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Up-cycling Low Value Proteins Through the Use of Functional Food Technologies Promotes Sustainability While Enhancing Profitability

Starkey Laboratory
Processing Product Upcycling and Pet Food

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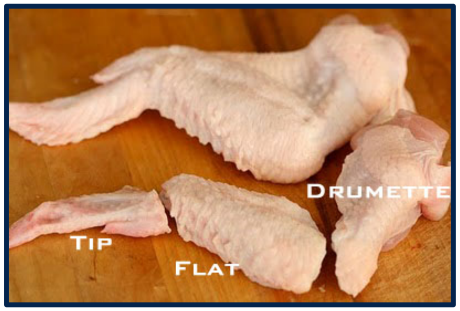
- 107 Undergraduate research assistants
- 43 International visiting scholars
- 22 Graduate students
- Training in Food Science
- Abstract generation ~80
- Publishable projects ~20
- 1 undergraduate Thesis
- 4 Masters Thesis

Introduction
Animal Co-Products

- Low-value Protein conversion co-products
  - Often sold for rendering
  - Co-products are often sold at 6-13¢ per kg.
- Pet treats
  - Valuable product ($22 to ≥ 55 per kg)
  - Pet food manufacturers already use animal co-products to manufacture pet treats rich in nutrients
    - Marti et al., 2012
- Structure forming technologies
  - Allow the conversion of these products into functional treats



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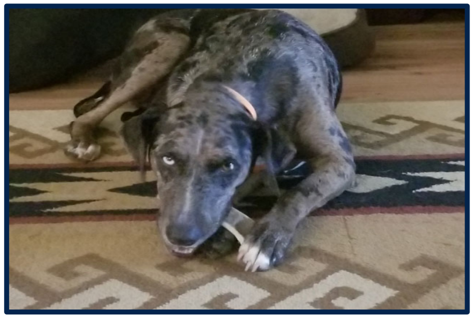


Introduction
Animal Co-Products

- Animal co-products (ACP) may be considered a delicacy, or an undesired material destined for purposes other than human consumption
- They do not participate largely in American dish and are rarely found on menus
    - Marti et al, 2012
- ACP are rich in protein, vitamins and minerals, and have some distinct functional and sensory properties
    - Ockerman and Basu, 2014

Introduction
Animal Co-Products

- Processing is the conversion of live animals into smaller retail cuts for human consumption
  - USDA, 2013

- Processing generates lower value co-products

Introduction
Animal Co-Products

- Combined value of production from broilers, eggs, turkeys, and the value of sales from chickens in 2020 was $35.5 billion, 61% from broilers
  - USDA, 2020
- Total number of broilers produced in 2020 was 9.22 billion
  - USDA, 2020

Raw wing tips (WT)

Introduction
Animal Co-Products

- Chicken co-products are the most common protein source used in dry dog treats
  - Watson, 2006
- United States has a robust poultry industry, with an inventory of over 518 million chickens
  - Shahbandeh, 2021
- For the last decade, the United States has exported 6 to 7 billion pounds of broiler
  - Shahbandeh, 2021

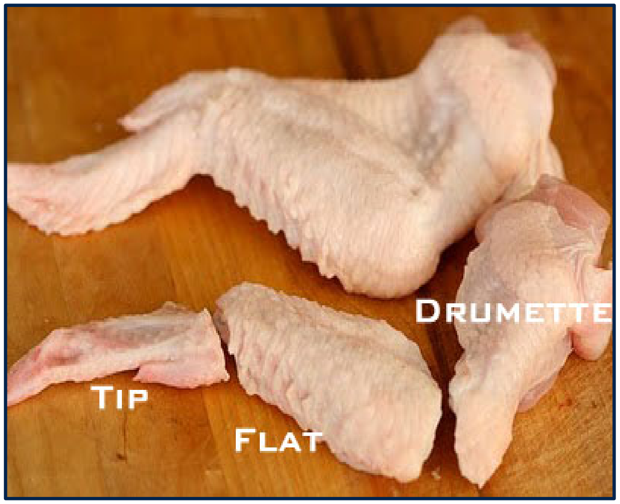
Introduction
Animal Co-Products

- **Parts of processed animal not included in dressed carcasses**
  - Galanakis, 2018
- **Animal co-products (ACP) are often repurposed for other usages than human consumption**
  - Ockerman & Basu, 2014
- **Co-products can represent up to 44% and 37% of cattle and poultry live weight, respectively**
  - Marti et al., 2012, Tyler, 2021

Introduction
Animal Co-Products

- Broiler wing tips (WT) are a low-value broiler processing co-product
- WT are in abundant supply and can be repurposed into more marketable products

Raw broiler WT



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Introduction
Animal Co-Products

- Broiler carcass frames and Wooden Breast (WB) meat are low-value broiler co-products
- Both are in abundant supply and can be repurposed into more marketable products


Broiler carcass frames


Wooden Breast

Introduction
Animal Co-Products

- Largest gland in animals and most consumed animal co-product
- Contains a protein level close to lean meat
- High levels of carbohydrates
- Rich in Fe, Mg, Cu, vitamins A, B6, B12, C, niacin, and folacin

Introduction
Animal Co-Products

- Represents 0.5% of cattle live weight
  - Ockerman and Basu, 2014
- Rich in protein, niacin, riboflavin, Fe, Zn, Se, and P
  - Marti et al, 2012
- Consumed as a deli and used in traditional gastronomy in some countries

Introduction
Animal Co-Products

- Processing co-products have additional opportunities to supply a valuable protein source to the pet food industry
- Establishing quality parameters for certain processing products is useful for future product development

Pet treats in packaging system

Introduction
Overview of the Pet Food Industry

- Pet humanization and premiumization of pet foods have led to significant changes in animal co-product markets
  - Mullen et al, 2017
- Pet owners seek new protein-based and healthy food products for their pets
  - Mullen et al., 2017
- Pet food manufacturers use animal co-products to develop pet treats rich in protein, vitamins, and minerals
  - Marti et al., 2012

Introduction
Overview of the Pet Food Industry

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- Nearly 82% of pet owners buy some type of treats with some regularity
  - Simmons National Consumer Survey, 2014
- Pet owners frequently provide treats to cats and dogs as a demonstration of affection and reward or a way to motivate them during training
  - He et al, 2020
- Treats can deliver functional nutrients and benefits such as defense against disease, brain or dental health
  - Smironova, 2020

Introduction
Overview of the Pet Food Industry

- Pet treats success in the market is influenced by several factors such as price, packaging, marketing claims, and sensory properties
  - Koppel, 2014
- Treats' sensory attributes such as appearance, color, texture, and flavor can contribute to their acceptance by pets and largely influence pet parents' purchase decisions
  - Di Donfranceso et al., 2014

Introduction
Overview of the Pet Food Industry

- Pet industry expenditures
  - Of the $103.6 billion spent on pets, $42 billion were for pet food and pet treats in 2020
  - Out of 90.5 million households with a pet there are 69 million with at least one dog
  - Dog food and treats market was valued at $66.16 billion during 2020, and will exhibit a 4.5% CAGR from 2021 to 2027
    - Global Market Insights, 2020

Introduction
Overview of the Pet Food Industry

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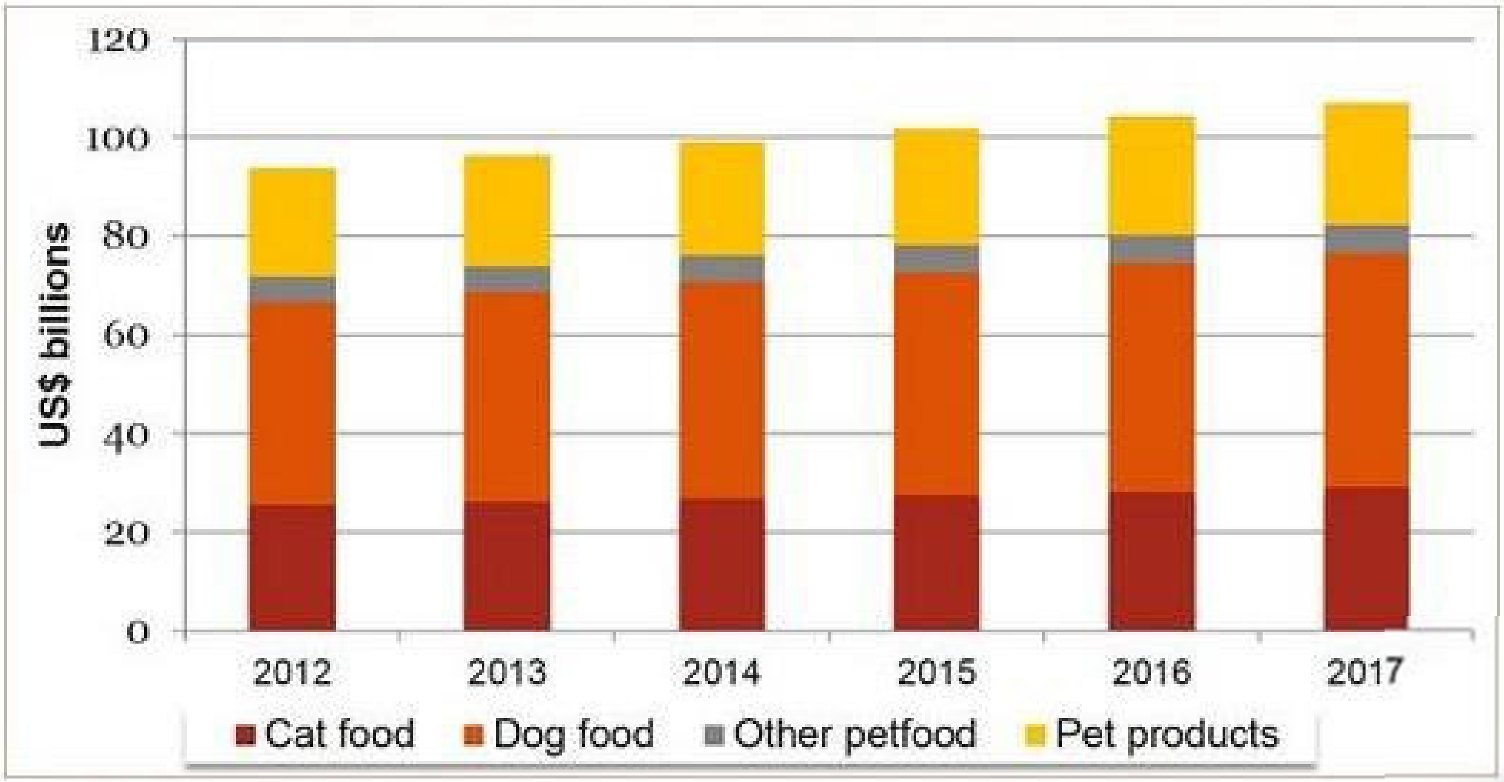
Global Pet Product Growth

- The global pet care market reached U.S.$125 billion in 2018
  - 73 % of that total, about U.S.$91.1 billion, was global pet food sales.
  - Represent a 6 % compound annual growth rate (CAGR) since 2013
  - 31% overall growth during the same period
- For reference, during the same time period:
  - Human packaged foods (23% growth)
  - Fresh food for humans (16% growth)
  - Home care (23% growth)

Euromonitor International, 2019

Global Pet Product Growth Projections by Category 2012-2017



Euromonitor International

Introduction
Overview of the Pet Food Industry

- Co-products are the most common protein source used in dry dog treats
  - Watson, 2006

Dog treats
(Mullins, 2021)

Chicken liver and heart pet treats

Restructured Pet Treats from ACP

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- Animal co-products (ACP) can be processed into restructured pet treats by using hydrocolloids as functional ingredients
  - Challen and Moorhouse, 2011
- Hydrocolloids are high molecular weight polymers used to improve the rheological and textural properties of food products
  - McArdle and Hamill, 2011
- Selection of adequate type of hydrocolloid is crucial to attaining desired quality, sensorial acceptability, stability, and shelf life
  - McArdle and Hamill, 2011

Economics

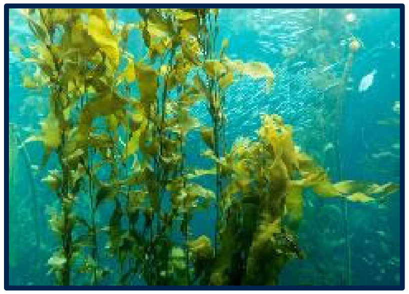
Input	Costs/lb	Costs/week
Paws	$0.76	$76,000
ALGIN	$2.77	$16,346.65
Packaging	$0.64	$65,184
Labor	$0.75	$75,000
Total	$4.92	$232,530.65

Hydrocolloids in Product Development
Sodium Alginate

- Alginate is a type of hydrocolloid used in product development as a structure-forming ingredient
  - Qin et al., 2018
- Alginate can provide mechanical strength and flexibility to restructured meat products, such as pet treats

Hydrocolloids in Product Development
Sodium Alginate

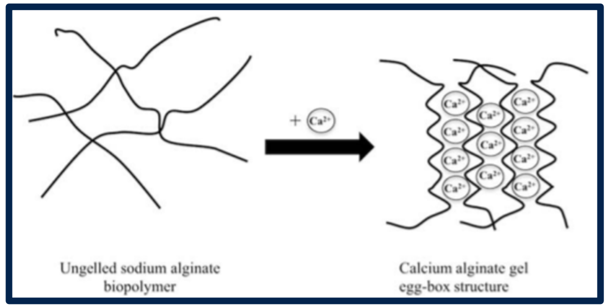
- Alginate is produced from marine brown algae
  - Goh et al, 2012
- Alginate is extracted from algal tissue and brought into solution by neutralization with an alkali, such as sodium carbonate
- Soluble sodium alginate is precipitated and converted into commercial sodium alginate
  - Draget, 2009



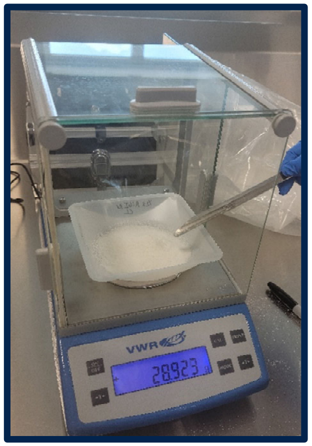
USC Dornsife

Hydrocolloids in Product Development

- Hydrocolloids are high-molecular-weight, hydrophilic molecules
- Used as functional ingredients in food formulation
- Increases food consistency, improves gelling effect, and controls the microstructure, texture, flavor, and shelf life of food products
  - Gawai et al., 2017



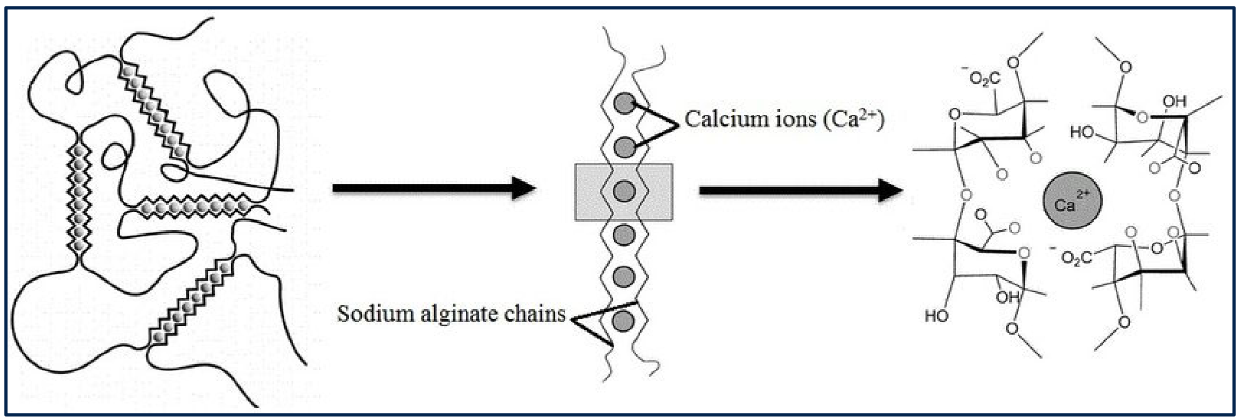
Ching et al., 2017



ALGIN being weight before mixing

Hydrocolloids in Product Development
Sodium Alginate

- Sodium alginate is a hydrocolloid with gelling and stabilizing properties that could improve textural characteristics of meat products
  - Edley, 2007
- Divalent metal ions, such as calcium, line up alginate chains to form a stable gel



Egg-box structure

Destruel et al., 2016

Hydrocolloids in Product Development
Alginate Gelation

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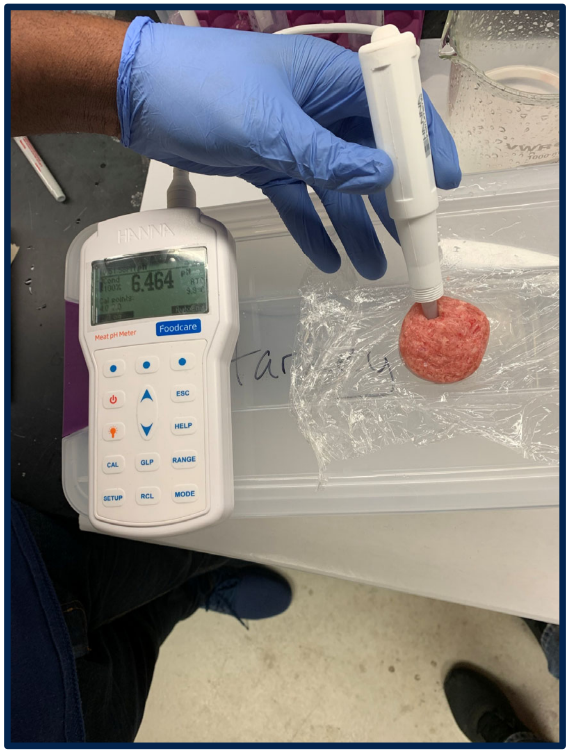
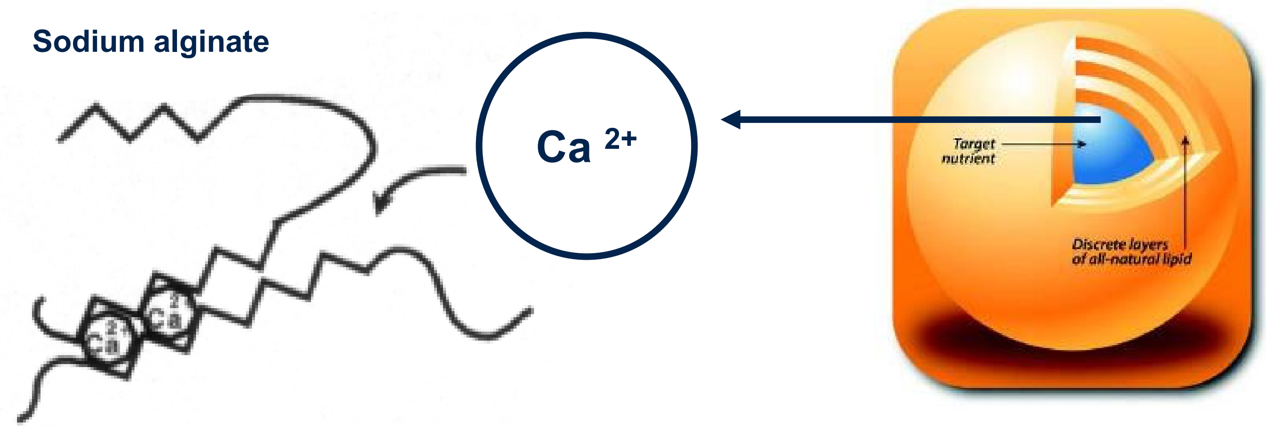
- Calcium salts can be totally soluble, sparingly soluble, and insoluble
- Calcium lactate is a totally soluble calcium salt with a rapid gelation rate and poorly controlled
  - Challen and Moorhouse, 2011
- Because of the fast gelation rate, mixture of sodium alginate and calcium lactate ions rarely produces a homogeneous gel
  - Draget et al., 2005



Hydrocolloids in Product Development
Alginate Gelation

- **Calcium lactate may be encapsulated to control release of calcium ions into a soluble alginate solution for gel formation and development of restructured products**
  - **Challen and Moorhouse, 2011**

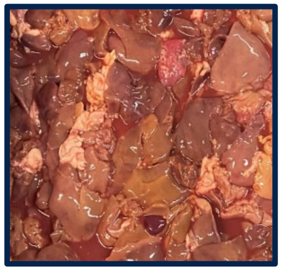
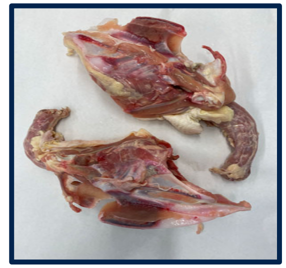
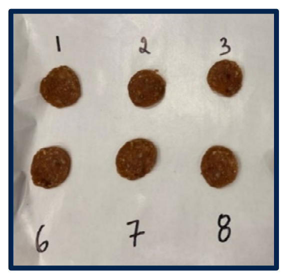


Introduction
Restructured pet treats

- ALGIN= sodium alginate + encapsulated calcium lactate
- ALGIN can enhance the quality and add stability to mixtures of minced protein components through a gelation process
- Co-products may be processed into pet treats by using ALGIN as a structure-forming component

Sodium alginate

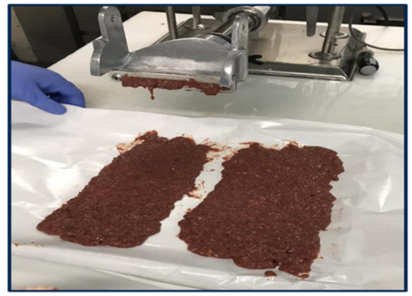
The process

	Chicken liver and heart	Chicken carcass frames	Chicken paws
Raw product			
Mixtures			
Final product			

The process

BL:BH mixture

BL:BH mixture with ALGIN



Extruded raw product

Cutting raw product

Forming raw BL:BH treats

Measuring color on raw BL:BH treats

Dehydrated BL:BH treats

Measuring color on cooked BL:BH treats

The products

The products

The products

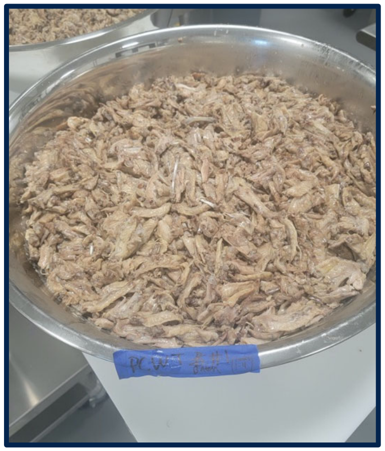
The products

Materials and methods
Cooking

- WT were cooked in a GoWise electric pressure cooker (n = 4) with 7% added water
  - At 55 kPa for 90 min
  - Average cooking moisture loss was 18.57%

Raw WT

Draining pressure cooked WT



Pressure cooked, drained WT

Materials and methods
Grinding

- Cooked WT were ground twice
  - First grind: kidney grinder plate
  - Second grind: 4.8-mm grinder plate

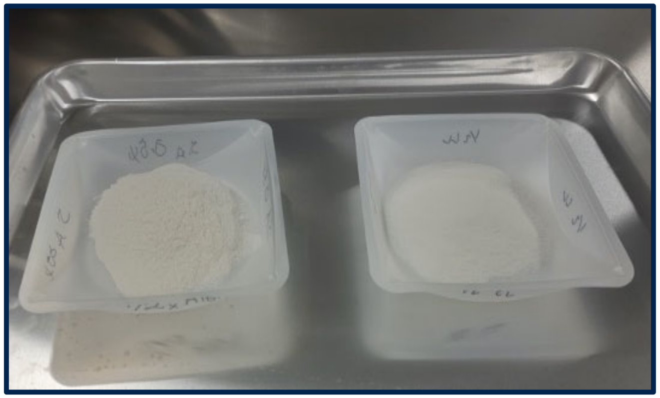
Kidney grinder

WT after first grind

4.8-mm grinder plate

WT after second grind

Materials and methods
ALGIN inclusion



Sodium alginate and encapsulated calcium lactate

ALGIN addition

	ALGIN			
	0x	0.5x	1x	2x
Sodium alginate, %	0.000	0.500	1.000	2.000
Encapsulated calcium lactate, %	0.000	0.425	0.850	1.700

Materials and methods
Sample preparation

- Each mixture was stuffed into 63.5-mm-diameter casings, and secured with hog rings
- Chubs were stored at 4 °C for 12 h to facilitate gelation, and then frozen at -20 °C for 3 h prior to slicing into 5-mm-thick slices
- For data collection, samples were stored at 4 °C for 7 d

Raw WT in chubs

5-mm-thick raw WT treat slices

Materials and methods
Sample Preparation

- Oven was set at 93 °C until samples' internal temperature reached 74 °C
- Smokehouse temperature was dropped to 66°C until treats' water activity (a_w) reached 0.80
- Expressible moisture and cooking loss were measured on raw samples
- Color variation and textural characteristics measurements were conducted on raw and dehydrated treats

Quality Parameters of Pet Treats
Physico-chemical Characteristics

- Water Activity (a_w)
  - Important attribute that assesses food stability with respect to microbial growth, chemical, and biological reactions
  - Park, 2008
- pH
  - Quality parameter that affects color, water holding capacity, tenderness, flavor, and shelf life of meat products
  - Honikel, 2014

Quality Parameters of Pet Treats
Physico-chemical Characteristics

- Expressible moisture
  - Amount of liquid squeezed from products' protein system by the application of external forces
  - Pearce et al., 2011
- Cooking loss
  - Loss of sample weight in percentage during cooking, caused by heat-induced protein denaturation
  - Bejerholm, 2014

Quality Parameters of Pet Treats
Textural Characteristics

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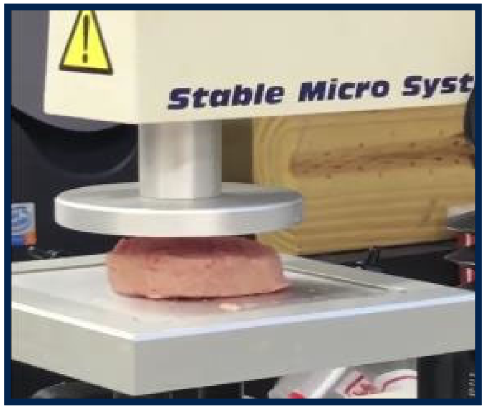
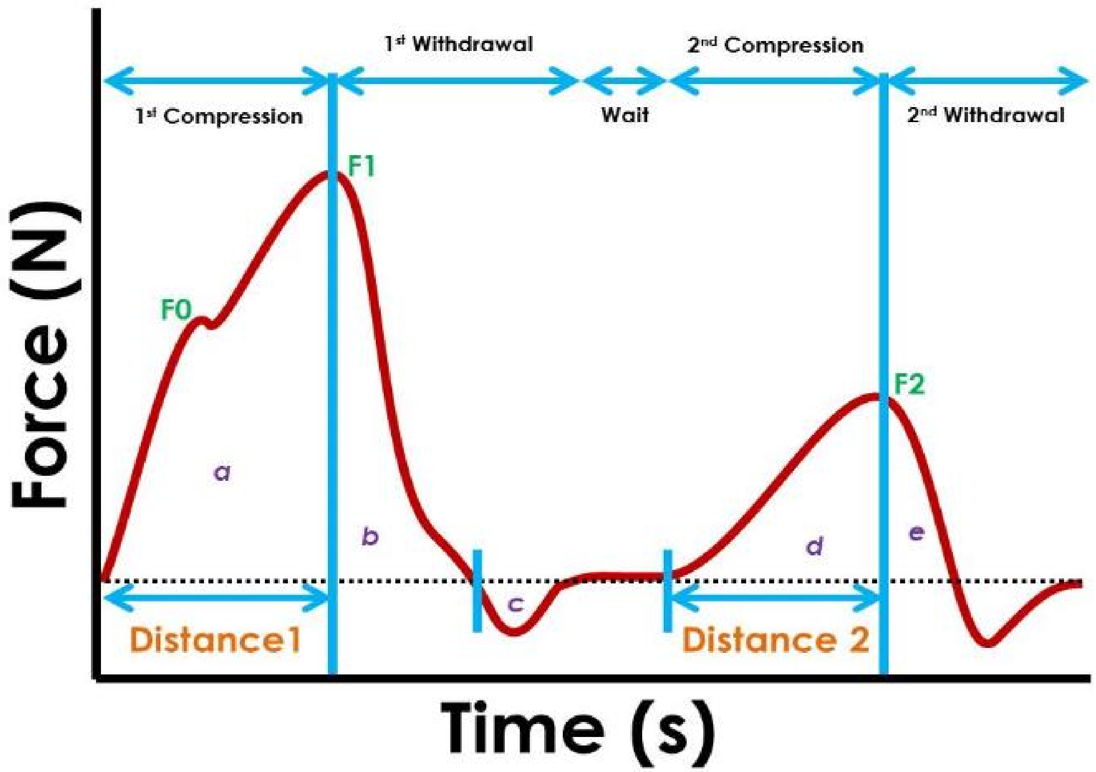
- Rheological and structural properties of foods perceived by senses of sound, sight, and touch
  - Chen and Opara, 2013
- Textural properties of pet foods may affect their palatability and provide pleasant sensations that stimulate pets to eat a portion of food in preference to others
  - Fox, 2020
- Textural attributes of foods are assessed using descriptive sensory methods and instrumental analysis
  - Li et al., 2020

Quality Parameters of Pet Treats
Textural characteristics Measurements

- Texture Profile Analysis (TPA)
- Double compression type test that mimics first two bites of the mastication process of foods in the mouth
- Assesses Hardness, Adhesiveness, Cohesiveness, Springiness, and Chewiness of pet treats



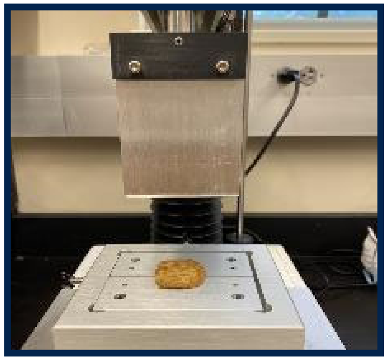
Quality Parameters of Pet Treats
Textural Characteristics Measurements

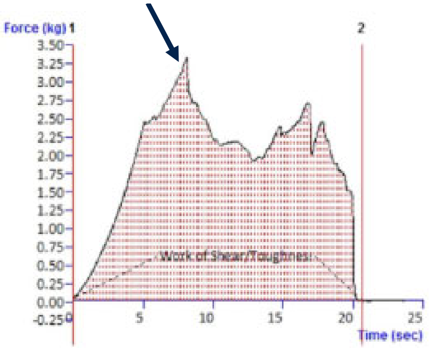


Adapted from Centre for Industrial Rheology

Quality Parameters of Pet Treats
Textural Characteristics Measurements

- Shear Force Test
- Measures degree of tenderness of meat products
- Evaluates Firmness and Toughness of pet treats

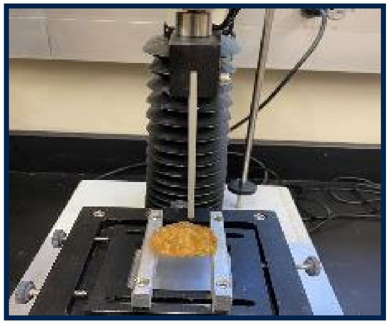




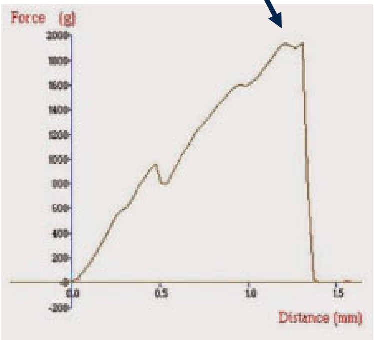
Stable Micro Systems

Quality Parameters of Pet Treats
Textural Characteristics Measurements

- **Three-point Bending Test**
- **Measures break strength or flexibility by bending samples**
- **Assesses Peak force and Flexibility of pet treats**



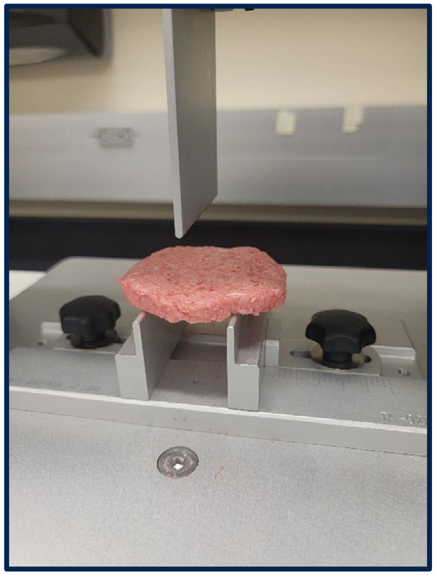
Peak force



Stable Micro Systems

Materials and methods
Texture analysis: 3-point bend (3PB)

- Hardness, flexibility, and stiffness were analyzed applying the 3PB bend test to 10 samples per treatment (TA-HDplusC with a TA-43R probe)
  - Hardness, g
  - Flexibility, mm
  - Stiffness, g per mm



- Blade speed was 1 mm per s for 10 mm

Quality Parameters of Pet Treats
Color Variation

- **Consumers rely heavily on fresh meat color as an indicator of wholesomeness at the point of sale**
  - **Suman and Joseph, 2014**

- **Pet owners rely on pet treats characteristics such as color to make judgments on their quality and purchase decisions**
  - **Guy, 2015**

Quality Parameters of Pet Treats
Color Variation

- Color is brain perception of an object after its interaction with light
- Perceived color is affected by three components:

  - Lawless and Heymann, 2010

Quality Parameters of Pet Treats

Color Variation

- Color of meat products is mainly influenced by myoglobin and is also affected to smaller extents by other pigments such as hemoglobin and cytochrome *c*
  - Bechtold et al., 2018
- When meat products are exposed to heat during cooking, myoglobin loses its stability and forms hemichrome that gives a dull-brown color
  - Claus, 2007

Quality Parameters of Pet Treats
Color Variation

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- Pet parents rely on pet treats' physical characteristics such as color to make judgments on their quality and purchase decisions
  - Guy, 2015
- Human color perception of foods is subjective and is affected by our visual characteristics and preferences
  - Pérez-Alvarez and Fernández-López, 2010

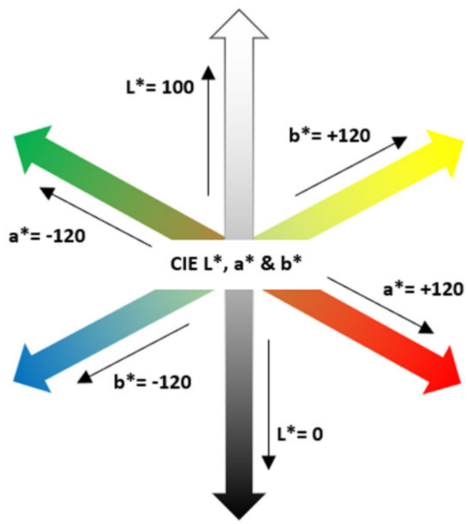
Quality Parameters of Pet Treats
Color Variation

- Instrumental color measurement simulates the ability of human eyes to perceive colors and can provide quantitative values
  - Mancini and Hunt, 2005
- One of the most common methods to analyze instrumental color analysis is using a CIE L* a* b* colorimeter

www.hunterlab.com

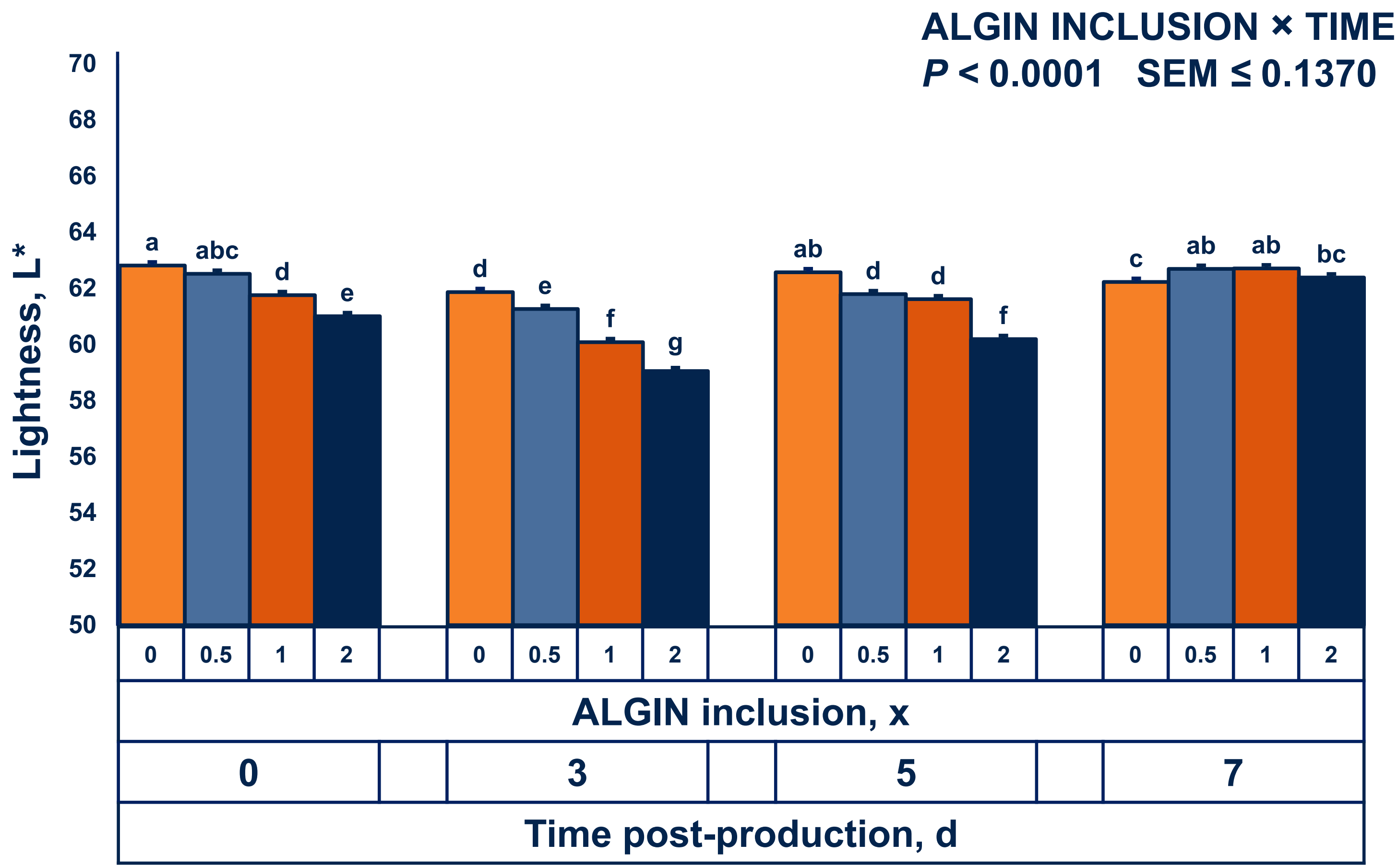
Quality Parameters of Pet Treats
Color Variation

- Data on color was collected on d 0, 3, 5 and 7 post-production
  - L* - Lightness
    - 0 to 100, black to white
  - a* - Redness
    - -120 to 120, green to red
  - b* - Yellowness
    - -120 to 120, blue to yellow

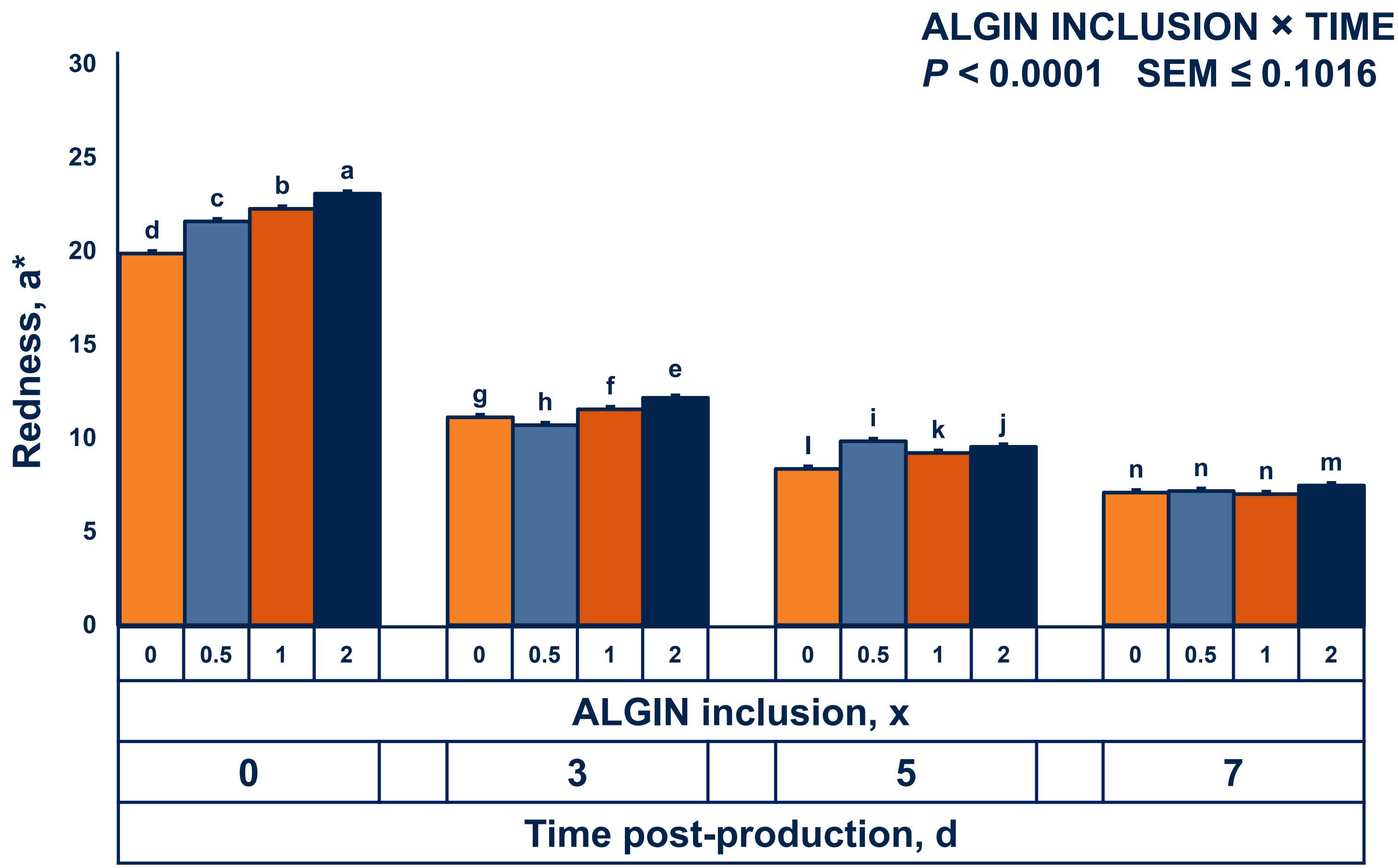


Adapted from Cavanaugh, 2008

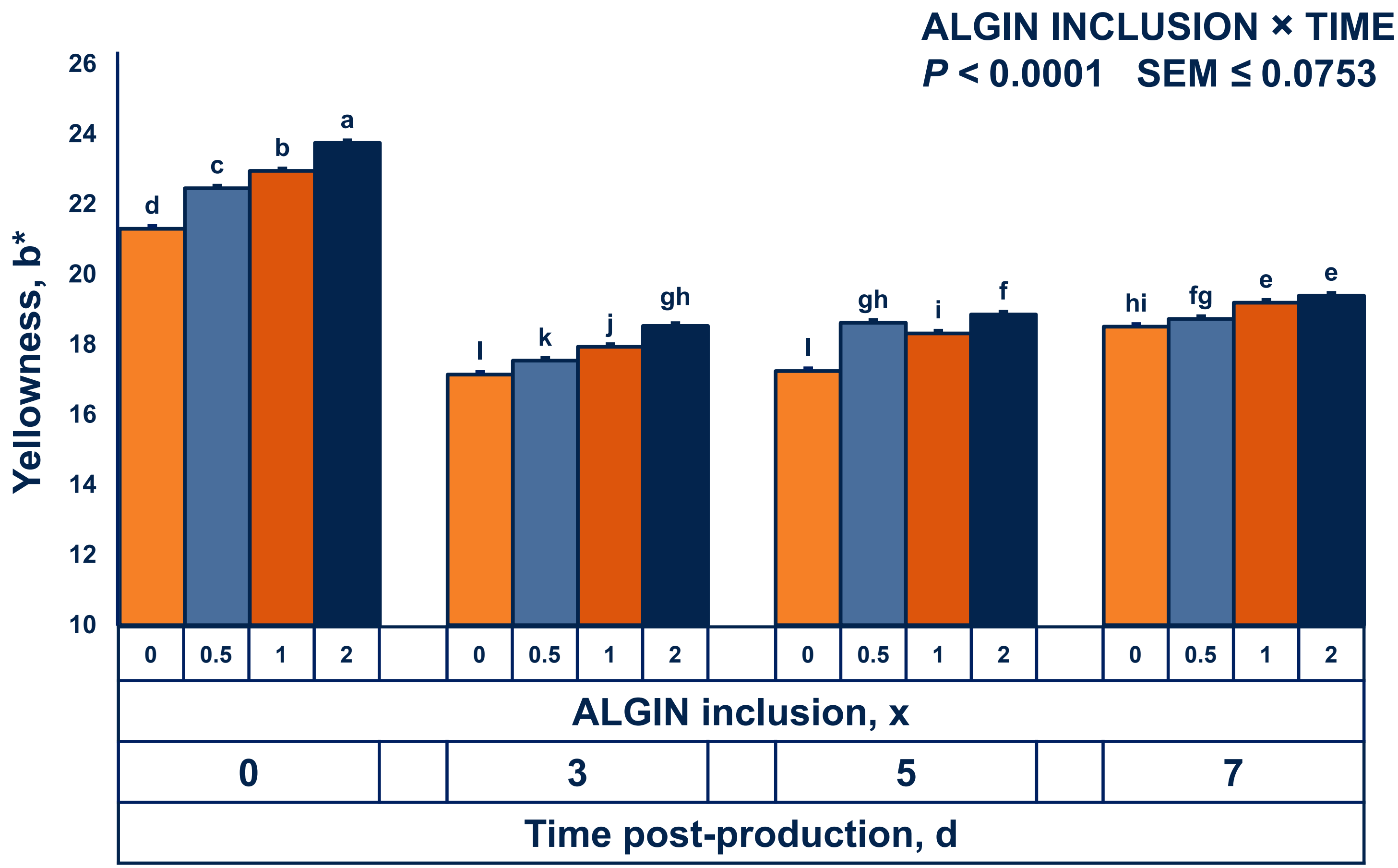
Results
Lightness (L*) of raw pet treats



Results
Redness (a*) of raw pet treats



Results
Yellowness (b*) of raw pet treats



Quality Parameters of Pet Treats
Color Variation

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- **Regardless of ALGIN inclusion over time post-production, lightness decreased, redness and yellowness increased.**
- **Delta-e (The measure of change in visual perception of two given colors) values indicate that the color differences among treatments during all d 3, 5, and 7 post-production would not be obvious to a pet owner.**
  - **AMSA Meat Color Measurement Guidelines, 2012**

Conclusions

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- Animal co-products combinations and ALGIN inclusions can be utilized to improve pet treats' quality characteristics, enabling new product development opportunities for the pet food industry
- Inclusion of ALGIN improved water retention of treats and allowed less water during cooking loss and expressible moisture tests
- Flexibility values increased in treats generated from BL:BH, CL:CH, and GF:WB as ALGIN inclusion increased
- Raw treats' hardness and chewiness decreased as ALGIN decreased, but dehydrated treats were harder and chewier with increasing ALGIN

Economics

Input	Costs/lb	Costs/week
Paws	$0.76	$76,000
ALGIN	$2.77	$16,346.65
Packaging	$0.64	$65,184
Labor	$0.75	$75,000
Total	$4.92	$232,530.65
Sale price	$18.20	$1,820,000
Difference	$13.28	$1,587,469.35

Summary

- Demands for pet treats has increased in the last few decades
- This trend has affected animal co-product markets which can be used to develop treats rich in protein, vitamins, and minerals
- Hydrocolloids show potentials for adding values to animal co-products by improving sensory properties and adding stability to restructured pet treats
- Parameters such as physico-chemical characteristics, color variation, and textural properties affect quality of pet treats and may impact purchase decisions
- Undervalued animal co-products have been repurposed to develop restructured pet treats with varying quality characteristics

Completed work

- Chicken liver / chicken hearts
- Beef liver / beef hearts
- Wooden breast carcass frames 1
- Wooden breast carcass frames 2
- Paws
- Wing tips
- Slice thickness

- Food chemistry
  - Texture
  - Color
  - Sensory

Future studies

- Conduct consumer sensory and pet palatability evaluations
- Evaluate the ability of different processing co-product combinations to form various pet treat types
- Evaluate meat products combined with non-meat products to develop functional pet treats
- Reconstituted proteins, Insects, Plant based proteins, Aquaculture

sciencemeetsfood.org

dogfoodadvisor.com

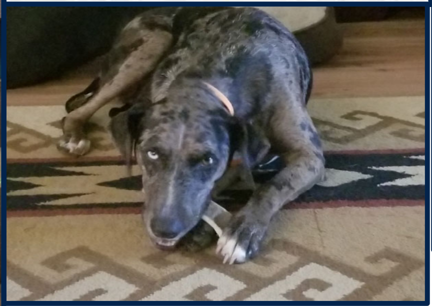
Future work

- Sensory
- Oxidative chemistry
- Complete and balanced
- In home palatability

- Field applications, soldier and dog co-nutrient delivery

- Human nutrient supplementation

Thank You



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