To Be or Not To Be?

Nanotechnology and Packaging

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"There is no doubt that nanotechnology has the potential to make the world a better place," said Project on Emerging Nanotechnologies Chief Scientist Dr. Andrew Maynard in his presentation before a public meeting of the President's Council of Advisors on Science and Technology (PCAST) on Monday, June 25, 2007.

"But if consumers and other stakeholders are not convinced that the benefits outweigh the risks, many applications will not see the light of day. Likewise, if the benefits are unclear and the risks uncertain, the products of nanotechnology will be a hard sell."
The development of nanotechnology is creating exciting new possibilities for scientists.

(http://nano.cancer.gov/resource_center/tech_backgrounder.asp)
FIGURE 1. ESTIMATED ANNUAL GLOBAL PRODUCTION RATES FOR Engineered Nanomaterials

Values are based on estimates in the 2004 Royal Society and Royal Academy of Engineering report on nanotechnology. They are intended for guidance only, as validated figures are commercially confidential.

Nanotechnology and Food

- Development of functional food
- Nutrient delivery systems
- Methods for optimizing food appearance
  - color, flavor and consistency.
- Food packaging
- Food monitoring
Nanowire Sensor

Particles flow through the microfluidic channel

Nanowire sensor

Electrodes

Nanowires detect biomarkers of cancer

Reference: Jim Heath, California Institute of Technology

Nanoscale Cantilevers

Cantilevers detect biomarkers of cancer

Proteins

Antibodies

Cancer cell

Binding events change cantilever conductance

Reference: Arun Majumdar, University of California at Berkeley
**Nanoshells**

*Nanoshells kill tumor cells selectively*

Reference: Jennifer West, Rice University

**Nanoparticles**

*Nanoparticles used for molecular imaging of malignant lesions*

Reference: Ed Neuwelt, Oregon Health Sciences University
Nanotechnology + Biotechnology

- Quantum dots
  - Cancer detection *in vivo* via MRI or X-ray imaging
Outline

• Food Packaging Today
• Current Nano Developments
  – Biosensors
  – Antimicrobials
  – Nanocomposites
  – Carbon nanotubes
• Other Areas of Potential
• Food Safety Implications
Food Packaging Today

Chesapeake Fields
1.25 oz Soy Saucers
MEMS

http://www.memx.com/images/ratchet.jpg

Smart Packaging

http://www.dcu.ie/chemistry/asg/pacquita/files/DSC00043.JPG

Biodegradable Plastic Bags


RFID

http://www.leuveninc.com/SITE/UPLOAD/IMAGE/flex.jpg
NutriSystem's Aquaescents water bottle uses an aroma-enhanced cap to provide noncaloric flavor to plain drinking water.

http://www.packagingdigest.com/articles/200502/images/520.jpg

http://scentsationaltechnologies.com/images/compelaroma_wlogo.jpg
Development: Nanosensors

• Direct oxygen indicator (OxyDot by OxySense)
  – Non-invasive, uses oxygen partial pressure
  – Unaffected by pH, salt, other gases
  – Resistant to pasteurization processes
  – Ruthenium complex (luminescent)

• pH-sensitive
  – Measures total volatile basic nitrogen
  – Readily visible (color change)
  – Bromocresol green, is combined with tetracytl ammonium bromide to prevent leaching
Detection of Pathogen DNA by Fluorescence Nanobarcodes

Nanopore Sensor by NASA

Atomistic scale simulations performed on the NASA Columbia supercomputer (SGI Altix-3000) allow detailed study of DNA translocation to enhance the abilities of DNA sequencers.

(www.ipt.arc.nasa.gov/nanopore.html)
Development: Antimicrobials

Food Microbiology: Specific Detection

Controlled Release: Precise Delivery


(http://cmir.mgh.harvard.edu/nano/nano_main.php?targetName=nano&menulD_=222)
Active Packaging

Structure of a common antimicrobial multilayer active film (Ozdemir and Floros, 2004)

http://www.packagingdigest.com/articles/200502/images/521.jpg
Dip Pen Nanolithography (DPN)

NanInk uses a scanning probe—a molecule-coated probe tip that acts like a pen—to deposit material onto a surface.
Development: Nanocomposites

- Using nanocomposites improved mechanical, thermal, barrier and physicochemical properties can be obtained as compared to original polymer.
- Most studied biodegradable nanocomposites are starch and derivatives, polylactic acid, polybutylene succinate (PBS), and polyhydroxybutyrate (PHB).

Edible Coatings and Films

- Hydrocolloids – good barrier to oxygen, poor water barrier
  - Nisin/chitosan as a paper coating for orange juice and milk
- Lipids – good barrier to water, poor oxygen barrier
- Composites – good barrier to both water and oxygen
  - Addition of propyleneglycol alginate to soy protein isolates decrease the water-vapor permeability and water solubility
  - Integration of nisin absorbed onto the cross-linked hydroxyl groups HPMC and the carboxyl groups of citric acid
Starch and Derivatives

- Starch alone does not form films with appropriate mechanical properties.
- It has to be
  - chemically modified (plasticized starch)
  - treated in an extruder by application of mechanical and thermal energy (thermoplastic starch, TPS)
- Common plasticizers are glycerol, polyhydroxy compounds, polyethers etc.
Opportunities for Starch

• Starch-based absorbents can be a good alternative to conventional absorbent for meat exudation
• As films or bags starch could be employed as packaging for fruits and vegetables, or dry products
• These applications require efficient mechanical, oxygen and moisture protection
Clay Nanoparticles + Starch

• However, TPS alone cannot meet these requirements
• Clay nanoparticles have been shown to improve
  – tensile strength of TPS
  – oxygen permeability in ethylene-vinyl alcohol copolymer (EVOH) used in shrinkable films and plastic containers

http://www.primidi.com/images/nanoclay_structure.jpg
PLA & Polyhydroxybutyrate (PHB)

- Microbially produced PLA/PHB offer numerous opportunities in packaging applications
  - Can be formed into films or molded objects
  - Compatible with many foods such as dairy products, beverage, fresh meat products and ready meals
- Applications hampered due to low performance
- PLA/PHB-clay nanocomposites have shown improved mechanical and thermal properties
Carbon Nanotubes

- Great strength
- Electrical & conductive properties
- Nanotubes incorporated into films
  - Increase transport of gases ($O_2$)
  - Patent to improve color of meat in packaging
Nanoparticles

- Functionalize nanoparticles for the targeted delivery of drugs to the tissues and cells of interest, while increasing drug bioavailability and solubility.
Bioactive Substances

• Bioactive constituents of food evoke physiological, behavioral, and immunological effects

• Secondary products of plant metabolism
  – can modulate xenobiotic metabolizing and cholesterol synthetic enzymes

• Food-derived peptides from casein, fish muscle, and plant protein hydrolysates
  – influence intestinal transit, modify nutrient absorption and excretion, and exhibit immunostimulating & antihypertensive activity
2005 sales in the U.S.: $764 million
Antibiotic Resistance

The overuse and misuse of antibiotics and antibacterial products by people play a huge role in development of superbugs - antibiotic resistant bacteria.
$10^7$ CFU/g

$10^6-10^7$ CFU/g
**Polyelectrolyte complex (PEC) gels** are formed by mixing two oppositely charged polyelectrolytes in aqueous solution due to the electrostatic attractions.

**pH-SENSITIVE SWELLING OF XANTHAN-CHITOSAN COMPLEX**

![Graph showing the log number of viable cells versus time](image)

- **Log Number of viable cells (ctu/ml)**
- **Time (min)**

- **encapsulated**
- **free**

**Protective effect of encapsulation at pH= 2**
Bioactivity of Active Ingredients

Ephedrine (C_{13}H_{13}NO)  

Pseudoephedrine

Amphetamine

Methamphetamine
After 72h Treatment of Ephedrine

A. Control

B. 0.2 mg/ml

C. 0.4 mg/ml

D. 0.6 mg/ml

Rat myoblastoma H9c2 (2-1)
Nano Safety = Nano Smart
NANO HACCP?

• Hazard identification
  – Biological?
  – Physical?
  – Chemical?

• Hazard evaluation
  – Likely to occur?
  – Unacceptable risk?

Have Another Cup of Coffee & Pray?
Thank You!

Acknowledgement

• JIFSAN
• Dr. K. Fukushima
• Sanem Argin
• Daniel Reese
• Pavan Soma
• Patrick Williams
• Dr. Mickey Parish

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