

# One Processing Technology – Variable Applications

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# Introduction

- Encapsulation is a commonly applied technology for:
  - Better performance and handling
  - Safety
  - Additional functionalities (CR, protection, masking of properties)
- Can be achieved using several technologies & materials
- Extension far beyond the medical applications



# Drivers

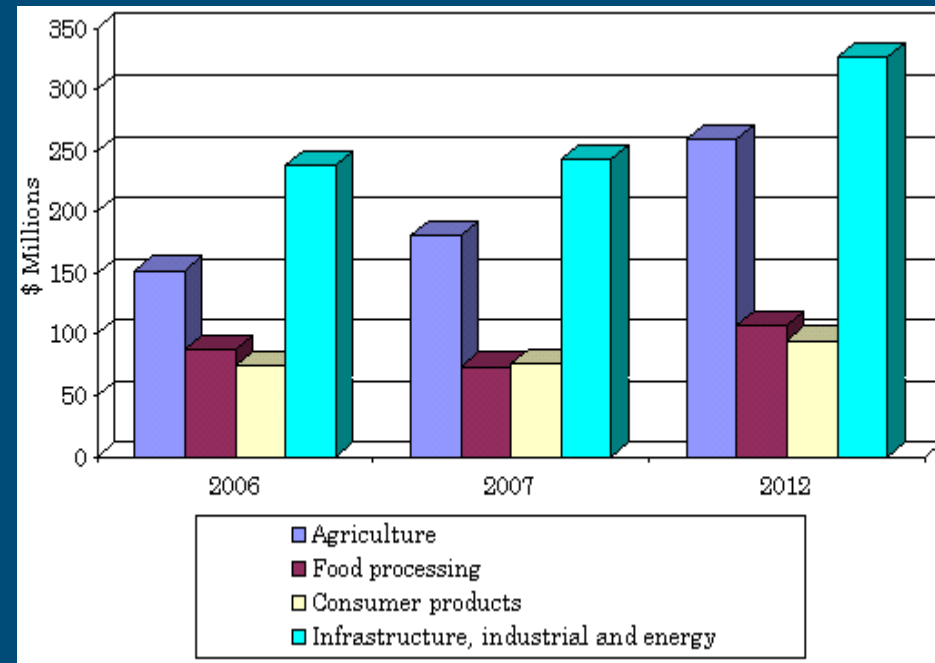
- Need for more sustainable products and approaches
  - Instable energy costs
  - Environmental concern
  - Efficiency of raw materials, processes and products
- Consumer demand
  - Better price, quality, presentation and performance.
  - Products that are more practical in use
- Regulations
  - European Union (EU) waste directives
  - EU rules that could restrict the use of as many as 30,000 commonly used industrial chemicals.

Leading to

- Growth in utilization of encapsulation technologies
  - Less expensive products including commodities.
  - Controlled release features from high-margin specialty products to low-margin mass marketed products

# Forecasts

- Growth of existing applications
- Emerge of new ones



*Report ID:MST027G, Published: September 2006, Jim Wilson*

# Focus

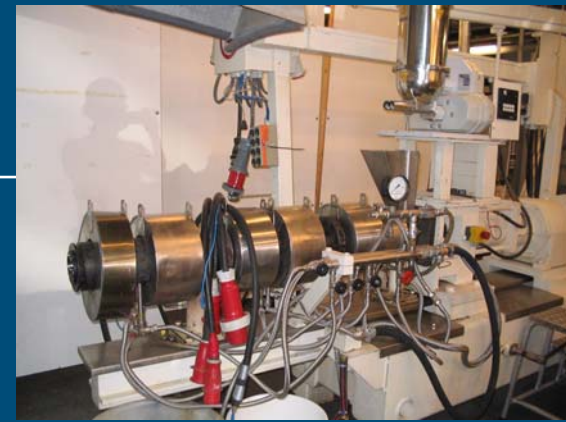
- Production technology that is
  - Flexible
  - Energy and cost efficient
  - Suitable for high volumes
- Matrices, coating materials and additives that are
  - Abundant
  - Versatile

# Encapsulation via melt extrusion

- Flexible
- Energy and cost efficient
- Suitable for high volumes

AND

- Well studied and explored for various applications
- Solvent free
- Suitable for numerous matrix materials & encapsulants



# Extruders for encapsulation

Co-rotating, double screw extruders, with sinusoidal screws (self-wiping) are preferred:

- Narrow, well-defined residence time
- Mixing performance is optimal, since the surfaces of the screws move towards each other
- Modular screw design

# Processing issues

- Suitable screw (required shear & mixing efficiency)
- Temperature profiles and screw speeds
- Closed/open system
- Less or more compression
- Encapsulant properties
  - Sensitivity (T, O<sub>2</sub>, shear, pressure, light, moisture)

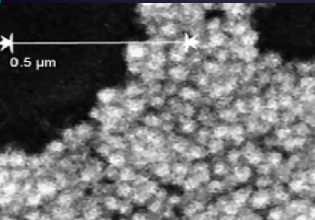


# Formulation

- Matrix materials
  - Natural polymers
  - Synthetic polymers
- Combinations of matrix material tailor made properties
- Modifications during processing
- Processing aids & additives
- Encapsulant properties
  - Interactions with the matrix
  - Stability (Further processing, application, storage or consumption)

# Products

- Shaped articles
- Granules
- Pellets
- Powder
- Gels
- Dispersions
- Emulsions
- (Multilayer or coated) films/tablets/granules
- Latexes/nano-particles



# How do they release the contents?

- Diffusion
- Degradation/surface erosion
- Combination

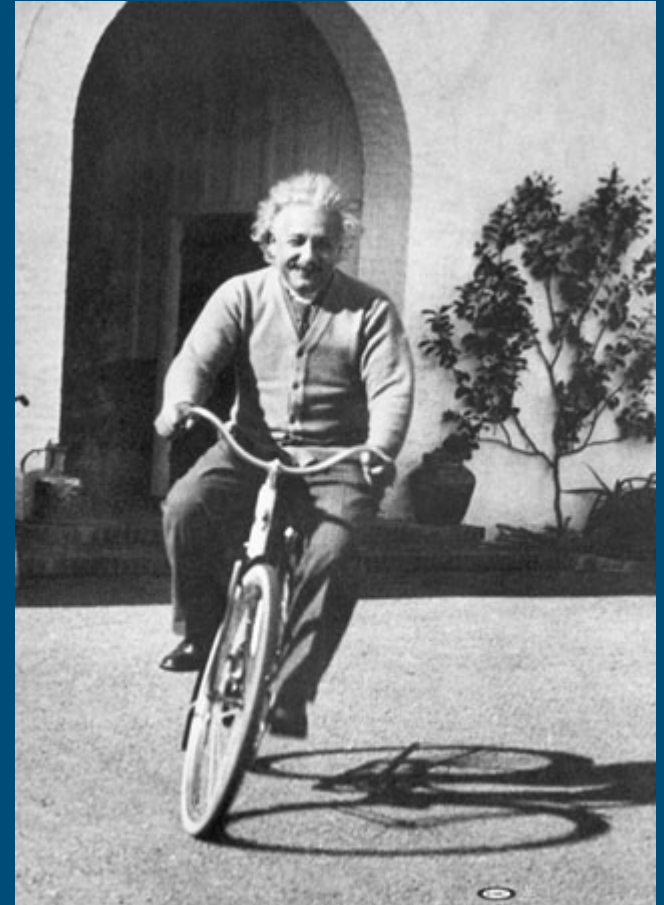
# Intellectual property

- Since 1950s
  - First patents emerge in the food industry (starch)
- Processing and product patents
- Usually by variation of the formulation

# Dare to imagine!

Imagination is more important than knowledge.

For while knowledge defines all we currently know and understand, imagination points to all we might yet discover and create



# So..

- We know how extrusion encapsulation works
- We know a lot about properties and processing of possible matrix materials
- We know well established applications of extrusion technology
- Why not combine?

# Cold Extrusion

- Enables working with encapsulants that have heat sensitivity;
  - 5°C-room temperature
- Working with a special cooling unit
- Careful selection of matrix materials
- Advantages
  - High viability and encapsulation efficiency
  - Preservation of structure and functionality
  - Good storage stability

# Cold extrusion-Applications

## Food Industry

- Flavors
- Probiotics
- Prebiotics/dietery fibre
- Vitamins
- Processing aids (enzymes, bacteria)



# Cold extrusion-Applications

## Household applications

- Fragrances

## Agriculture

- Essential oils with biological activity

## Medical/pharma

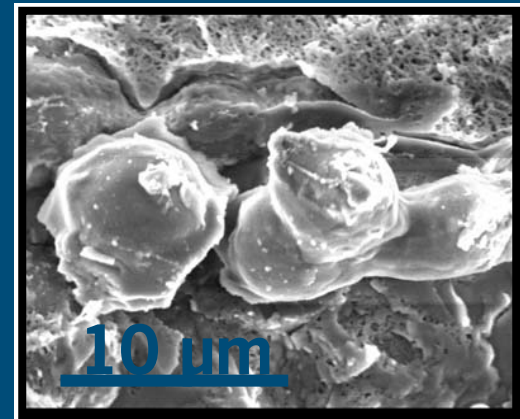
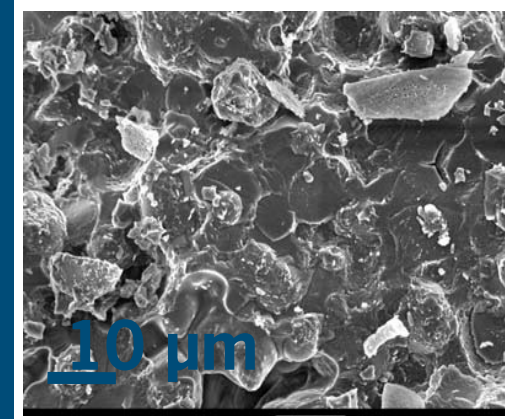
- Proteins/peptides
- Vaccines

## Packaging

- Flavors/perfumes
- Essential oils

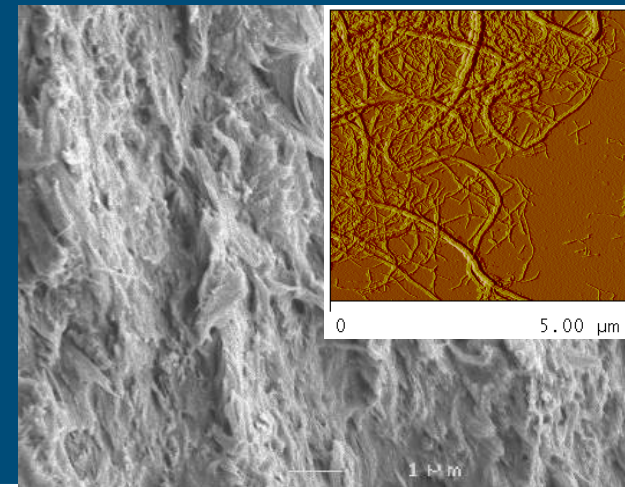
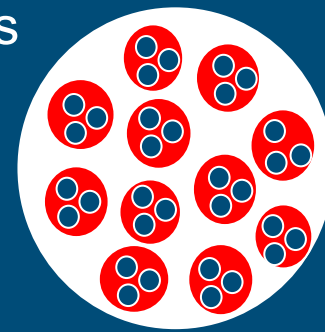
# Example

- **Encapsulation of bioactive organisms**  
(Lactic acid bacteria, bakers yeast, bifidobacteria)
- Processing at ambient temperature
- Survival ratio up to 97%
- Good stability first 2 weeks of storage
- Good stability at elevated temperatures



# Multiple component extrusion

- Enables combination of properties/functions
- Variable Combinations
  - Cyclodextrin complexes
  - Nanofibres containing actives
  - Particles containing actives
  - Multiple emulsions
  - Multiple matrix polymers
  - Multiple encapsulants
- Advantages
  - Additional functionality
    - Durability
    - Self healing
    - Better adhesion/drying
    - Built in trigger
  - Tailor made release
    - Pulsatile release
    - Slow release (several years)
  - Improved compatibility of components
  - Endless variations

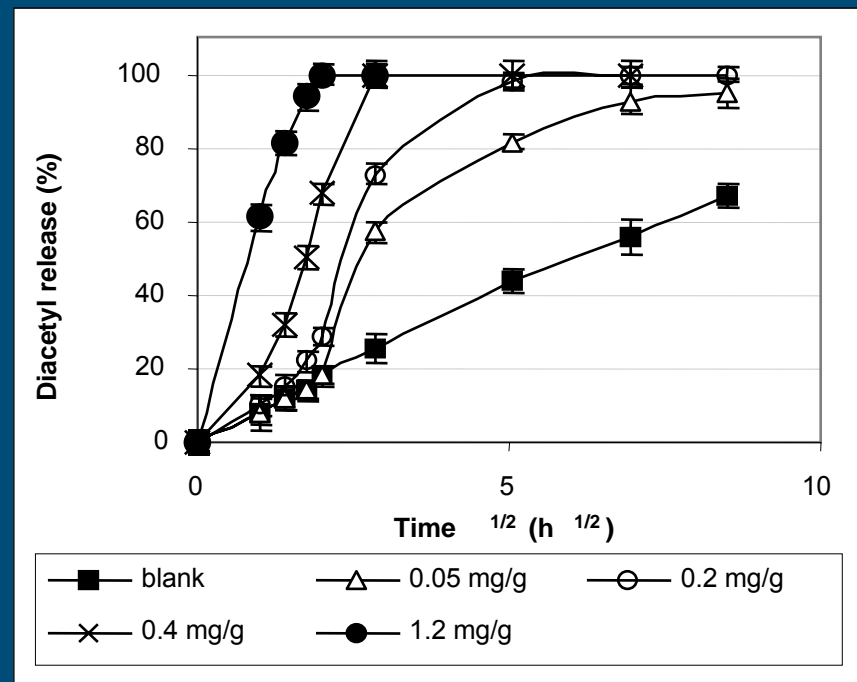
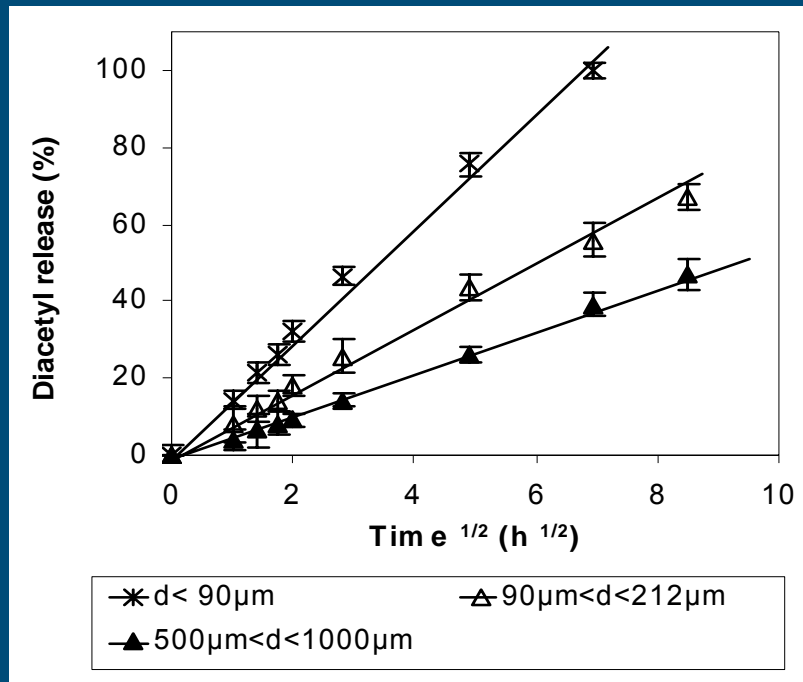


# Multiple component extrusion – Applications

- Coatings/paints/laminates
  - Curing agents
  - Cross-linkers
- Plastics
  - Additives (UV stabilizers, enzyme inhibitors)
  - Processing aid (catalysts, crosslinker, mold release agents..)
- Agriculture
  - Herbicides, pesticides, fungicides
  - Fertilizers
- Construction materials
  - Phase change materials

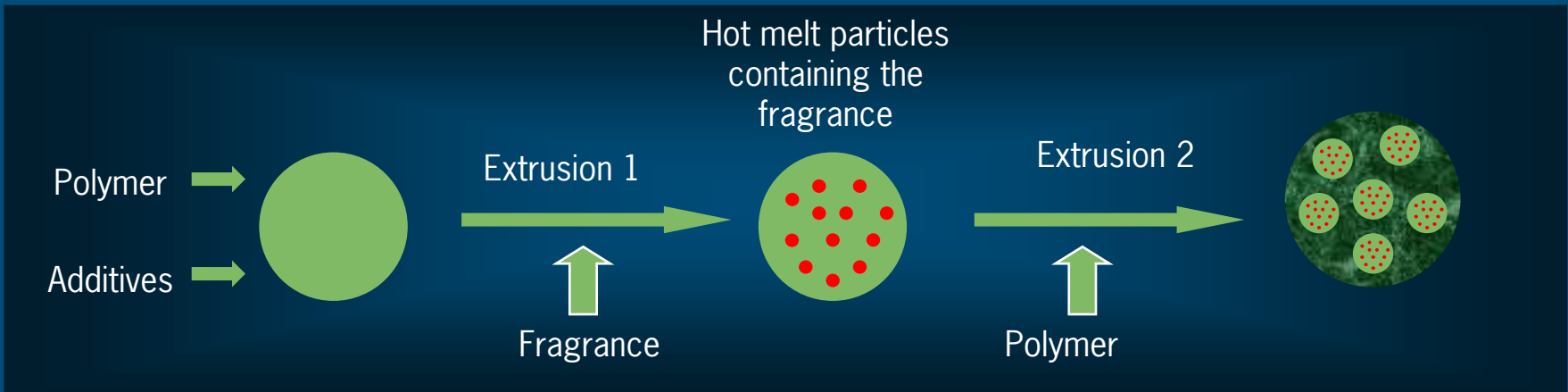
# Example

- Co encapsulation of a matrix degrading enzyme and triggered release of a volatile
- Triggered upon increase in the RH
- Extent of release can be controlled



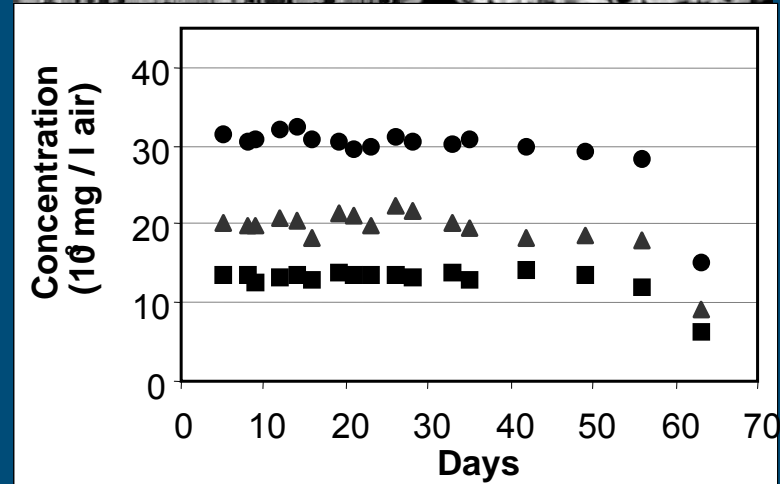
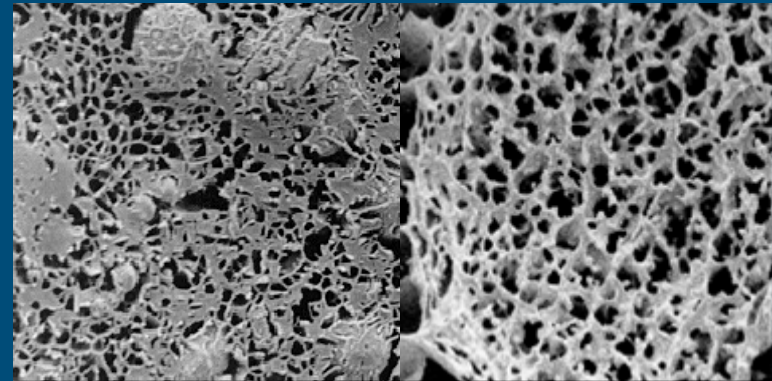
# Example

- Hotmelt delivery system
- For laundry applications
- Responsive to pH or water
  - Some retain size (10-30  $\mu$ ), others disintegrate to smaller entities ( $\cong$  10-30  $\mu \rightarrow \cong$  1-20  $\mu$ )
  - Deposition of the particles on clothes by SEM (cotton and polyester)



# Example

- Multi component matrix system
- Zero order release
- Containing a biologically active volatile compound
  - Tailor made release as a function of morphology
  - Morphology as a function of process variables



# Example

- Encapsulated PCM to be incorporated in gypsum board, plaster or flooring
- A phase change occurs when, as a result of heating or cooling, an element changes between the liquid, solid or gaseous states. PCM are often paraffin wax or salt hydrates, and are commonly used as hot or cold gel packs (for transporting medication, laptop coolers, warm pizza boxes, etc.).
- Increases the thermal mass and capacity of lightweight buildings.
  - By night the PCM cools and solidifies.
  - During the day the warm air mixes with the cool walls/floors, reducing the daily temperature swing by several degrees



# Extrusion coating

- Enables combination of encapsulation and lamination/coating process
- Applicable in various surfaces
- Polymer matrix is in molten stage exiting the extruder and adheres to the substrate
- Combinations are possible with multiple component extrusion
- Advantages
  - Compact processing
  - Added functionality (release of an active, gloss)

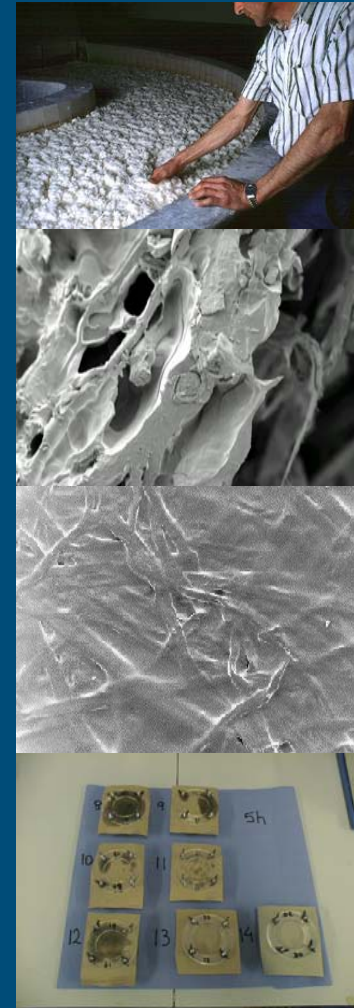
# Extrusion coating-Applications

## ■ Packaging

- Paper and board applications
- Flavor and perfumes
- Essential oils
- Antimicrobials
- Growth regulators
- Compounds to enhance barrier properties (scavengers, absorbents, antioxidants)

# Example

- Board for packaging
- Extrusion coated for;
  - Grease resistance
  - Release of perfume
    - Perfume pre-encapsulated in micro fibres
- Formulated using biodegradable plastic enhanced by nano-clays



# Co-extrusion

- Enables combination of encapsulation and production of multilayer films production
- Combinations with multiple component extrusion
- Advantages
  - Different functionalities
  - Enhancement of properties

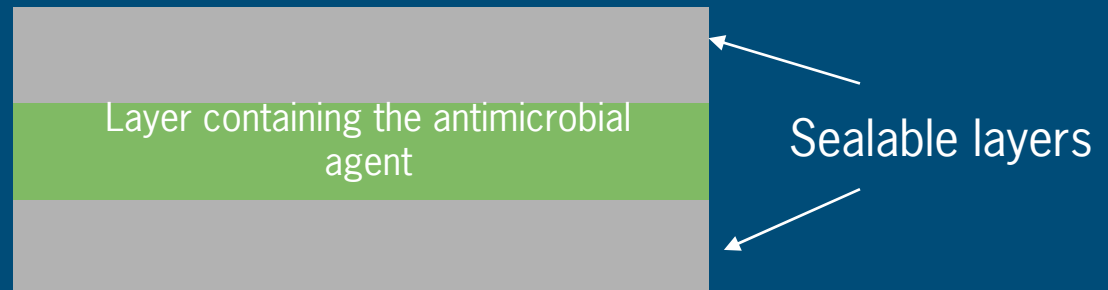
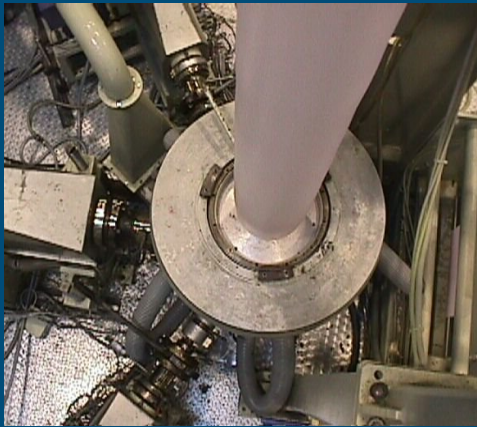
# Co extrusion-applications

## ■ Packaging

- Flavor and perfumes
- Essential oils
- Antimicrobials
- Growth regulators
- Compounds to enhance barrier properties (scavengers, absorbents, antioxidants)

# Example

- Packaging film containing antimicrobial agents
- 100-150  $\mu\text{m}$
- Compostable
- Improved shelf life
- Improved barrier properties
- Sealable



# Fibre extrusion

- Enables combination of encapsulation and fibre spinning process
- Advantages
  - Additional functionality
    - Delivery of compounds
    - Enhancement of durability

# Fibre extrusion-Applications

- Agrotextiles and geotextiles
  - Herbicides, pesticides
  - Fungicides
  - Fertilizers
  - UV stabilizers/enzyme inhibitors
- Textiles
  - Perfumes
  - Cosmetically active compounds
- Personal care/Hygiene products
  - Perfume
  - Antimicrobials



# Example

- Compostable agrotextiles
  - Applicability for one season
  - Containing a volatile pesticide
- Spinning process very critical
  - Melt strength
  - Mechanical properties
- Field trials ongoing

# To Conclude

## Encapsulation via extrusion technology enables

- Encapsulation of wide range of
  - Compounds & organisms: Vitamins, minerals, peptides, proteins, hormones, drugs, enzymes, essential oils, bacteria, yeast, algae, flavors, perfumes, detergents...
  - Large variety of activities: Anti-microbial, anti-biotic, growth regulation, nutrition, pest control detergent...
- Process flexibility
- Efficient and economically feasible

# Future prospects

- More complex formulations
  - For site specific delivery
  - Specific delivery patterns
- Combinations with chemical approaches in one step
  - Encapsulant-matrix
  - Matrix modification-reactive extrusion
- More products making it to the market especially for high volume applications
  - Agriculture
  - Household
  - Intelligent packaging
  - Coatings
  - Processing aids
  - Paper and board
  - Hygiene products

# Just a glimpse of a little bit more

- Supercritical fluid aided encapsulation via extrusion
  - Extrusion equipment is developed for extraction
  - Modification required for encapsulation
    - Impregnation of porous carriers
  - Carbon dioxide as supercritical fluid
- Advantages
  - Creation of new structures
  - Possibly creation of new functionalities
  - Continuous process

# Recognize the opportunities

Sometimes they can go unnoticed..



A committee of the British Parliament in 1878 reported Thomas Edison's ideas of developing an incandescent lamp to be

**“good enough for our transatlantic friends... but unworthy of the attention of practical or scientific men”**

*Source: Clarke, Arthur C. Profiles of the Future. New York, Harper and Row, 1962. p.*

# Thank You!

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