Opportunities for Bio-Based Packaging Technologies to Improve the Quality and Safety of Fresh and Further Processed Muscle Foods

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Overview

• Introduction

• Active/intelligent/interactive packaging

• Bio-based polymers or biopolymers*
  – Biomass-derived
  – Bio-derived monomers
  – Microorganism-derived

• Composite films

• Antimicrobial films

• Summary
Introduction

- Plastic (polyethylene or co-polymers)
  - Manufactured from petroleum
  - $100 billion market
  - 70% is used for food and beverages
  - < 10% of plastic packaging is recycled (not including bottles) → landfill issues

(Comstock et al., 2004. Green packaging report. University of Washington Symposium)
Issues with plastic packaging

• “...With the exception of paper and board...most packaging materials are...non-renewable materials...therefore, more alternative packaging materials based on renewable resources need to be found.”

• “...bio-based packaging materials are beginning to replace standard packaging materials...”

Packaging

- Globalization of the food supply
- Consumer trends towards convenience
- Consumers want packaging materials that are more natural, disposable, recyclable or biodegradable
Active/Intelligent/Interactive packaging

- **Chemicals**
  - Chelators, antioxidants, flavors, essential oils, etc.

- **Antimicrobials**
  - Bacteriocins, organic acids, lysozyme, etc.

- **Gases**
  - Ethylene, carbon dioxide, oxygen, nitrogen, etc.
Active/Intelligent/Interactive packaging

- Humidity absorbers/controllers
- Scavengers or emitters
- Aroma absorbers
- Active enzyme systems

Food Reviews International 20:357-387)
Bio-based polymers
or biopolymers

• May be compostable or biodegradable
• Some bio-based packaging materials may be biodegradable
• Not all biodegradable packaging materials are bio-based
• Can be processed similarly to petroleum-based plastics
  – Extrusion, spinning, injection molding, thermoforming
Desirable properties of biopolymers

- Good sensory qualities
- High barrier properties
- Mechanical efficiency
- Microbial, biochemical, & physio-chemical stability
- Non-toxic
- Simple
- Non-polluting
- Inexpensive
Desirable properties of biopolymers applied to muscle foods

- Edible
- Transparent
- Reduces moisture loss
- Minimizes lipid oxidation
- Prevents discoloration
- Reduces drip
- Flexible
- Resistant to breakage and abrasion
- Improves microbial safety and stability of food
Application of biopolymers to muscle foods

- Foaming
- Dipping/Submerging
- Spraying
- Casting
- Brushing
- Wrapping
- Rolling
BIO-BASED POLYMERS

Polymers extracted from biomass
- Polysaccharides
  - Starch: potato, corn, wheat, rice, other derivatives
  - Cellulose: cotton, wood, other derivatives
- Proteins
  - Animal: casein, whey, collagen, gelatin
  - Plant: zein, soy, gluten
- Lipids
  - Waxes, fats, oils

Polymers synthesized from bio-derived monomers
- Polylactate
- Other polyesters

Polymers produced from microorganisms
- Bacterial compounds
  - Xanthan, curdlan, pullulan

Starch

• Compounds are generally derived from cereal grains, potatoes, tapioca or arrowroot

• Starch films tend to be odorless, tasteless, colorless, non-toxic, absorbable, semi-permeable to CO₂, & oxygen impermeable

• Starch films can retard moisture migration into muscle food during storage → lowers water activity → retards microbial growth → longer shelf life
Cellulose

- Non-digestible component of plant cell walls
- Used primarily for production of ready-to-eat sausages; peeled and discarded after cooking
- Films typically are water soluble
Cellulose

• Films are resistant to fats and oils, tough, flexible, transparent, & peelable

• When used with muscle foods, cellulose films can reduce oil uptake during frying, minimize run-off during cooking, and reduce moisture loss when applied as a glaze
Alginate

- Derived from seaweed
- Divalent cations (calcium) are used as gelling agents
- Other edible polysaccharides can be added to improve properties of alginate films
Alginate

- When applied to muscle foods, alginate films are known to improve moisture retention, retard oxidation, improve adhesion between batter and muscle food surfaces, extend shelf life, reduce shrink, and improve product texture, juiciness, color, and odor
Carageenan

- Isolated from red algae, seaweed, or seamoss
- Mix of polysaccharides
- Can incorporate antioxidants, salt, antimicrobials into the matrix
- When used with muscle foods, coatings can prolong the shelf life and safety of beef
Pectin

• Plant derived polysaccharide
• Limited research conducted with pectin
• Works well with low-moisture foods since they are poor moisture barriers
• With muscle foods, pectin gels reduced cooler shrinkage and bacterial growth on beef plates
Argar

- Seaweed-derived polysaccharide
- Used in microbiological media to provide firmness
- Forms strong gels with higher melting points
- Used as delivery system for antimicrobials to improve safety of muscle foods
Chitin/Chitosan

- Derived from the exo-skeleton of insects, crustaceans and some fungi
- One of the most abundant biopolymers available in the world
- Desirable properties include: good oxygen & CO₂ permeability, good mechanical properties, acts a chelator in biological systems, and exhibits antimicrobial activity
- Exhibits high sensitivity to water
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  - Plant: zein, soy, gluten
- Lipids
  - Waxes
  - Fats
  - Oils

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Polymers produced from microorganisms
- Bacterial compounds: cellulose, xanthan, curdlan, pullulan

Casein & Whey

- Derived from milk
- High nutritional value
- Exhibit good mechanical and barrier properties, soluble in water, act as emulsifiers, & industrial surplus
- When applied to muscle foods, films can reduce moisture loss, delay lipid oxidation, reduce peroxide values
- Enzymes may degrade films; allergen issues
Gelatin

- Excellent gas and solute barrier
- Improves oxidative and color stability, retains flavor, taste, and aroma of muscle foods
- Can be used as delivery systems for antioxidants and antimicrobials
- Decreases oil adsorption during frying
- Lacks strength; requires drying to form more durable films
Collagen

- Commercial use with processing of cooked meat products (Coffi™ films)
- Forms edible “skin” on cooked product
- Reduces shrink loss, increases permeability of smoke, enhances juiciness, absorbs fluid exudate
- Reduces transport of gas and moisture
Cereal & oilseed

- Limited information on use of these compounds with muscle foods
- Corn zein treated with antioxidants, emulsifier, and plasticizer → reduce lipid oxidation in muscle foods
- Soy protein/wheat gluten films can reduce moisture loss & lipid oxidation
- Allergen issues
BIO-BASED POLYMERS

Polymers extracted from biomass
- Polysaccharides
  - Starch: potato, corn, wheat, rice, other derivatives
  - Cellulose: cotton, wood, other derivatives
  - Gums: guar, locust bean, alginate, carrageenan, pectins, agar
  - Chitosan/chitin

Polymers synthesized from bio-derived monomers
- Polylactate
- Other polyesters

Polymers produced from microorganisms
- Bacterial compounds: cellulose, xanthan, curlan, pullulan

Lipids
- Animal: casein, whey, collagen, gelatin
- Plant: zein, soy, gluten
- Waxes, fats, oils

Proteins
- Animal: casein, whey, collagen, gelatin
- Plant: zein, soy, gluten

Lipid Films

- Reduce shrinkage, prevent lipid oxidation, act as moisture & oxygen barriers
- Impart hydrophobicity, cohesiveness, flexibility
- Transparent, reduces freezer burn on muscle foods
- Prolongs freshness, color, aroma, tenderness, and microbial stability of muscle foods
Lipid Films

• Can be used as flavor carriers

• At higher storage temperatures, films may create anaerobic conditions, lack structural integrity, & poor adherence

• Films may be subject to oxidation, cracking, flaking, retention of off-flavors
BIO-BASED POLYMERS

Polymers extracted from biomass
- Polysaccharides
  - Animal
    - casein
    - whey
    - collagen
    - gelatin
  - Plant
    - zein
    - soy
    - gluten
- Starch
  - potato
  - corn
  - wheat
  - rice
  - other derivatives
- Cellulose
  - cotton
  - wood
  - other derivatives
- Gums
  - guar
  - locust bean
  - alginate
  - carrageenan
  - pectins
  - agar
- Chitosan/chitin

Polymers synthesized from bio-derived monomers
- Polylactate
- Other polyesters
  - waxes
  - fats
  - oils

Polymers produced from microorganisms
- Bacterial compounds
  - cellulose
  - xanthan
  - pullulan

Polylactic Acid Films

- **Starch**
  - Light
  - Water
  - CO₂

- **Fermentation** → Lactic acid
  - Lactic acid
  - Lactide
  - Polylactic acid

- **Biodegradation**
  - Hydrolysis

- **Commodity**
Polylactic Acid Films

- Biodegradable polymer made from corn following fermentation of starch
- Made up of chains of lactic acid → strength
- Resistant to oils, are sealable at low temperatures, act as flavor/odor barrier
- Can be used as delivery system for antimicrobials or combined with irradiation to improve safety of muscle foods
- Incompatible with chitosan
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  - Starch: potato, corn, wheat, rice, other derivatives
  - Gums: guar, locust bean, alginate, carrageenan, pectins, agar
  - Chitosan/chitin: cellulose, xanthan, pullulan

- Polymers synthesized from bio-derived monomers
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Xanthan

• Produced by *Xanthomonas campestris*
• Used to keep ingredients suspended uniformly and provide thickening
• Soluble in both hot and cold water, stable over a wide range of pH levels and temperatures
• Functionality is not influenced by salts, pH, acids, alkalis or enzymes
• When used in combination with equal amounts of locust bean, an elastic gel is formed
• Can be used in pâtés, aspics, brawns
Pullulan

- Produced from starch following fermentation by *Aureobasidium pullulans*
- Water-soluble polysaccharide
- Odorless, flavorless, and highly stable
- Heat sealable, exhibits good oxygen barrier properties
- Surface can be printed, colors or flavors added to matrix

![Chemical structure of Pullulan](image)
Composite Films

• Combinations of 2+ materials (including plasticizers) can improve flexibility, permeability, solubility of films

• Can improve gas exchange and moisture vapor permeability and adherence to coated muscle foods

• Reduces drip loss, handling, and packaging waste

• Enhances juiciness

• More research needed on consumer acceptability
Antimicrobial Films

- Compounds applied to muscle foods via films:
  - Organic acids
  - Bacteriocins
  - Grape seed extracts
  - Spice extracts
  - Thiosulfinates
  - Enzymes
  - Isothiocyanates
  - Chelators
  - Metals
  - Parabens
Antimicrobial Films

• Antimicrobials are more effective against bacteria associated with fresh and further processed muscle foods when delivered via film system as compared to direct application (liquid)
• Application of biopolymers treated with antimicrobials can control spoilage and enhance the safety of muscle foods
Summary

- Alternatives are needed to petroleum-based packaging materials
- New materials should be natural, recyclable, biodegradable, and/or compostable
- A variety of biopolymers have been extracted from biomass, synthesized from bio-derived monomers, or produced from microorganisms
Summary

- Examples of biopolymers extracted from biomass include polysaccharides, proteins, or lipids from plant, animal, or marine sources.

- Polylactic acid is an example of a biopolymer synthesized from bio-derived monomers.

- Xanthan and pullulan are biopolymers produced from microorganisms.
Summary

• When applied to muscle foods, biopolymers should impart desirable characteristics such as stability, gas permeability, transparency, moisture retention, edibility, etc.

• The application of biopolymers with antimicrobials can enhance the quality and safety of fresh and further processed muscle foods.
Questions?