dehydrated for 6 h, while other dehydration times exhibited intermediate lightness changes. Overall, the results indicate a clear impact of dehydration time on the color stability of jerky-style pet treats over time, with longer dehydration times generally leading to less pronounced color changes as post-production days progressed.

Contrary to our results, no significant differences in lightness were observed in dried duck jerky combined with collagen and konjac. Based on this research, different combinations of hydrocolloids did not impact the final color of the samples (Kim et al., 2020). Similar results were reported by Chen and Lin, 2017, where different levels of disaccharides were added to Chinese-style pork jerky samples; no significant differences were for lightness in these samples (Chen and Lin, 2017). Another study assessed the quality characteristics of beef jerky after cooking, revealing that cooking methods can influence its color. Fried jerky samples were found to be darker than dehydrated ones, a difference attributed to the Maillard reaction occurring during cooking (Luo et al., 2020). According to data reported by Shi et al., 2020 found that beef jerky from Hohhot dried traditionally had lower lightness values compared to modern methods, whereas samples from Bayan Nur showed higher lightness values with traditional drying. These differences can be attributed to the lipid content of the samples (Shi et al., 2020).

3.5.2 Redness (a*)

The redness values of jerky-style pet treats were significantly influenced by dehydration time and time post-production ($P < 0.0001$). Figure 3.2 presents the results of the interactions between various dehydration times and time post-production on the redness (a*). At d 0 post-production, redness values significantly decreased as dehydration time increased, peaking at 3 h of dehydration and decreasing until 5 h of dehydration ($P < 0.0001$). However, samples dehydrated for 5, 6, and 7 h were similar. Samples dehydrated for 3 h at d 1 and 5 post-production had the highest redness values compared to other treatments ($P < 0.0001$).

On d 3 post-production, similarities in results from the previous were observed on this day, with treats dehydrated for 3 h being the reddest compared to the rest of the samples at the same time post-production ($P < 0.0001$). After 7 d of storage, jerky-style pet treats dehydrated for 3 h had the second highest redness values among all treatments ($P < 0.0001$), while similar results from previous observations were maintained for the other dehydration times. Overall, samples dehydrated for 3 h across all post-production durations maintained a higher and more intense red color over the storage period.

According to a study performed on chicken jerky combined with various sugars at different storage times, the redness of the jerky samples increased with extended storage periods, which is contrary to the results found in our study (Wongwiwat and Wattanachant, 2016). Similarly to our results, a study conducted on MDCM (mechanically deboned chicken meat) on semi-dried chicken jerky found that samples exposed to 75 °C had lower levels of red. This can be attributed to the denaturation of the hemoglobin in MDCM (Song et al., 2014). Samples exposed to thermal treatments tend to form hemi chrome due to the denaturation of myoglobin caused by heat (Brewer, 2009).

A study on venison jerky observed significant differences in redness between curing ingredients from d 1 to 21, with samples stored for the same period. However, no interactions were found among treatments and storage time. The sample color changed from red to brown due to the development of metmyoglobin during the drying process (Tangkham and LeMieux, 2016). Furthermore, results reported by Liu et al., 2022 in pork jerky samples evaluated using different drying methods found similar outcomes to our study. The starting redness values were higher with the drying oven method, but they decreased with prolonged drying time (Liu et al., 2022). The inclusion of hydrocolloids can be another factor influencing the color of the samples. A study conducted on cold-cut duck meat found that redness values were higher in samples with hydrocolloid inclusions (Kim et al., 2020).

3.5.3 Yellowness (b*)

The yellowness values of jerky-style pet treats were significantly influenced by dehydration time and time post-production, as observed in Figure 3.3 ($P < 0.0001$). At d 0 post-production, significant differences were observed between 3 and 7 h of dehydration, with those dehydrated for 3 h having higher yellowness values ($P < 0.0001$). On d 1, 3, and 5 post-productions, samples dehydrated for 3 h had a higher lightness, followed by treats dehydrated for 4 h. Jerky-style pet treats dehydrated for 5 and 6 h had the lowest yellowness values, and samples dehydrated for 7 h remained intermediate ($P < 0.0001$).

Jerky-style pet treats stored for 7 d post-production followed a similar results pattern to those stored for 3 d, with samples dehydrated for 3 h having higher yellowness values and then followed by samples dehydrated for 4 h ($P < 0.0001$). Similar findings were found in restructured pork jerky evaluating different temperatures and durations in the process, where yellowness values decreased with increased temperature and extended dehydration time (Kim et al., 2021). Another study evaluating hot-air exposure in beef jerky found similar results to the previous ones, with no significant differences between treatments in yellowness values (Shi et al., 2020).

According to findings reported by Liu et al., 2016, yellowness values (b*) in beef jerky decreased with extended drying time, which supports our results. This decrease may be due to the oxidation of the myoglobin content in the product, leading to the formation of metmyoglobin, the oxidized form of myoglobin (Liu et al., 2016). Contrary results were observed in another study performed on beef jerky, where no differences were observed between yellowness values regardless of the treatments (Zhang et al., 2023).

In terms of binder inclusion, a study found that adding binders to pork sausage formulations increased yellowness values (b*), with 1% protein pork plasma resulting in higher values compared to all other treatments. Pork plasma enhances the product's emulsification properties due to its globulin and albumin protein content (Jin et al., 2019). Contrary to our findings, research on cooked pork sausages during storage observed that after 30 d, yellowness values in pork sausages combined with extract from natural plants were higher compared to all other treatments (Seo et al., 2019).

3.5.4 Delta-E (ΔE)

Results for Delta-E values calculated using L*, a*, and b* values for SP jerky-style pet treats are shown in Table 3.2. Color changes perceptible to the human eye in jerky-style pet treats were observed between the time post-production and dehydration time. Delta-E values were highest among all dehydration times from day 0 to d 1 post-production which means that these changes were perceptible by the human eye at a glance ($2 \leq \Delta E < 10$ = perceptible at a glance). Additionally, when comparing Delta-E values from d 1 to d 7, color differences were also categorized as perceptible at a glance on d 3 post-production.

In contrast, when evaluating Delta-E values from d 0 to d 7, SP jerky-style pet treats dehydrated for 3 h (lowest dehydration time treatment) had the least stable color over time, whereas those treats dehydrated with longer times (5 and 6 h) had the most stable color whose changes from d 0 to 7 post-production being less than one and not perceptible by the human eye ($\Delta E < 1.0$ = not perceptible). After d 3 post-production, color changes in the treats were not perceptible by the human eye ($\Delta E < 1.0$ = not perceptible). Moreover, regardless of dehydration time, non-drastic color changes in jerky-style pet treats would be observed after 3 days post-production. The remaining comparisons between time post-production and dehydration time in terms of color differences were categorized as either not perceptible by the human eye ($\Delta E < 1.0$ = not perceptible) or perceptible upon close observation ($1 \leq \Delta E < 2$ = perceptible by close observation).

A study on beef steaks during storage revealed that higher Delta-E values were associated with more significant color changes in the samples (De Alcântara Salim et al., 2023). The rate of discoloration observed may be attributed to oxidation reactions within the samples (Insani et al., 2008), and the level of intramuscular fat content present in the steaks (Luciano et al., 2011). In contrast to our findings, Delta-E values in frozen steaks increased with extended storage time, indicating more pronounced color changes and greater discoloration in the samples. This increase in discoloration may be associated to a decline in metmyoglobin-reducing activity over prolonged storage periods (Henriott et al., 2020).

3.6 Conclusions

Prolonged heat treatments can significantly impact the final color of SP jerky-style pet treats. This study demonstrated that on day 1 post-production samples dehydrated for 3 h were the lightest ($P < 0.0001$). Similarly, on days 1, 3, and 5 post-production, SP samples dehydrated for 3 h were the reddest and yellowest ($P < 0.0001$). Noticeable color changes, indicated by Delta-E values, were most evident between days 0 and 1 post-production across all dehydration times. Among the samples, those dehydrated for 3 h exhibited the least color stability over time, while samples dehydrated for 5 and 6 h maintained the most stable color, with changes not detectable by the human eye. As previously noted, the color of pet food influences consumer purchasing decisions, even more so than attributes like aroma (Di Donfrancesco et al., 2014). Additionally, color changes during extended storage can play a crucial role in determining the final product's quality, with ΔE serving as a valuable parameter for assessing these differences over time. However, this parameter is mostly used in studies on beef, leaving a gap in the literature for other species such as chicken and pork. Overall, the greatest color changes occurred between d 0 and 1 post-production in samples from all dehydration times, but as storage time progressed, ΔE values fell below 1 or ranged between 1 and 2, resulting in color changes that were either not perceptible by the human eye or changes perceptible upon close observation.

3.7 References

1. (APPA), A. P. P. A. (2024). *Industry Trends and Stats*. American Pet Products Association. Retrieved Sept 3, 2024 from https://www.americanpetproducts.org/research-insights/industry-trends-and-stats

2. Agafonychev, V., Makhonina, V., & Roslikov, D. (2021). Kinetics of convective drying during dehydration of poultry meat products. *IOP Conference Series: Earth and Environmental Science*, *937*(3), 032060. https://doi.org/10.1088/1755-1315/937/3/032060

3. Bowser, T. J., Frazier, R. S., Weckler, P. R., & Kowalski, S. J. (2009). Optimizing jerky drying time with minimal product impact. *The Open Food Science Journal*, *3*(1).

4. Brewer, M. (2009). Irradiation effects on meat flavor: A review. *Meat Science*, *81*(1), 1-14.

5. Chen, C.-M., & Lin, H.-T. (2017). Supplementary effects of higher levels of various disaccharides on processing yield, quality properties and sensory attributes of Chinese-style pork jerky. *Asian-Australasian Journal of Animal Sciences*, *30*(12), 1773.

6. De Alcântara Salim, A. P. A., Da Silva Ferreira, M., Monteiro, M. L. G., De Lima, L. C. S., Magalhães, I. T. M., Conte-Júnior, C. A., & Mano, S. B. (2023). Production system influences color stability and lipid oxidation in gluteus medius muscle. *Animal Bioscience*, *36*(5), 785-796. https://doi.org/10.5713/ab.22.0271

7. Di Donfrancesco, B., Koppel, K., Swaney-Stueve, M., & Chambers, E. (2014). Consumer Acceptance of Dry Dog Food Variations. *Animals*, *4*(2), 313-330. https://doi.org/10.3390/ani4020313

8. CFR - Code of Federal Regulations Title 21, (2023). https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=184.1724

9. García-Segovia, P., Andrés-Bello, A., & Martínez-Monzó, J. (2007). Effect of cooking method on mechanical properties, color and structure of beef muscle (M. pectoralis). *Journal of Food Engineering*, *80*(3), 813-821.

10. Henriott, M. L., Herrera, N. J., Ribeiro, F. A., Hart, K. B., Bland, N. A., & Calkins, C. R. (2020). Impact of myoglobin oxygenation level on color stability of frozen beef steaks. *Journal of Animal Science*, *98*(7). https://doi.org/10.1093/jas/skaa193

11. Hii, C. L., Itam, C. E., & Ong, S. P. (2014). Convective Air Drying of Raw and Cooked Chicken Meats. *Drying Technology*, *32*(11), 1304-1309. https://doi.org/10.1080/07373937.2014.924133

12. Insani, E. M., Eyherabide, A., Grigioni, G., Sancho, A. M., Pensel, N. A., & Descalzo, A. M. (2008). Oxidative stability and its relationship with natural antioxidants during refrigerated retail display of beef produced in Argentina. *Meat Science*, *79*(3), 444-452.

13. Jin, S.-K., Kim, S.-H., Choi, J.-S., & Yim, D.-G. (2019). Effect of diverse binder materials and their addition levels on physico-chemical characteristics of sausages. *Journal of Food Measurement and Characterization*, *13*(2), 1558-1565. https://doi.org/10.1007/s11694-019-00071-1

14. Kim, S.-M., Kim, T.-K., Kim, H.-W., Jung, S., Yong, H. I., & Choi, Y.-S. (2021). Quality Characteristics of Semi-Dried Restructured Jerky Processed Using Super-Heated Steam. *Foods*, *10*(4), 762. https://doi.org/10.3390/foods10040762

15. Kim, T.-K., Kim, H.-W., Lee, Y.-Y., Jang, H. W., Kim, Y.-B., & Choi, Y.-S. (2020). Quality characteristics of duck jerky: combined effects of collagen and konjac. *Poultry Science*, *99*(1), 629-636. https://doi.org/https://doi.org/10.3382/ps/pez561

16. Kim, T.-K., Yong, H. I., Jang, H. W., Kim, Y.-B., Sung, J.-M., Kim, H.-W., & Choi, Y.-S. (2020). Effects of hydrocolloids on the quality characteristics of cold-cut duck meat jelly. *Journal of Animal Science and Technology*, *62*(4), 587-594. https://doi.org/10.5187/jast.2020.62.4.587

17. King, D. A., Hunt, M. C., Barbut, S., Claus, J. R., Cornforth, D. P., Joseph, P., Kim, Y. H. B., Lindahl, G., Mancini, R. A., Nair, M. N., Merok, K. J., Milkowski, A., Mohan, A., Pohlman, F., Ramanathan, R., Raines, C. R., Seyfert, M., Sørheim, O., Suman, S. P., & Weber, M. (2023). American Meat Science Association Guidelines for Meat Color Measurement. *Meat and Muscle Biology*, *6*(4). https://doi.org/10.22175/mmb.12473

18. Liu, C.-Z., Liu, X.-J., Yan, X.-H., Gou, M.-X., Jia, S., Liu, Y., & Inc, D. (2016). The influence of drying time on moisture content and quality of beef jerky. In: Destech Publications Inc.

19. Liu, Z., Zheng, W., Shen, C., Yang, H., He, M., Zhang, Y., Zhao, C., & Zhao, Z. (2022). Effect of different drying methods on the physical properties of pork jerky. *International Journal of Gastronomy and Food Science*, *30*, 100619. https://doi.org/https://doi.org/10.1016/j.ijgfs.2022.100619

20. Luciano, G., Moloney, A., Priolo, A., Röhrle, F., Vasta, V., Biondi, L., López-Andrés, P., Grasso, S., & Monahan, F. (2011). Vitamin E and polyunsaturated fatty acids in bovine muscle and the oxidative stability of beef from cattle receiving grass or concentrate-based rations. *Journal of Animal Science*, *89*(11), 3759-3768.

21. Luo, Y., Zhao, L., Xu, J., Su, L., Jin, Z., Su, R., & Jin, Y. (2020). Effect of fermentation and postcooking procedure on quality parameters and volatile compounds of beef jerky. *Food Science & Nutrition*, *8*(5), 2316-2326. https://doi.org/10.1002/fsn3.1515

22. Mishra, B., Mishra, J., Pati, P., & Rath, P. (2017). Dehydrated meat products: A review. *Int. J. Livest. Res*, *7*, 10-22.

23. Samant, S. S., Crandall, P. G., Jarma Arroyo, S. E., & Seo, H.-S. (2021). Dry Pet Food Flavor Enhancers and Their Impact on Palatability: A Review. *Foods*, *10*(11), 2599. https://doi.org/10.3390/foods10112599

24. Seo, J.-K., Parvin, R., Yim, D.-G., Zahid, M. A., & Yang, H.-S. (2019). Effects on quality properties of cooked pork sausages with Caesalpinia sappan L. extract during cold storage. *Journal of Food Science and Technology*, *56*(11), 4946-4955. https://doi.org/10.1007/s13197-019-03965-6

25. Shi, S., Kong, B., Wang, Y., Liu, Q., & Xia, X. (2020). Comparison of the quality of beef jerky processed by traditional and modern drying methods from different districts in Inner Mongolia. *Meat Science*, *163*, 108080.

26. Song, D.-H., Choi, J.-H., Choi, Y.-S., Kim, H.-W., Hwang, K.-E., Kim, Y.-J., Ham, Y.-K., & Kim, C.-J. (2014). Effects of Mechanically Deboned Chicken Meat (MDCM) and Collagen on the Quality Characteristics of Semi-dried Chicken Jerky. *Korean Journal for Food Science of Animal Resources*, *34*(6), 727-735. https://doi.org/10.5851/kosfa.2014.34.6.727

27. Tangkham, W., & LeMieux, F. (2016). Sensory, physicochemical and microbiological characteristics of venison jerky cured with NaCl and KCl.

28. Toldrá, F., Reig, M., & Mora, L. (2021). Management of meat by- and co-products for an improved meat processing sustainability. *Meat Science*, *181*, 108608. https://doi.org/https://doi.org/10.1016/j.meatsci.2021.108608

29. Tomasevic, I., Tomovic, V., Milovanovic, B., Lorenzo, J., Đorđević, V., Karabasil, N., & Djekic, I. (2019). Comparison of a computer vision system vs. traditional colorimeter for color

evaluation of meat products with various physical properties. *Meat Science*, *148*, 5-12. https://doi.org/10.1016/j.meatsci.2018.09.015

30. Vinnikova, L., Synytsia, O., & Kyshenia, A. (2019). THE PROBLEMS OF MEAT PRODUCTS THERMAL TREATMENT. *Food Science & Technology (2073-8684)*, *13*(2).

31. White, B. L. (2022). Insights-driven development of humanized foods for pets. *Meat and Muscle Biology*. https://doi.org/10.22175/mmb.14397

32. Wongwiwat, P., & Wattanachant, S. (2016). Color characteristics and Maillard reactions of chicken meat jerky with different sweeteners during storage. *Walailak Journal of Science and Technology (WJST)*, *13*(3), 141-155.

33. Zhang, W.-K., Zhang, C., Qi, B., Mujumdar, A. S., Xie, L., Wang, H., Ni, J.-B., & Xiao, H.-W. (2023). Hot-air impingement roast drying of beef jerky: Effect of relative humidity on quality attributes. *Drying Technology*, *41*(2), 277-289. https://doi.org/10.1080/07373937.2022.2049294

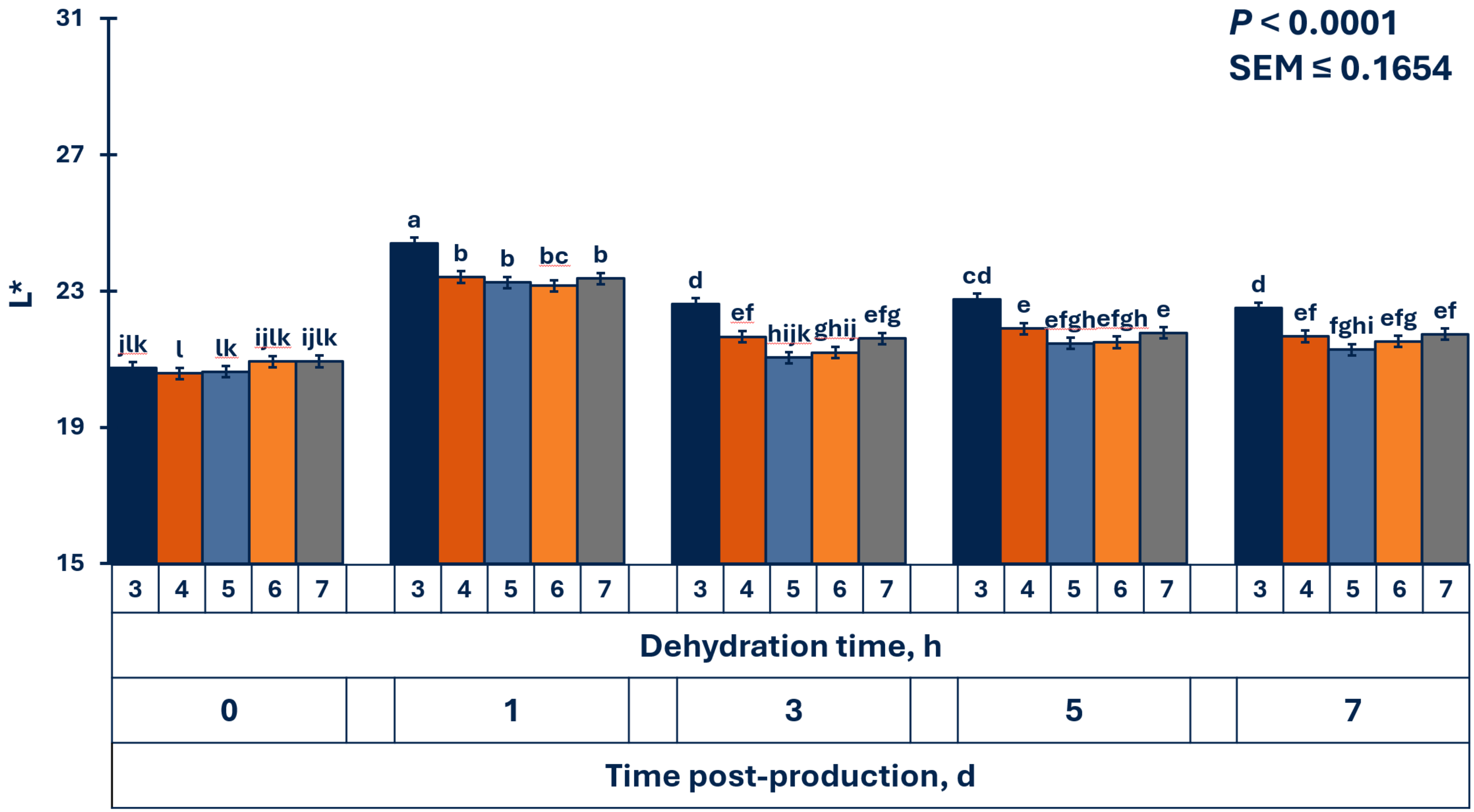

Figure 3.1 Effect of dehydration time on lightness (L*) values over time post-production of jerky-style pet treats made with swine pluck.

Raw swine pluck (SP) was ground using a 4.76-mm grinder plate and a commercial 20-quart meat grinder. The ground product was mixed with 1% sodium alginate (SA) and 0.85% encapsulated calcium lactate (ECL) (weight per weight). L* = lightness (0 = black and 100 = white). SEM = highest standard error of the LS means comparisons. [a-k]Means with different superscripts differ $P < 0.05$.

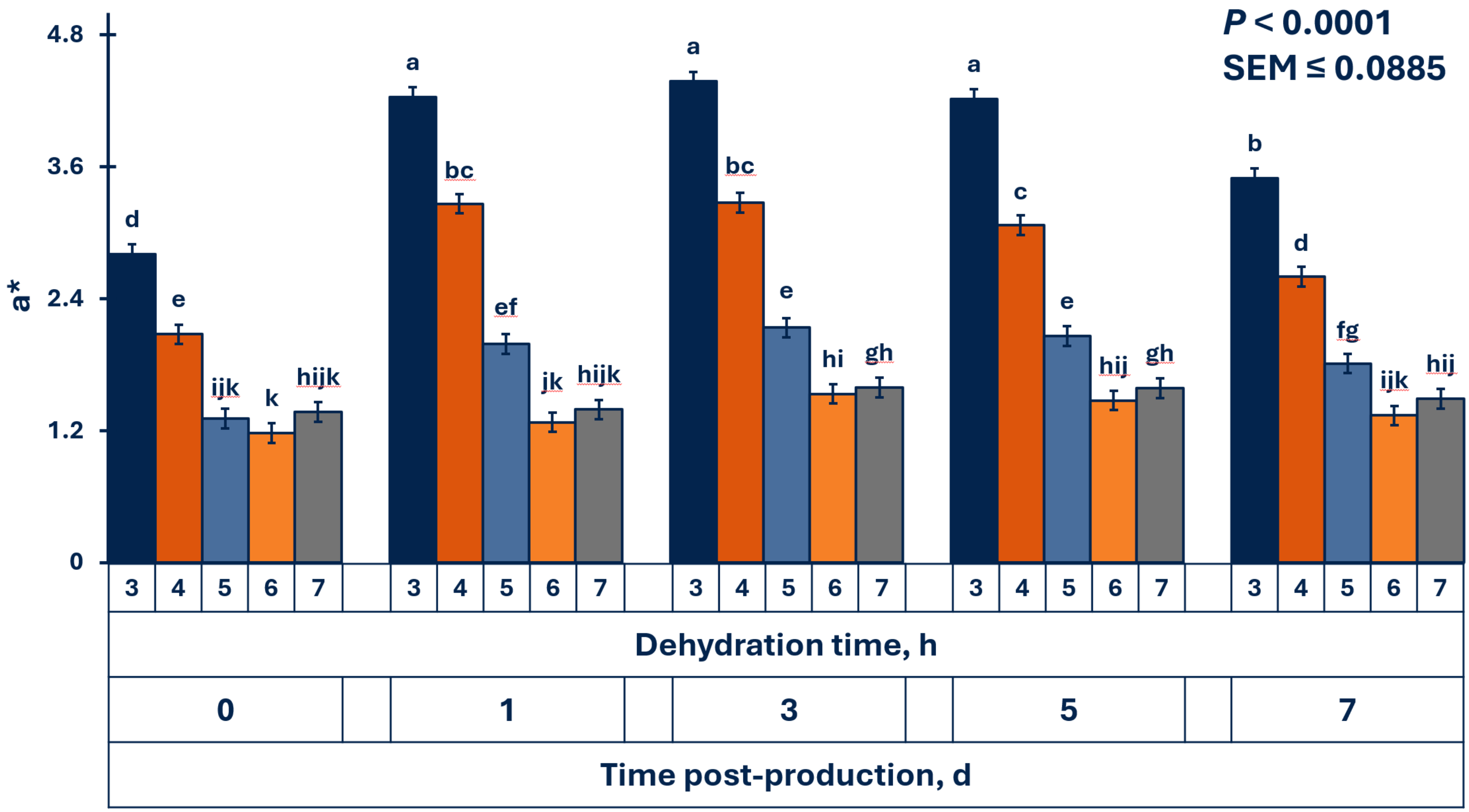

Figure 3.2 Effect of dehydration time on redness (a*) values over time post-production of jerky-style pet treats made with swine pluck. Raw swine pluck (SP) was ground using a 4.76-mm grinder plate and a commercial 20-quart meat grinder. The ground product was mixed with 1% sodium alginate (SA) and 0.85% encapsulated calcium lactate (ECL) (weight per weight). a* = redness (-120 = green and 120 = red). SEM = highest standard error of the LS means comparisons. [a-k]Means with different superscripts differ $P < 0.05$.

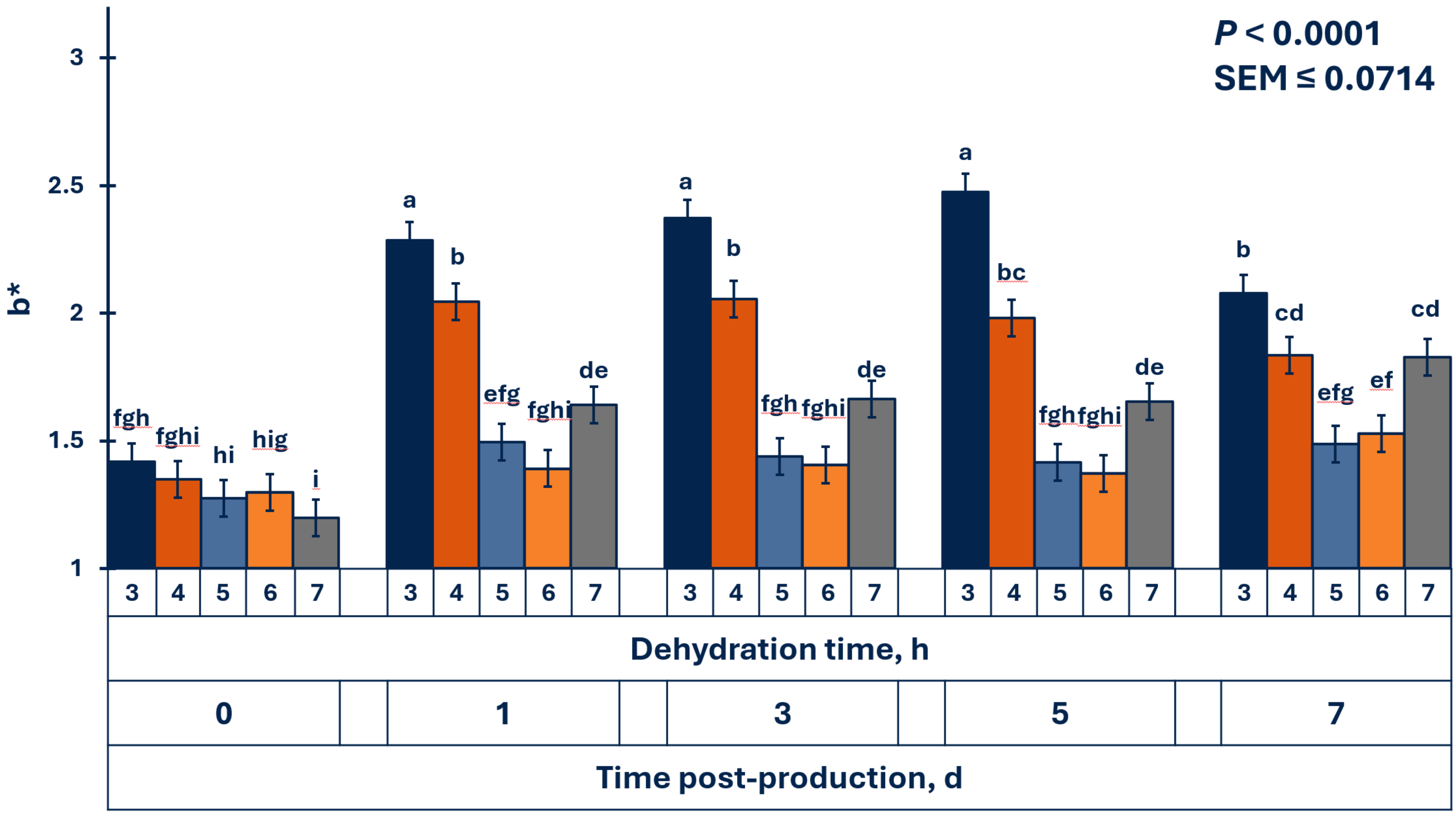

Figure 3.3 Effect of dehydration time on yellowness (b*) values over time post-production of jerky-style pet treats made with swine pluck.

Raw swine pluck (SP) was ground using a 4.76-mm grinder plate and a commercial 20-quart meat grinder. The ground product was mixed with 1% sodium alginate (SA) and 0.85% encapsulated calcium lactate (ECL) (weight per weight). b* = yellowness (-120 = blue and 120 = yellow). SEM = highest standard error of the LS means comparisons. [a-k]Means with different superscripts differ $P < 0.05$.

Table 3.2 Effect of dehydration time and time post-production on Delta-E values of dehydrated jerky-style pet treats made with swine pluck.

	Delta-E[1] (ΔE) of dehydrated jerky-style pet treats[2]									
	Time post-production, d[3]									
Dehydration time[4], h	0 vs 1	0 vs. 3	0 vs. 5	0 vs. 7	1 vs. 3	1 vs. 5	1 vs. 7	3 vs. 5	3 vs. 7	5 vs. 7
3	4.02	2.62	2.67	2.00	1.80	1.66	2.06	0.23	0.94	0.86
4	3.15	1.76	1.76	1.30	1.75	1.53	1.87	0.32	0.71	0.54
5	2.72	0.94	1.13	0.85	2.21	1.79	1.98	0.43	0.41	0.32
6	2.23	0.46	0.65	0.65	1.98	1.67	1.64	0.31	0.40	0.21
7	2.47	0.85	0.98	1.03	1.77	1.60	1.64	0.16	0.23	0.20

[1]Delta-E serves as an indicator of the human eye's visual perception of color differences.
[2]The dehydration of jerky-style pet treats took place in a dehydrated oven set at 68.3 °C until each dehydration time was reached.
[3]Delta-E was calculated across 10 different time intervals by comparing various day combinations among days 0, 1, 3, 5, and 7 post-production.
[4]Dehydration time was collected during five different periods, including 3, 4, 5, 6, and 7 h.
Delta-E values with the same color fall in the same category. Blue (ΔE < 1.0): color changes are not perceptible by the human eye. Pink (1 ≤ ΔE < 2): color changes are perceptible under close observation. Orange (2 ≤ ΔE < 10): color changes are perceptible at a glance.

Chapter IV. Effect of dehydration time on sensory properties of jerky-style pet treats made with swine pluck among pet owners

4.1 Abstract

Sensory evaluation, a key method for analyzing the product characteristics such as texture, color, and aroma, plays a vital role in influencing pet food purchasing decisions, driven by the growing prevalence of pet ownership and pet humanization trends in the U.S. Pet food manufacturers have responded by incorporating animal processing co-products, these products often incorporate meat animal processing co-products due to their relatively low market value combined with their high protein and nutrient content. Consequently, swine pluck (SP), a combination of heart, lungs, esophagus, and trachea, can serve as a viable protein source in pet food and treats due to its convenient single-unit removal during swine processing. Beyond nutrition, sensory parameters such as appearance, color, and texture can play a major role for pet owners when selecting products for their pets. Therefore, understanding human perception can be crucial for product marketability considering pet owners typically have an initial interaction with the product before providing it to their pet. The objective of this study was to evaluate the effect of dehydration time on various sensory characteristics of jerky-style treats made with SP. To prepare samples, raw SP was ground using a 4.76-mm grinder plate, mixed with sodium alginate (1%), and encapsulated calcium lactate (0.85%), extruded into jerky strips, and refrigerated for 16 h at 4 ºC to allow product gelation. Then, 3-inch jerky strip samples were dehydrated at 68 ºC for 5 different dehydration times (3, 4, 5, 6, and 7 h). One hundred pet owners evaluated 5 jerky samples using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like) to assess the intent to purchase among pet owners as well as product overall liking, appearance, color, and texture using Red Jade software. Data were analyzed using a mixed model in XLSTAT 2023 version 3.1, with dehydration time as a fixed effect and participants as a random effect. Means were considered different when $P \leq 0.05$. Pairwise comparisons were achieved using Tukey's

Honestly Significant Differences (HSD) test. Overall liking for SP treats averaged 5.38 ± 0.238, with appearance scoring 5.19 ± 0.198. Interestingly, both overall liking and appearance scores were similar among all SP jerky-style treats regardless of product dehydration time (*P* = 0.135 and 0.846, respectively). However, the color liking score for SP treats averaged 4.84 ± 0.150; liking score was greater for SP treats dehydrated for 3 and 4 h compared with those dehydrated for 7 h (*P* = 0.005). Texture liking score was 5.11 ± 0.300, this parameter was greater for treats dehydrated for 4, 5, 6, and 7 h compared with those dehydrated for 3 h (*P* < 0.0001). The intent of purchase liking score averaged 3.06 ± 0.130, with greater intent observed for SP jerky treats dehydrated for 4 and 5 h compared with those dehydrated for 3 h with those dehydrated 6 and 7 h being intermediate (*P* = 0.008). Overall, the sensory evaluation of jerky-style pet treats developed using SP provides insight into pet owners' acceptability and purchasing decisions. Future work will focus on performing a preference test with both owners and their pets.

4.2 Keywords: sensory evaluation, pet owners, appearance, color, texture, jerky-style pet treats.

4.3 Introduction

Sensory evaluation is a method used to analyze a product's characteristics, including texture, color, appearance, smell, and others, as perceived by the human sense specifically sight, smell, touch, taste, and hearing (Ruiz-Capillas and Herrero, 2021). In the context of pet food and treats, the increasing prevalence of pet ownership, with 82 million of households in the U.S. currently owning a pet in the U.S. (APPA), 2024) and the growing trend of pet humanization can influence purchasing decisions on pet owners when selecting food and treats for their pets (Schleicher et al., 2019).

Pet food manufacturers have responded by incorporating animal processing co-products which offer both economic and nutritional benefits (Lynch et al., 2018). For instance, swine pluck (SP) a combination of heart, lungs, esophagus (without the thyroid gland), and trachea serves as a convenient protein source for pet food, being readily available from the single-step removal process during swine processing.

Beyond nutritional value, sensory characteristics such as appearance, texture, and aroma play a crucial role in the acceptability of pet food among both pets and their owners. Manufacturers can utilize this sensory data to identify preferences and develop pet food that satisfies both pets and their owners (Koppel, 2014). For jerky treats, studies have highlighted that texture is one of the most important attributes when evaluating the sensory qualities of jerky (Albright et al., 2000; Lee and Kang, 2003). Therefore, understanding processing methods, such as dehydration and its influence on sensory characteristics, can improve product quality (Oliveira et al., 2016).

Jerky pet treats are considered a common treat for dogs, consisting primarily of fat and protein, with a medium moisture content that allows for longer shelf-life without requiring refrigeration (Kim et al., 2020). A lower water content and water activity can be achieved through dehydration, one of the oldest preservation techniques used in meat products (Ayanwale et al., 2007). In terms of sensory characteristics, the drying method can impact the quality of jerky products. For instance, dehydration can reduce the nutritional content and alter the color of the samples (Doymaz et al., 2016), as well as affect the product's structure by creating pores and causing shrinkage, which ultimately influences its texture (Koc et al., 2008).

Additionally, the texture of a product can be affected by dehydration, particularly when ingredients like hydrocolloids are added. Hydrocolloids in formulations can influence heat penetration during processing, which in turn affects the texture of canned food (Dainton et al., 2021). Other parameters like aroma can be formed during cooking process by the formation of volatiles compounds thus ultimately contributing to the flavor of the meat (Wang et al., 2023). For pet owners, evaluating taste characteristics in pet food can be challenging, as human panelists are not typical consumers of these products. Consequently, factors like appearance and aroma tend to have a greater influence on the acceptability of pet food (Di Donfrancesco et al., 2014).

Regarding purchasing decisions for pet food, owners are often highly influenced by the product's overall appearance (Herrera-Corredor et al., 2007). Furthermore, pet owners commonly use treats to strengthen their emotional bond with their pets (Calancea et al., 2024), as incentives for good behavior, and during training sessions (Luño et al., 2021). Therefore, understanding human perception can be crucial for product marketability considering pet owners typically have an initial interaction with the product before providing it to their pet. The objective of this study was to evaluate the effect of dehydration time on various sensory characteristics of jerky-style treats made with SP among pet owners.

4.4 Materials and Methods

4.4.1 Preparation of raw samples and ingredient composition

Swine pluck (SP) was the main ingredient used in the formulation process to manufacture the jerky-style pet treats. This component comprising the trachea, heart, lungs, and esophagus (excluding the presence of the thyroid gland) was collected as a single unit during hog processing at the plant. SP is a valuable protein source for pet food products. Raw SP was obtained from the Lambert-Powells Meat Lab at Auburn University and stored at -20 °C to preserve its quality. Before preparation, the SP was transferred to refrigerated temperature for a period of 48 h prior to usage. Once thawed, the SP was ground using a 4.76-mm diameter grinder plate in a commercial 20-quart meat grinder.

4.4.2. Structure forming technology inclusion

A combination of 1% of sodium alginate (SA; Tilley distribution, Waldo, ME, USA) and 0.85% encapsulated calcium lactate (ECL; Balchem in New Hampton, NY, USA) was mixed with ground raw SP. The mixture of SA and ECL was referred to as ALGIN. According to the Food and Drug Administration (FDA), the maximum permitted level of sodium alginate in all other food categories excluding gelatins and puddings, hard candy, and processed fruits and fruit juice intended for human consumption is 1% (FDA, 2023). During sample preparation, half of the SA was initially added and mixed at a low speed for 30 s, followed by a high-speed mix for another 30 s. The remaining SA was then introduced using the same mixing method. ECL was incorporated similarly, adhering to the same mixing procedure.

4.4.3. Sample extrusion and drying method

The ground SP mixture was shaped into jerky strips using a single-strip nozzle probe with a width of 38.1 mm. These strips were then wrapped in plastic to retain moisture and refrigerated at 4 °C for 16 h to facilitate gelation. The long jerky strips were cut into shorter segments, approximately 76.2 mm in length. For drying, the dehydrator oven (KWASYO Food Dehydrator Machine) was preheated at its maximum temperature of 90 °C for 8 min. Therefore, the jerky strips previously placed on metal racks were transferred to the preheated dehydrator oven. The drying temperature was set to 68.3 °C. Once this temperature was achieved, samples were collected during five different dehydration times, including 3, 4, 5, 6, and 7 h. Moreover, the water activity (a_w) of the samples was at or below 0.85 after the samples were dehydrated for 7 h.

4.4.4 Demographics characteristics of pet owners

The demographic characteristics of pet owners surveyed in this study are presented in Table 4.1. Participants were pre-screened based on prior pet ownership and their involvement in purchasing pet treats. Regarding age distribution, 60% of the pet owners were between 22 to 30 years, followed by 16% who were between 18 to 21. The remaining age groups included 9 % between 31 to 40, 8% between 41-50, 4.0% between 51 to 60, and 3% between 61 and 70 years. Based on ethnicity characteristics, 65% of the pet owners were Caucasian, followed by 22% of Hispanic or Latino. Other ethnicities represented in this study include 8% Asian and Pacific Islander, 3% Black, and 2% other ethnicity.

Regarding gender, most pet owners participants were female (67%), while 33% were male. Occupation was another characteristic surveyed among the participants, with the majority falling into two categories: 31% were master of science students, and 31% were either faculty or staff members of Auburn University. This was followed by 20% of undergraduate students, 13%

of doctoral students, and 5% who were categorized under other occupations. The demographic questionnaire also included questions on pet ownership, previous experience living with pets, pet treat purchases, and whether they checked the ingredient list when purchasing pet treats.

4.4.5. Sensory parameters in jerky-style pet treats

One hundred pre-screened pet owners from Auburn University (Auburn, AL, USA) were selected to participate in this study. Each jerky strip, categorized by dehydration time, was placed into a 152.4-mm paper plate for sample preparation. A three-digit code was assigned to each dehydration time and distributed in a random order generated by a sensory software (Red Jade Sensory Solutions LLC, Pleasant Hill, CA, USA). Participants evaluated a total of 5 samples in a period of 15 minutes, and they were compensated for their evaluation time. Liking scores of SP jerky-style pet treats were evaluated using a 9-point hedonic scale, ranging from 1 = extremely dislike to 9 = extremely like, to assess the samples' overall liking and sensory attribute liking (appearance, color, and texture) among the pet owners participants based on observation, touch, and smell. However, pet owners were not allowed to taste the samples.

Purchase intent among pet owners was measured using a 5-point purchase intent scale ranging from 1 = definitely would not buy to 5 = definitely would buy. After evaluating the samples, each participant completed a basic demographic questionnaire such as age, ethnicity, gender, occupation, and some questions related to the purchasing decision of pet food. Data was collected using Red Jade Software (Red Jade Sensory Solutions LLC, Pleasant Hill, CA, USA).

4.4.6 Comparison between overall liking and demographic characteristics

The demographic characteristics of pet owners may influence the sensory evaluation of jerky-style pet treats. To determine if these characteristics affected the overall liking scores, the scores were compared against various demographic factors, including gender, ethnicity, pet ownership, and prior experience living with pets.

4.4.7. Statistical analysis

Data were analyzed using a mixed model, with dehydration time as the fixed effect and participants as the random effect, using XLSTAT 2023 version 3.1 (Lumivero, Denver, CO, USA). A 2-way ANOVA test was performed to evaluate the interaction of overall liking scores and demographic characteristics to determine if participant demographics influenced overall liking. The experimental unit for this study was each jerky strip. Pairwise comparisons were performed using Tukey's Honestly Significant Differences (HSD) test. Means were considered different when $P \leq 0.05$. Incomplete responses from participants were removed from the statistical analysis.

4.5 Results and Discussion

4.5.1. Demographic characteristics of pet owners

Pet ownership-related questions among pet owners are observed in Table 4.2. A total of one hundred pet owners participants were surveyed in this study. However, some responses were excluded from the analysis due to inconsistencies in the data. Regarding pet ownership, most respondents were dog owners (36%), followed by 29% of owners with dogs, cats, and other species. Other categories included 17% who were dog and cat owners, 16% who were only cat owners, and 2% who had other species of pets. Data on previous experience living with pets showed that 82% of pet owners had lived with pets for ten years or more. This was followed by 10% who had lived with pets for around 2-5 years (10%). Additionally, 7% of pet owners had lived with pets for 6-9 years, and only 1% had lived with pets for less than a year.

This study also surveyed pet treat purchase frequency to understand purchasing decisions. The data showed that most pet owners (49%) purchased pet treats once a month. Furthermore, 27% of pet owners purchased treats every two weeks. Regarding the remaining frequencies, 11% purchased treats once a week, 7% purchased treats once every two months, 4% of pet owners purchased treats less than once every two months, and 2% purchased treats twice a week. Pet owners were also surveyed about their habits of regularly checking the ingredients when purchasing pet treats. The data revealed that 42% of pet owners sometimes check the ingredient list, while 34% always check the ingredients. Among the other respondents, 19% rarely check the ingredient list, and 5% never check it when purchasing pet treats. Pet owners evaluated factors such as appearance, color, ingredients, price, and shape based on their level of importance when purchasing pet treats. Data revealed that ingredients have the highest importance of all these factors, followed by price.

According to U.S. pet ownership statistics from the American Pet Products Association, 58 million out of the 82 million pet-owning households have a dog. These findings align with the results observed in this study (APPA, 2024). Furthermore, the American Veterinary Medical Association (AVMA) reported similar results, with 62 million households in the U.S. owning a dog ((AVMA), 2022). Another sensory study of pet owners' purchasing behavior for pet food found that most pets take approximately four weeks to finish a whole package of food. Similarly, our survey on pet treats showed that the majority of pet owners purchase these products every month (Morelli et al., 2021).

The ingredients in pet food impact pet food purchasing decisions. Previous research has shown that dog owners prefer natural ingredients over traditional formulations and are willing to spend more on premium-quality products (Simonsen et al., 2014). Similar to our findings, a study on pet food purchasing choices found that dog owners check the ingredients labels more nowadays (Boya et al., 2015). In another study, pet owners were surveyed regarding wet and dry food purchasing choices. The results showed that label ingredients are an essential factor for owners when purchasing wet pet food (Vinassa et al., 2020).

4.5.2 Sensory parameters evaluated in jerky-style pet treats

Dehydration time significantly influences sensory parameters of jerky-style pet treats made with SP among pet owners ($P < 0.0001$). Results from sensory parameters will be displayed in Table 4.3. Regarding overall liking, no statistical differences among owners were observed between dehydration time ($P = 0.1350$). Likewise, regarding appearance, similar results were found for this parameter, with no significant differences between dehydration time and appearance ($P = 0.8463$). The color of pet treats made with SP dehydrated during different time frames was significantly different among pet owners ($P = 0.0045$).

Based on color liking scores, those treats dehydrated for 3, 4, 5, and 6 h were higher than those dehydrated for 7 h ($P = 0.0045$). However, treats dehydrated for 5 and 6 h had similar liking scores as samples dehydrated for 7 h. Furthermore, texture parameters were statistically different between treatments among pet owners ($P < 0.0001$). Samples dehydrated for 4, 5, 6, and 7 h had higher texture liking by pet owners than those dehydrated for 3 h, with the lowest liking scores.

This study evaluated pet owners' intent to purchase jerky-style pet treats from swine pluck dehydrated at different times. Significant differences were observed between dehydration time and intent to purchase the treats ($P = 0.0008$). Pet owners had greater intent to purchase jerky-style pet treats dehydrated for 4, 5, 6, and 7 h. On the other hand, pet treats dehydrated for 6 and 7 h had a similar intent to purchase by owners compared to those dehydrated for 3 h.

In contrast to our findings, a sensory study performed on dry dog food reported that the overall liking of the product was strongly linked to its appearance. Likewise, pet owners' overall liking scores influenced their color liking scores (Di Donfrancesco et al., 2014). When it comes to purchase intent, the overall appearance of a product can significantly impact buying decisions (Herrera-Corredor et al., 2007).

A study on extruded pet food yielded results contrary with ours, where pet owners did detect significant differences in appearance-liking scores in chicken byproduct meal samples. The study also assessed the product's shelf-life, finding that fresh chicken byproduct meal samples received higher liking scores among pet owners than those made with bone and beef meat. Moreover, the unappealing color of some samples contributed to lower liking scores from some pet owners (Chanadang et al., 2016). Furthermore, panelists' color preference scores differed from our findings, as the color of beef jerky samples dehydrated for varying durations was perceived similarly across samples. This suggests that each panelist may have distinct preferences when evaluating jerky products (Konieczny et al., 2007).

The texture of a product can also impact the sensory evaluation of pet food. Therefore, a sensory study performed can be employed to quantify the texture properties of pet food (Koppel, 2014). Regarding purchasing decisions among pet owners, texture of the product also influences their acceptance, alongside with other factors (Chanadang et al., 2016). According to data from Koppel et al., 2014, human panelists are used in the sensory evaluation of pet food due to their ability to be trained to describe the textural properties of pet food, as opposed to animal-based evaluations (Koppel et al., 2014).

4.5.3 Comparison between overall liking and demographic characteristics

Results comparing the overall liking of jerky-style pet treats made with SP across demographic characteristics are presented in Table 4.4. No significant interactions were observed among the treatment and gender ($P = 0.775$, ethnicity ($P = 0.972$), type of pet ($P = 0.748$), and previous experience living with pets ($P = 0.635$). However, when comparing genders, males had a higher overall liking than females ($P = 0.018$). Ethnicity also impacted overall liking scores, with Hispanic or Latino panelists rating overall liking higher than all other ethnic groups ($P = 0.001$). Regarding pet ownership, panelists that owned dogs had a higher overall liking than those of other pets ($P = 0.008$). Additionally, participants who had lived with pets for 2-5 years had a significantly higher overall liking score than those with different experience durations ($P = 0.011$).

With regard to liking scores based on gender, similar findings were found in a study performed on fat-rich meat, where males rated the products higher than females, including in comparison of pork. This gender difference may be attributed to fat content, as females tend to be more health-conscious (Spinelli et al., 2020). Another study on meat products observed significant gender differences, with males giving higher ratings in sensory evaluations of various meat samples. Although the majority of participants were female, the male group consistently rated the samples higher (Dinnella et al., 2023). These differences may be influenced by color preferences, as male panelists tend to favor red meat (Ritzel & Mann, 2021).

The ethnicity of panelists can also influence the overall liking of the samples. Similar findings were observed in a study evaluating food samples, where Hispanic participants gave higher liking scores to certain food items compared to other ethnic groups (Aldaz et al., 2022). When evaluating the overall liking of the product, pet ownership can also affect the scores.

However, our results contrast with a previous study on pet owners perception of pet food, where cat owners prioritized the smell and appearance of the samples, while dog owners were more concerned with the ingredients and the product healthfulness (Vinassa et al., 2020). Additionally, another study found that owners who had lived with pets for an extended period developed a deeper understanding of their pets preferences and acceptance of various pet foods (Bradshaw, 2006).

4.6 Conclusions

Sensory characteristics of dehydrated jerky-style pet treats made with swine pluck have an influence on pet owners liking scores of the samples. Among the 100 hundred pet owners surveyed, the overall liking and appearance of the samples were not impacted by the dehydration time evaluated in this study. However, pet owners were able to differentiate between the samples based on color and texture. Additionally, differences were found in purchase intent among SP samples, with intent scores ranging from 2.79 to 3.23 (± 0.13). SP jerky treats dehydrated for 3 h had the least favorable scores compared to other treatments.

Regarding demographic characteristics, the majority of pet owners had a dog (36%), had lived with pets for more than 10 years (82%), purchased pet treats once a month (49%), and sometimes checked the ingredients label of treats (42%). Furthermore, when comparing overall liking and demographics data, significant differences were observed across gender, ethnicity, type of pet, and previous experience living with pets. Male participants, Hispanic or Latino owners, dog owners, and those who had lived with their pets for 2 to 5 years reported higher liking scores compared to other categories.

Overall, the sensory evaluation of jerky-style pet treats made with swine pluck offers valuable insight into pet owners' acceptability and purchasing decisions, given that pet owners are the initial decision-makers. However, as a future direction, it would be important to conduct preferences tests involving both the owners and their pets. Gathering data on the pet owners purchasing decisions along with the pet's liking scores could help the pet food industry better align product characteristics with the preferences of both owners and pets, particularly in terms of organoleptic and palatability features.

4.7 References

1. (APPA), A. P. P. A. (2024). *Industry Trends and Stats*. American Pet Products Association. Retrieved Sept 3, 2024 from https://www.americanpetproducts.org/research-insights/industry-trends-and-stats
2. (AVMA), A. V. M. A. (2022). *U.S. Pet Ownership Statistics* Retrieved Sep 3, 2024 from https://www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics
3. Code of Federal Regulations Title 21, (2023). https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=184.1724
4. Albright, S., Kendall, P., & Sofos, J. (2000). Sensory properties of beef jerky processed under various conditions. Proceedings of IFT annual meeting, June,
5. Aldaz, K. J., Flores, S. O., Ortiz, R. M., Diaz Rios, L. K., & Dhillon, J. (2022). A Cross-Sectional Analysis of Food Perceptions, Food Preferences, Diet Quality, and Health in a Food Desert Campus. *Nutrients*, *14*(24), 5215. https://doi.org/10.3390/nu14245215
6. Ayanwale, B., Ocheme, O., & OO, O. (2007). The Effect of Sun-Drying and Oven-Drying on the. *Pakistan Journal of Nutrition*, *6*(4), 370-374.
7. Boya, U. O., Dotson, M. J., & Hyatt, E. M. (2015). A comparison of dog food choice criteria across dog owner segments: an exploratory study. *International Journal of Consumer Studies*, *39*(1).
8. Bradshaw, J. W. (2006). The evolutionary basis for the feeding behavior of domestic dogs (Canis familiaris) and cats (Felis catus). *The Journal of nutrition*, *136*(7), 1927S-1931S.
9. Calancea, B.-A., Daina, S., & Macri, A. (2024). The science of snacks: a review of dog treats. *Frontiers in Animal Science*, *5*. https://doi.org/10.3389/fanim.2024.1440644

10. Chanadang, S., Koppel, K., & Aldrich, G. (2016). The Impact of Rendered Protein Meal Oxidation Level on Shelf-Life, Sensory Characteristics, and Acceptability in Extruded Pet Food. *Animals*, *6*(8), 44. https://doi.org/10.3390/ani6080044

11. Dainton, A. N., Dogan, H., & Aldrich, C. G. (2021). The Effects of Select Hydrocolloids on the Processing of Pâté-Style Canned Pet Food. *Foods*, *10*(10), 2506. https://doi.org/10.3390/foods10102506

12. Di Donfrancesco, B., Koppel, K., Swaney-Stueve, M., & Chambers, E. (2014). Consumer Acceptance of Dry Dog Food Variations. *Animals*, *4*(2), 313-330. https://doi.org/10.3390/ani4020313

13. Dinnella, C., Napolitano, F., Spinelli, S., Monteleone, E., Pacelli, C., & Braghieri, A. (2023). Factors affecting stated liking for meat products: focus on demographics, oral responsiveness, personality, and psycho-attitudinal traits. *Meat Science*, *195*, 109004.

14. Doymaz, İ., Karasu, S., & Baslar, M. (2016). Effects of infrared heating on drying kinetics, antioxidant activity, phenolic content, and color of jujube fruit. *Journal of Food Measurement and Characterization*, *10*(2), 283-291. https://doi.org/10.1007/s11694-016-9305-4

15. Herrera-Corredor, J. A., Saidu, J. E. P., Khachatryan, A., Prinyawiwatkul, W., Carballo-Carballo, A., & Zepeda-Bautista, R. (2007). Identifying Drivers for Consumer Acceptance and Purchase Intent of Corn Tortilla. *Journal of Food Science*, *72*(9), S727-S731. https://doi.org/10.1111/j.1750-3841.2007.00564.x

16. Kim, T.-K., Kim, H.-W., Lee, Y.-Y., Jang, H. W., Kim, Y.-B., & Choi, Y.-S. (2020). Quality characteristics of duck jerky: combined effects of collagen and konjac. *Poultry Science*, *99*(1), 629-636. https://doi.org/https://doi.org/10.3382/ps/pez561

17. Koc, B., Eren, I., & Ertekin, F. K. (2008). Modelling bulk density, porosity and shrinkage of quince during drying: The effect of drying method. *Journal of Food Engineering*, *85*(3), 340-349.

18. Konieczny, P., Stangierski, J., & Kijowski, J. (2007). Physical and chemical characteristics and acceptability of home style beef jerky. *Meat Science*, *76*(2), 253-257.

19. Koppel, K. (2014). Sensory analysis of pet foods. *Journal of the Science of Food and Agriculture*, *94*(11), 2148-2153. https://doi.org/10.1002/jsfa.6597

20. Koppel, K., Gibson, M., Alavi, S., & Aldrich, G. (2014). The Effects of Cooking Process and Meat Inclusion on Pet Food Flavor and Texture Characteristics. *Animals*, *4*(2), 254-271. https://doi.org/10.3390/ani4020254

21. Lee, S. W., & Kang, C. S. (2003). Effects of moisture content and drying temperature on the physicochemical properties of ostrich jerky. *Food / Nahrung*, *47*(5), 330-333. https://doi.org/10.1002/food.200390076

22. Luño, I., Muniesa, A., Palacio, J., García-Belenguer, S., & Rosado, B. (2021). Detection of owner-perceived emotional eating in companion dogs: A regression modelling approach. *Veterinary Record*, *189*(2). https://doi.org/10.1002/vetr.63

23. Lynch, S. A., Mullen, A. M., O'Neill, E., Drummond, L., & Álvarez, C. (2018). Opportunities and perspectives for utilisation of co-products in the meat industry. *Meat Science*, *144*, 62-73. https://doi.org/https://doi.org/10.1016/j.meatsci.2018.06.019

24. Morelli, G., Stefanutti, D., & Ricci, R. (2021). A Survey among Dog and Cat Owners on Pet Food Storage and Preservation in the Households. *Animals*, *11*(2), 273. https://doi.org/10.3390/ani11020273

25. Oliveira, S. M., Brandão, T. R. S., & Silva, C. L. M. (2016). Influence of Drying Processes and Pretreatments on Nutritional and Bioactive Characteristics of Dried Vegetables: A Review. *Food Engineering Reviews*, *8*(2), 134-163. https://doi.org/10.1007/s12393-015-9124-0

26. Ritzel, C., & Mann, S. (2021). The old man and the meat: on gender differences in meat consumption across stages of human life. *Foods*, *10*(11), 2809.

27. Ruiz-Capillas, C., & Herrero, A. M. (2021). Sensory Analysis and Consumer Research in New Product Development. *Foods*, *10*(3), 582. https://doi.org/10.3390/foods10030582

28. Schleicher, M., Cash, S. B., & Freeman, L. M. (2019). Determinants of pet food purchasing decisions. *The Canadian Veterinary Journal*, *60*(6), 644.

29. Simonsen, J. E., Fasenko, G. M., & Lillywhite, J. M. (2014). The value-added dog food market: do dog owners prefer natural or organic dog foods? *Journal of Agricultural Science*, *6*(6), 86.

30. Spinelli, S., Dinnella, C., Tesini, F., Bendini, A., Braghieri, A., Proserpio, C., Torri, L., Miele, N. A., Aprea, E., & Mazzaglia, A. (2020). Gender differences in fat-rich meat choice: influence of personality and attitudes. *Nutrients*, *12*(5), 1374.

31. Vinassa, M., Vergnano, D., Valle, E., Giribaldi, M., Nery, J., Prola, L., Bergero, D., & Schiavone, A. (2020). Profiling Italian cat and dog owners' perceptions of pet food quality traits. *BMC Veterinary Research*, *16*(1). https://doi.org/10.1186/s12917-020-02357-9

32. Wang, S., Chen, H., Sun, J., Zhang, N., Wang, S., & Sun, B. (2023). Effects of cooking methods on aroma formation in pork: A comprehensive review. *Food Chemistry: X*, *20*, 100884. https://doi.org/https://doi.org/10.1016/j.fochx.2023.100884

Table 4.1 Demographic characteristics of pet owners evaluating jerky-style pet treats made with swine pluck.

Demographic characteristics[1]	**Percentage (%)**
Age (years; n = 100)	
18-21	16
22-30	60
31-40	9
41-50	8
51-60	4
61-70	3
Ethnicity (n = 100)	
Asian or Pacific Islander	8
Black	3
Hispanic or Latino	22
Native American	0
White	65
Other	2
Gender (n = 100)	
Female	67
Male	33
Occupation (n = 100)	
Faculty/Staff	31
Doctoral student	13
Master's student	31
Bachelor's student	20
Other	5

[1] Demographic characteristics: pet owners were asked to complete a demographic questionnaire regarding their age, ethnicity, gender, and occupation.

Table 4.2 Pet ownership questionnaire evaluating jerky-style pet treats made with swine pluck.

Pet ownership questionnaire	**Percentage (%)**
Type of pet (N = 100)	
Cat	16
Dog	36
Dog and cat	17
Dog and cat / other species	29
Other	2
Lived with pets (years; N = 98)	
< 1	1
2 to 5	10
6 to 9	7
10 or more	82
Treat purchase frequency (N = 88)	
Twice a week	2
Once a week	11
Every 2 weeks	27
Once a month	49
Once every 2 months	7
Less than once every 2 months	4
Check ingredients (N = 96)	
Always	34
Sometimes	42
Rarely	19
Never	5

Table 4.3 Effect of dehydration time on sensory parameters of jerky-style pet treats made with swine pluck.

	Sensory parameters[1] evaluated in SP jerky-style treats[2]						
	Dehydration time (h)[3]						
Variable	3	4	5	6	7	SEM[4]	*P* - value[5]
Overall liking	5.01	5.41	5.61	5.37	5.48	0.21	0.1350
Appearance	5.11	5.30	5.26	5.17	5.13	0.20	0.8463
Color	5.08[a]	5.03[a]	4.74[ab]	4.73[ab]	4.60[b]	0.15	0.0045*
Texture	4.19[b]	5.21[a]	5.65[a]	5.33[a]	5.16[a]	0.30	< 0.0001*
Intent to purchase[6]	2.79[b]	3.18[a]	3.23[a]	3.02[ab]	3.09[ab]	0.13	0.0079*

[1] Sensory parameters were evaluated in one hundred pet owners.
[2] The dehydration of jerky-style pet treats occurred in a dehydrator oven set at 68.3 °C until each dehydration time was reached.
[3] Dehydration time was collected during five different periods, including 3, 4, 5, 6, and 7 h.
[4] SEM = highest standard of the LS means comparisons.
[5] P – value: significant differences were determined when $P \leq 0.05$.
[6] Intent to purchase variable was measured using a 5-point purchase intent scale.
[a-c] Means within a row with different superscripts differ at $P \leq 0.05$.

Table 4.4 Comparison between overall liking and demographics of jerky-style pet treats made with swine pluck.

	Interaction between demographics and overall liking on sensory characteristics of jerky-style pet treats made with swine pluck[2]	
Variable	**Category[3]**	***P* – value[4]**
Gender	Males	0.018
Ethnicity	Hispanic or Latino	0.001
Pet	Dog	0.008
Lived with pets	2 to 5 years	0.011

[1] Interaction between overall liking and demographic characteristics was analyzed using a 2-way ANOVA.
[2] The dehydration of jerky-style pet treats occurred in a dehydrator oven set at 68.3 °C until each dehydration time was reached.
[3] The highest score among categories for each variable was selected to determine significant differences.
[4] Differences were declared when $P \leq 0.05$.