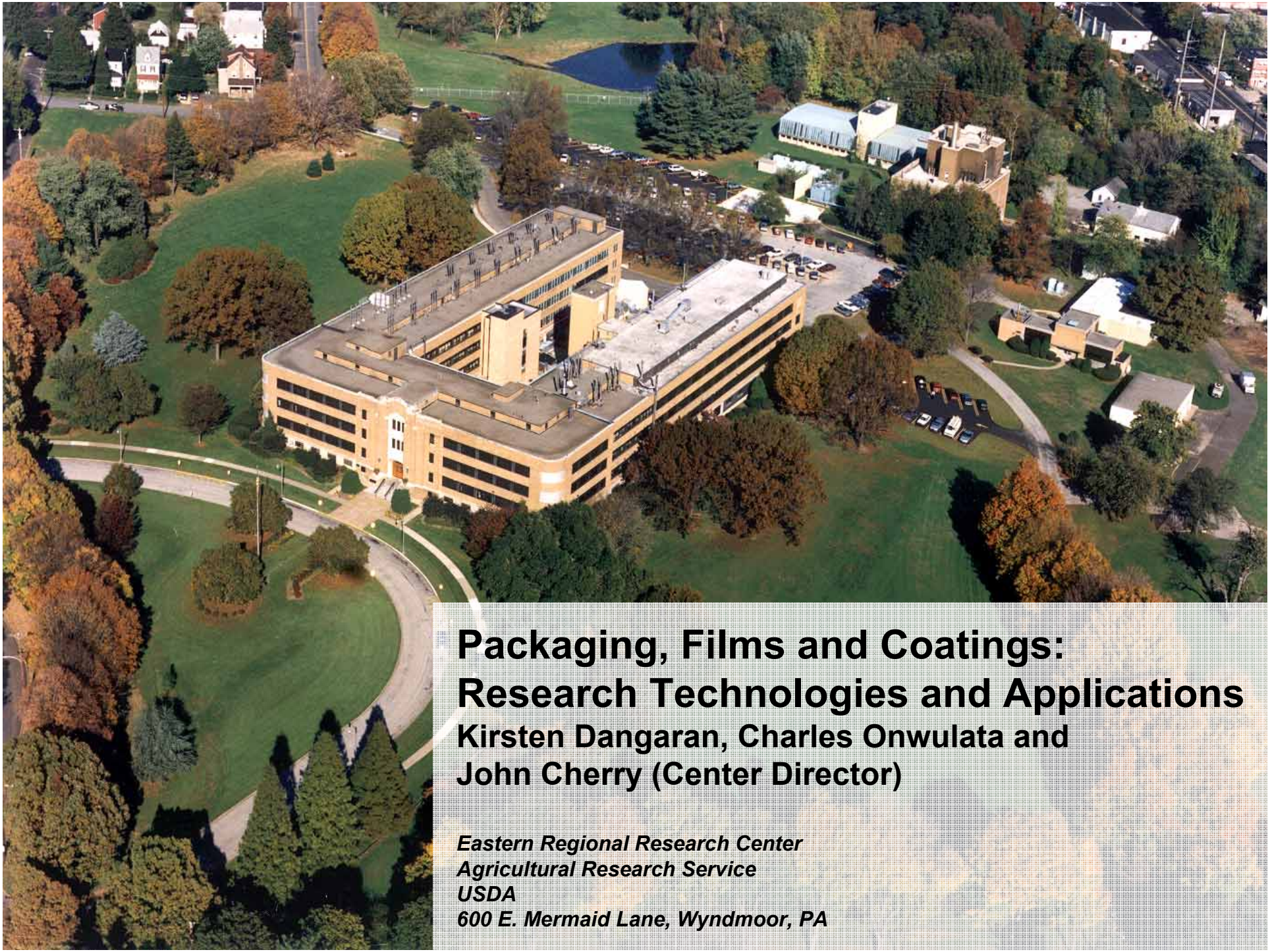


Packaging, Films and Coatings: Research Technologies and Applications

Kirsten Dangaran, Charles Onwulata and John Cherry (Center Director)

Eastern Regional Research Center
Agricultural Research Service
USDA
600 E. Mermaid Lane, Wyndmoor, PA

Four regional research centers, provide the major portion of ARS's capability for research and development of technology to increase the use of agricultural products and thereby enhance the economic viability and competitiveness of U.S. agriculture.

NCAUR (NRRC) – Peoria, Illinois

SRRC – New Orleans, LA

ERRC – Wyndmoor, Pennsylvania

WRRC – Albany, California

Worksites:
- University of Maryland Eastern Shore
- Delaware State University

$31.5 mil Budget
300 Employees
90 PhD Scientists/Engineers
17 Research Associates

USDA
Agricultural Research Service

Improving Production and Harvesting Technologies

USDA
Agricultural Research Service

Improving Quality and Adding Value to Foods, Fibers and Biobased Products

MyPyramid.gov
STEPS TO A HEALTHIER YOU

ARS National Program 306
Biodegradable Plastic Research

Mission of 306

Enhance the economic viability and competitiveness of U.S. agriculture by . . . through the development of value-added food and nonfood products and processes.

NP 306 Components & Action Plan

- **Convert low value agricultural residues into higher value products.**
- **Develop improved and new techniques and technologies to convert agricultural products into value-added biobased products.**
- **Improve/develop processes and technologies that are environmentally benign.**

Dr. Frank Flora, National Program Leader
Product Quality/New Products & Processes
Agricultural Research Service

ARS Investment in Biodegradable Plastics Research

Location	FY2007
WRRC (Albany, CA)	$0.8 M
NCAUR (Peoria, IL)	$1.5 M
ERRC (Wyndmoor, PA)	$1.4 M

More research and investments also at Beltsville, MD site (BARC)

US Government Support

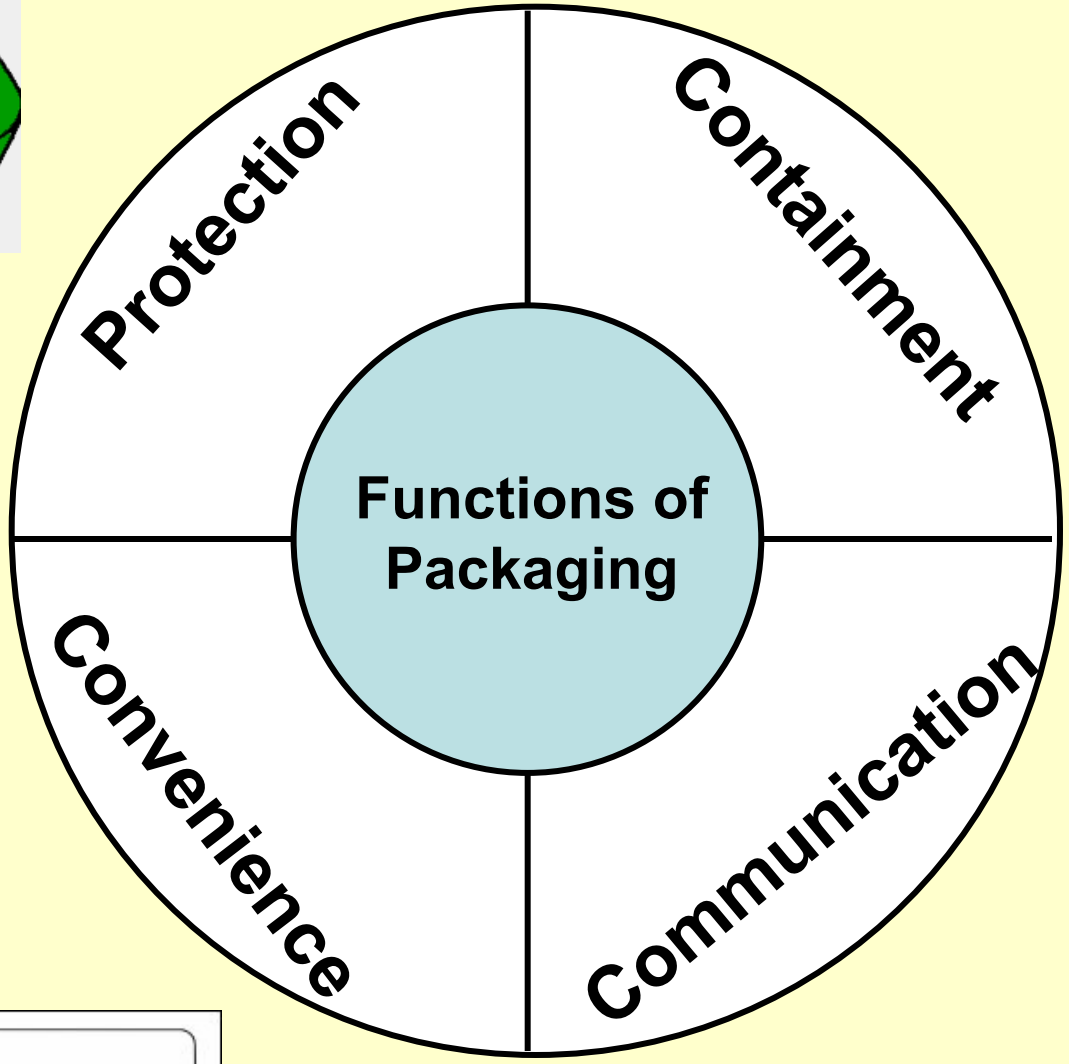
EO 13101: Mandatory Buy Recycled Program

EO 13134: Developing and Promoting Biobased Products and Bioenergy

Affirmative Procurement vs. Environmentally Preferable Purchasing

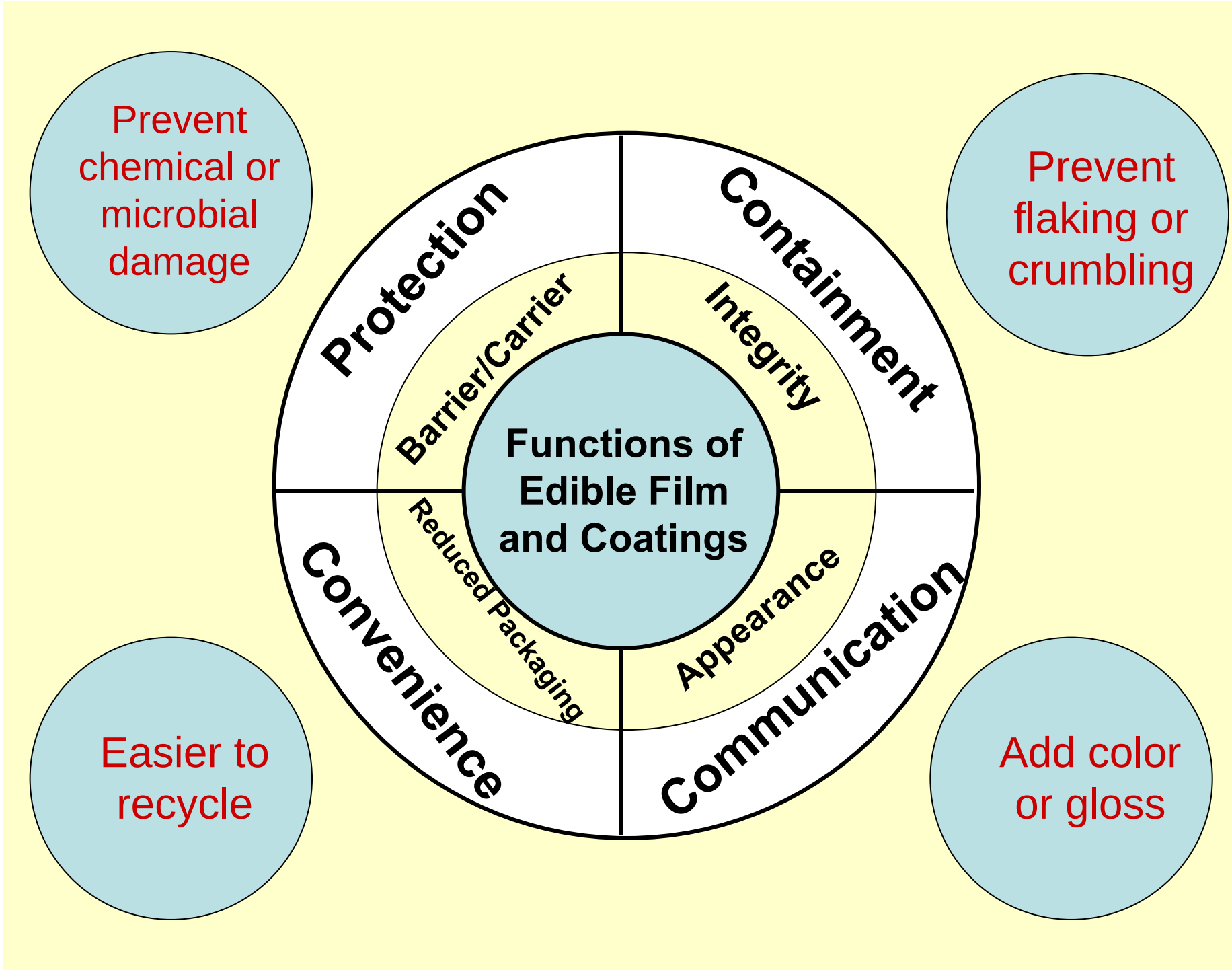
- Recycled-content materials
- EPA's Comprehensive Procurement Guidelines (CPG)

The U.S. government spends ~ $200 Billion


Protection
Containment
Functions of Packaging
Convenience
Communication


compostable
COMPOSTABLE
Biodegradable Products Institute
US COMPOSTING COUNCIL
TM


0 79200 15039 6


Prevent chemical or microbial damage
Prevent flaking or crumbling
Protection
Containment
Barrier/Carrier
Integrity
Functions of Edible Film and Coatings
Reduced Packaging
Appearance
Convenience
Communication
Easier to recycle
Add color or gloss

Zero Waste Mission

Commodity







Product

Cheese, juice, ethanol, flour, vegetable oils, biodiesel, eggs, textiles

"Waste"

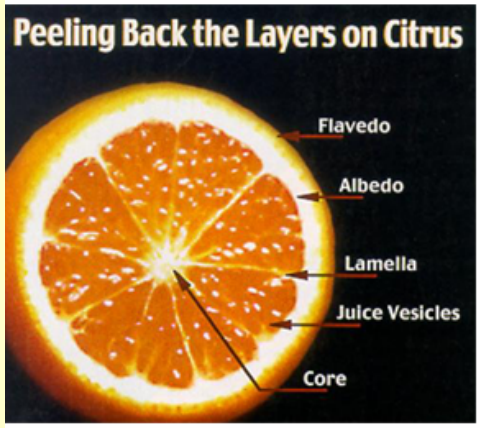
Whey, pulp, glycerol, feathers, peel, sugar beet fiber

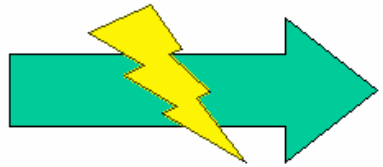
Biobased Packaging

Biopolymers, PLA, PHA, composites, films, coatings, monomers

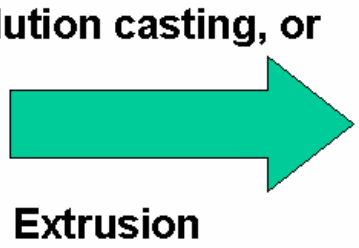
Fruit ⟶ Juice ⟶ Pectin

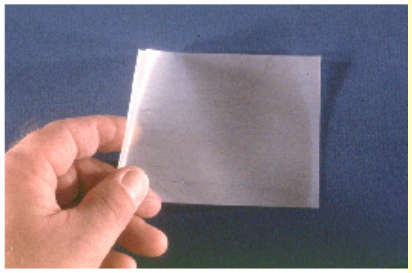
Citrus, sugar beet pectins – biopolymers





Developed flash extraction of high quality pectin from residues of orange juice processing





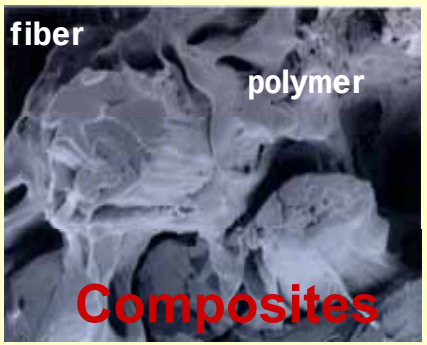
Developed edible and non-edible, biodegradable films from pectin with starch or polyvinylalcohol

Milk → **Cheese** → **Whey**

Chicken → Meat/Eggs → Feather Keratin

Keratin Fibers

Fiber Uses



Molded Keratin

Biodegradable mulching films, nursery containers, hoop house films

Soybean as a Source for Biopolymers

Soybean Biorefinery

etc…

Soy Oil, Soy Proteins (Food, feed, and non-food industrial uses)

Soy-biodiesel coproduct stream

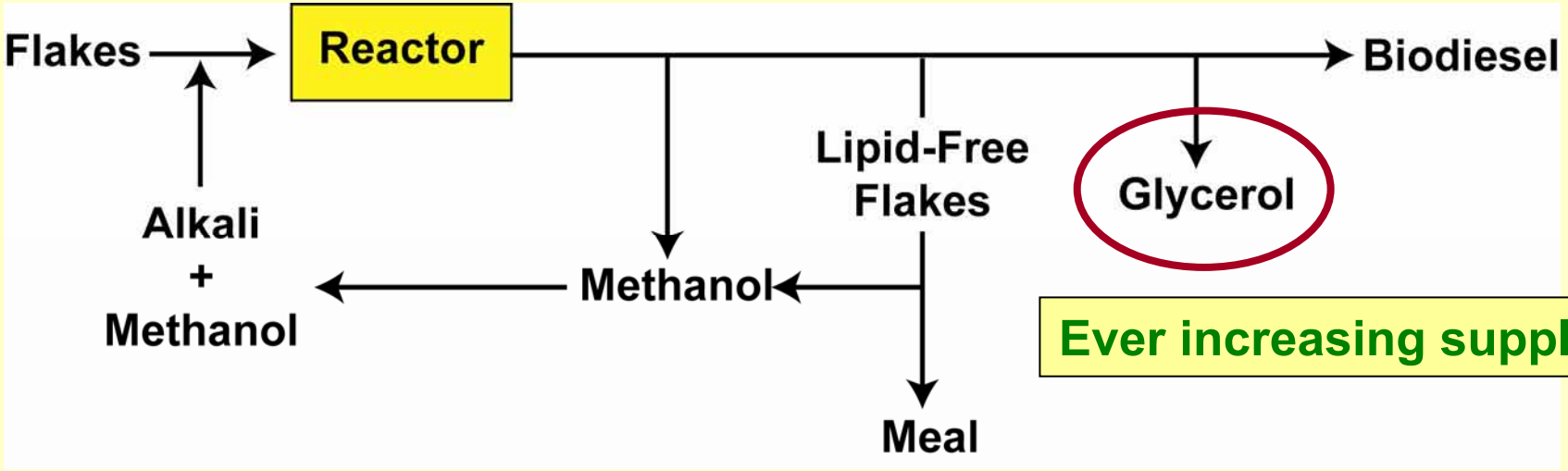
Hulls (biomass)

Soy solubles (molasses)

Fermentation

Biosurfactants; Biopolymers; Platform Chemicals

Biodiesel from *in situ* Transesterified Soybeans



Fermentation-Based Processes for the Production of Biobased Products from Fats, Oils, and Coproducts

- **Microbial Screening**
- **Strain Improvement**
- **Fermentation Manipulation**

Animal Fats

Vegetable Oils

Coproducts
(e.g., Soy Solubles/ Molasses, Crude Bio-Glycerol)

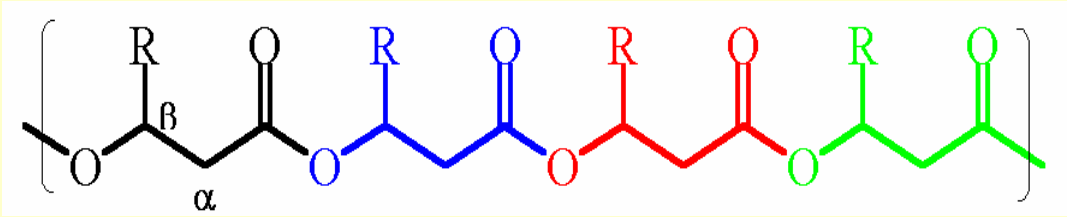
Polymer feedstocks
- **Itaconic acid**
- **ω-1 hydroxy fatty acids and amines**

Biopolymers
- **Poly(hydroxy-alkanoates)**

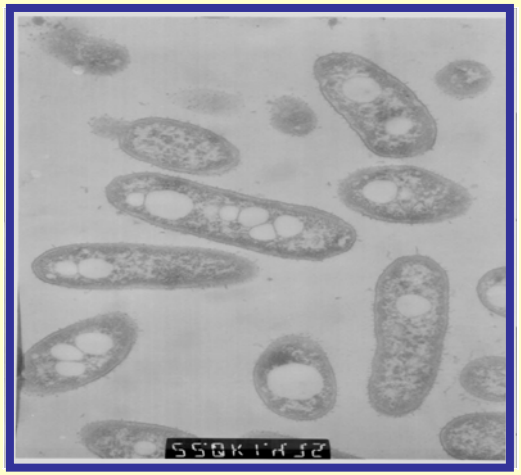
Biosurfactants
- **Sophorolipids**
- **Rhamnolipids**

Poly(β-hydroxyalkanoates) (PHA)

-- Biodegradable Polyesters --



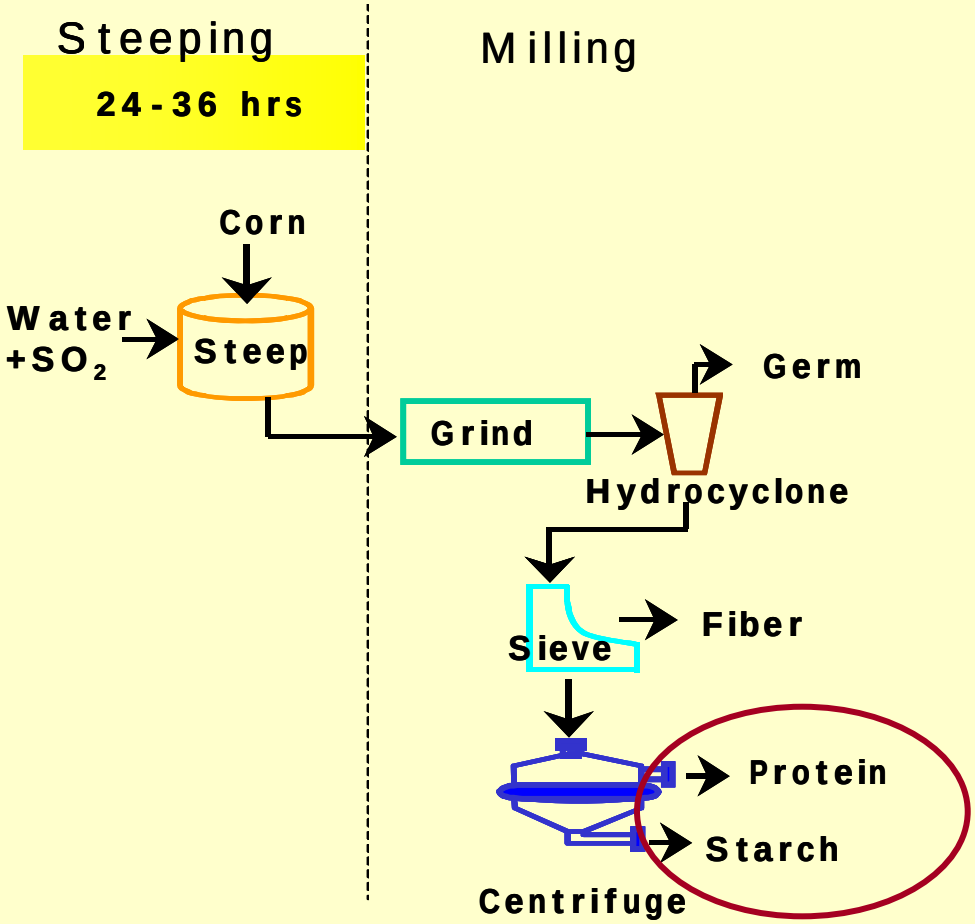
Pseudomonas resinovorans grown on tallow



- **Short-chain-length (scl-)PHA**
  - **R = H, 1 or 2 carbons**
  - **Thermoplastics**

- **Medium-chain-length (mcl-)PHA**
  - **R ≥ 3 carbons; may contain multiple double-bonds**
  - **Elastomers, adhesives**

Corn-based Packaging Materials



Corn Starch Extruded Plastics

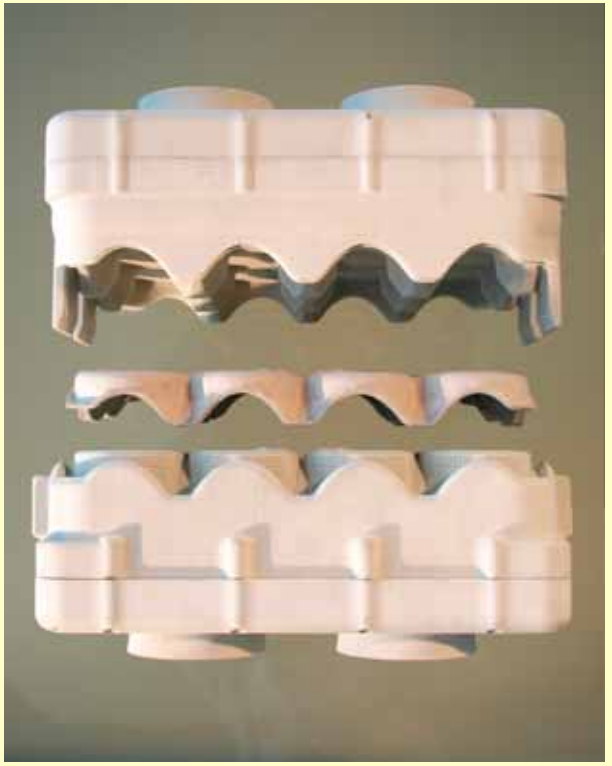
Developed electroactive starch-based polymers – controlled-release or environmental sensor potential

Molded Starch-Based Packaging.

EarthShell PACKAGING

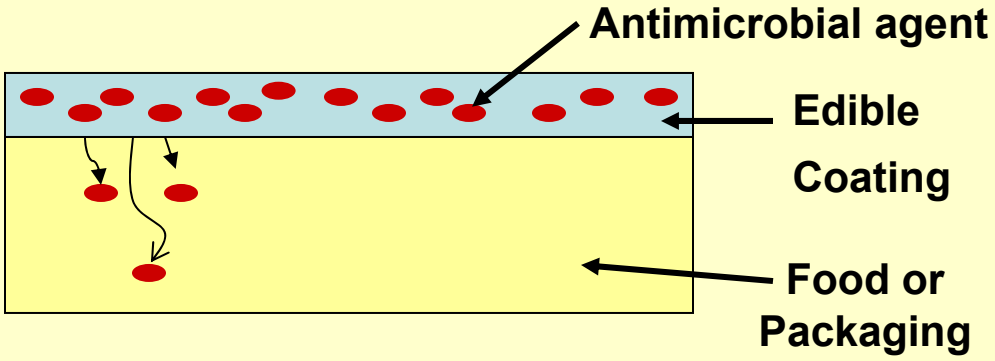
Smart & Final

Straw-based Molded Packaging

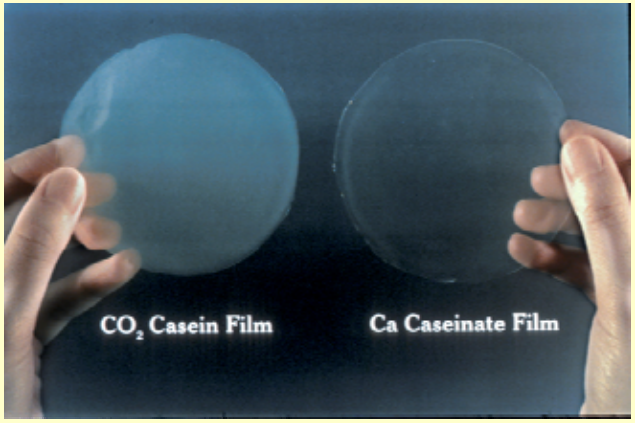


Active Edible Coatings for Foods

- Can reduce or replace barrier layers in traditional packaging systems
- Makes recycling of plastics easier
- Carriers
  - Antimicrobials -sorbates, benzoates, bacteriocins
    - can prevent post-processing contamination
  - Nutrients – vitamins, minerals
  - Phenolic compounds
- Controlled Release
  - Diffusion Coefficients



Appearance Properties



Casein

Whey Protein

Fruit and Vegetables (pectinate)*

*Origami Foods, www.origami-foods.com

Pectin

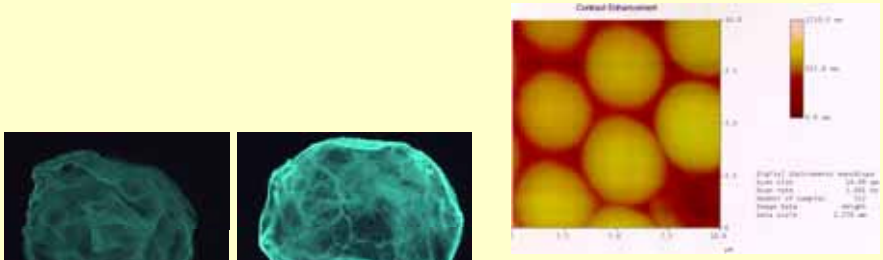
Biodegradable Packaging Research

- Currently, biodegradable packaging offers:
  - Best for applications of shorter shelf-life, high WVTR to prevent condensation, high oxygen barrier
- Areas of improvement
  - Proteins and carbohydrates offer many sites for potential improvement through chemistry
  - More experience with processing will increase potential applications
- To replace the wide variety of petroleum-based packaging (PS, PP, PE, EVA, etc…) will need a wide variety of ag starting materials

Other Research Areas

- Ag-based materials for drug delivery systems
  - Coatings for tablets
  - Encapsulation
  - Patches

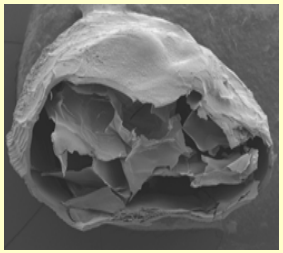
Drug Delivery Systems from Pectin Formulations



Pectin/Calcium Microspheres *D = 3-4 µm*

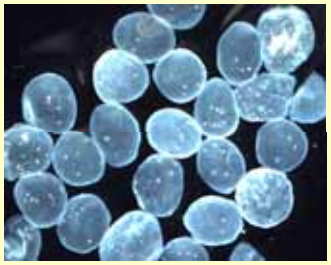
Pectin/Calcium

Pectin/Calcium/Zein

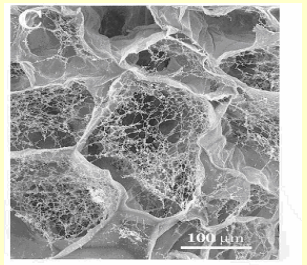


Honeycomb-like Pectin structure

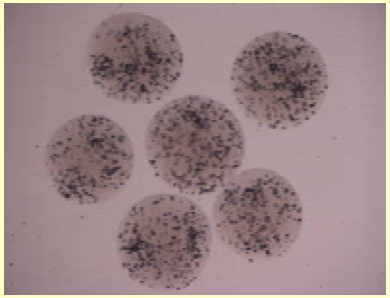
D = 150 µm



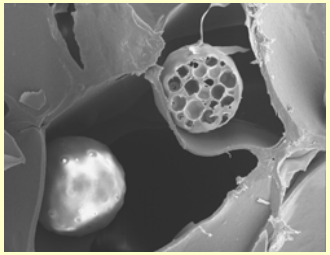
Novel hydrogel beads from two edible polymers: pectin and zein.



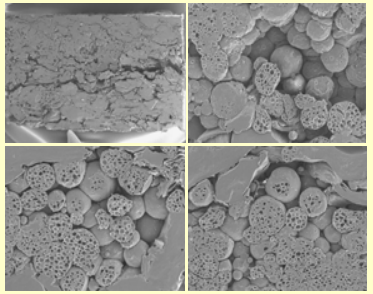
Double Network Structure of Pectin and Polyacrylmide



Shrapnel-like Pectin Structure (II)



Shrapnel-like Pectin Structure (I)



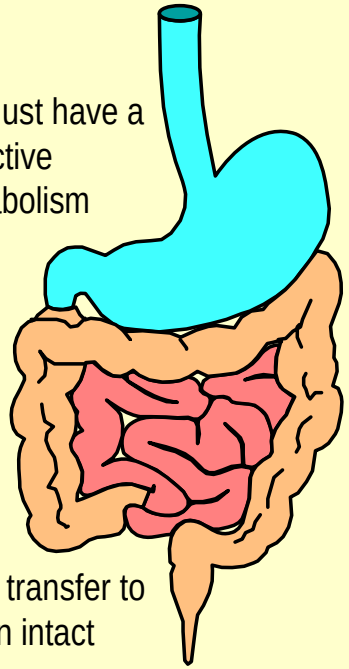
Compressed Tablets of Multiparticulates

Synbiotic Matrices Made from Pectin

Crop Conversion Science and Engineering

Citrus, sugar beet pectins – biopolymers

Prebiotic: A non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacterial species in the colon (Gibson and Roberfroid, 1995, *J. Nutrition* 125:1401-1412)

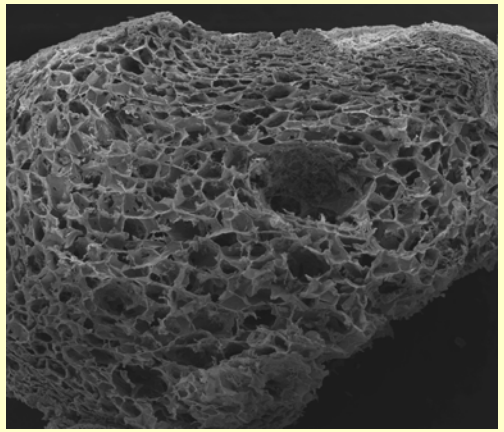


1. Must be stable under acidic conditions and small gut secretions

2. Must transfer to the colon intact

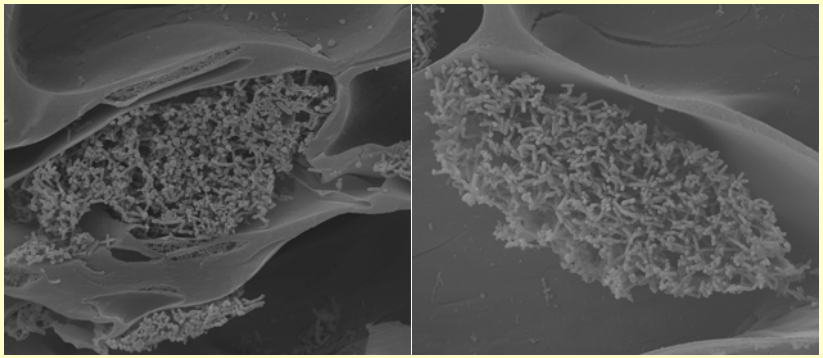
3. Must have a selective metabolism

Pectin and/or Alginate-Calcium Matrix



Probiotic *Lactobacillus acidophilus* after 4 days of growth

Probiotic Lactobacillus Growth in Alginate-Calcium Matrix



Lactobacillus acidophilus *Lactobacillus reuteri*

4 days of growth

Arland Hotchkiss - ERRC

What can USDA do for our collaborators?

- Provide valuable scientific expertise in technology development. With a potential of **~10 billion pounds of valuable feedstock** worth **billions of dollars**, this is critical
- Provide access to world class laboratories
- Transfer technology through Office of Technology Transfer
  - http://www.ars.usda.gov/partnering
- Cooperation with a central agency in the technology community

The Future Biodegradable Packaging Research in the ARS

What can we do to create and improve feedstocks? What are industries needs?

Technology transfer of ARS research and increased infrastructure?

How can we extend our commitment to developing responsible packaging?

Thank you

Eastern Regional Research Center

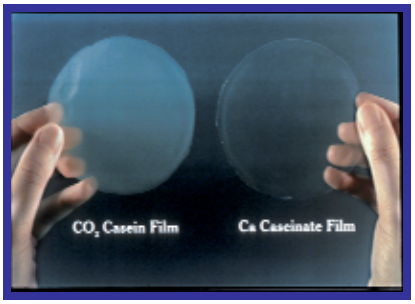
Agricultural Research Service
U.S. Department of Agriculture
600 E. Mermaid Lane
Wyndmoor, Pennsylvania 19038
www.ars.usda.gov/naa/errc

The ERRC is one of the four government-funded Regional Research Centers in ARS, established by Act of Congress in 1938. The scientific investigators of ERRC have had a favorable impact on the welfare of American farmers, industries, and the consuming public. In times of excess supplies of agricultural commodities, surplus to our need for export and domestic consumption, utilization research has pointed toward new ways to use that surplus. Biodegradable packaging is a research area that allows the scientists of the ERRC to develop new applications for surplus and agricultural waste streams. Progress in packaging from proteins, carbohydrates and lipids has been accomplished by multi-disciplinary teams studying the material properties, processing parameters and potential applications. The efforts of the ERRC scientific investigators has expanded the knowledge base on bio-based packaging and created more sources for environmentally-friendly, biodegradable or compostable packaging systems.

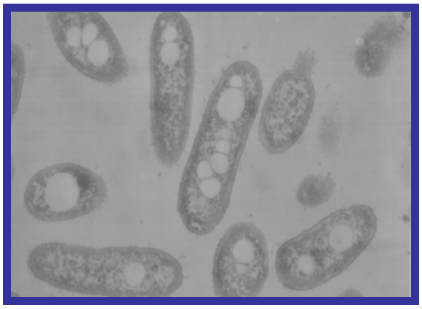
4 of the 6 Research Units (RU) at the ERRC have specific research initiatives focused on biodegradable packaging:
Dairy Processing and Products RU, Peggy M. Tomasula, Research Leader, 215-233-6703, Peggy.Tomasula@ars.usda.gov
Fats, Oils and Animal Coproducts RU, William Marmer, Research Leader, 215-233-6585, William.Marmer@ars.usda.gov
Crop Conversion Science and Engineering RU, Kevin Hicks, Research Leader, 215-233-6579, Kevin.Hicks@ars.usda.gov
Food Safety and Intervention Technology RU, Howard Zhang, Research Leader, 215-233-6583, Howard.Zhang@ars.usd.gov

Mission: Improve the properties, availability and applications of biodegradable packaging from agricultural feed stocks via the following objectives:

- Determine mechanical, barrier, appearance, and thermal properties of packaging made from biopolymers
- Develop new agricultural sources for bio-based packaging materials
- Determine processing conditions for formation of biodegradable, compostable packaging
- Devise technologies for increasing applications of packaging systems



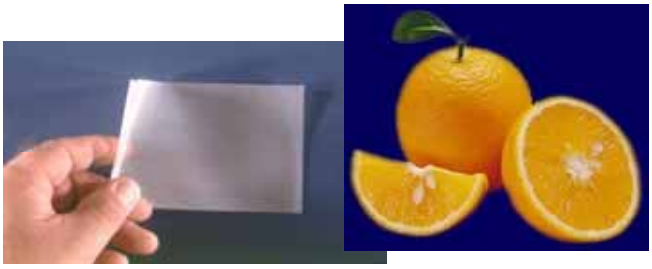
Edible Film from Dairy Proteins



Polyhydroxyalkanoates (PHA) from Fermented Vegetable and Animal Oils and Bio-glycerol

Molded Cups from Whey Proteins and Natural Fiber

Biodegradable Packaging Research in the Agricultural Research Service



Pectin-based Films
Dr. Marshall Fishman
ERRC-ARS-USDA
Marshall.Fishman@ars.usda.gov

Keratin-based Biodegradable Packaging
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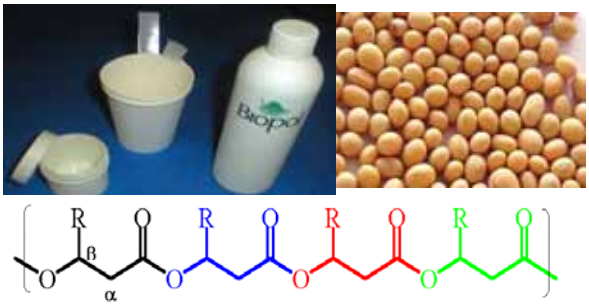
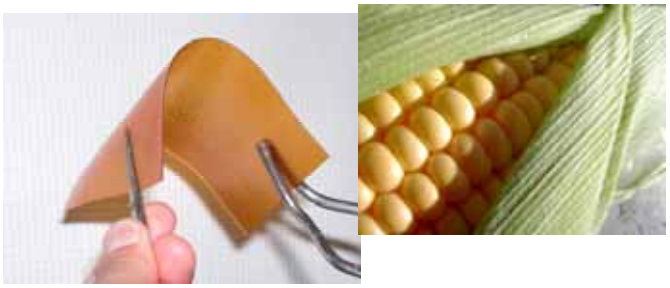
Beltsville-ARS-USDA
Justin.Barone@usda.gov

Whey-based Packaging
Dr. Charles Onwulata
ERRC-ARS-USDA
Charles.Onwulata@ars.usda.gov



Soy-based Biodegradable Polymers
Dr. Dan Solaiman
ERRC-ARS-USDA
Dan.Solaiman@ars.usda.gov



Corn-based Extruded Films
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NCAUR-ARS-USDA
willetjl@mail.ncaur.usda.gov

Starch Molded-Packaging from Wheat
Dr. Greg Glenn
WRRC-ARS-USDA
gmg@pw.usda.gov

Straw-based Packaging
Dr. Bill Ortz
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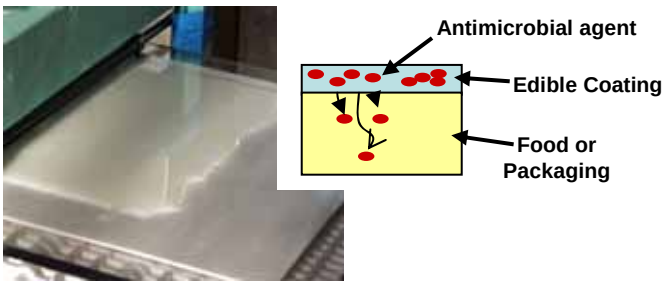
ortz@pw.usda.gov



Edible Films and Coatings
Dr. Kirsten Dangaran
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Kirsten.Dangaran@ars.usda.gov