Technological aspects of Encapsulation via Melt Extrusion Technology

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AGROTECHNOLOGY & FOOD SCIENCES GROUP
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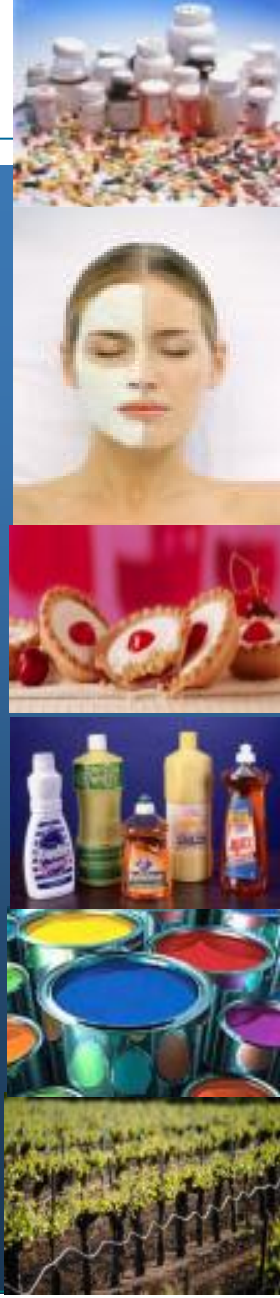
Encapsulation

Encapsulation is a commonly applied technology for, a.o.:

- Protection and stability
- Masking core material properties
- Better handling
- Safety
- Controlled release

Can be achieved using several technologies & materials:

- Combination of materials usually preferred
- Thermoplastic processing technologies gaining






STRIVADERM MD




HARTZ
Control
FOR CATS
Pet Care System
VELVET FLEA COLLAR
NATURALLY REPELS FLEAS








WRIGLEY'S
Winterfresh
SUGARFREE GUM

SMD - HUMITECTOR


Encapsulation via melt extrusion

- Well explored technology
- Compact, continuous (melting, modification, mixing, shaping) & flexible
- Minimal amount of solvents
- Low cost
- Suitable for numerous matrix materials & encapsulants
- Suitable for large volumes

But:

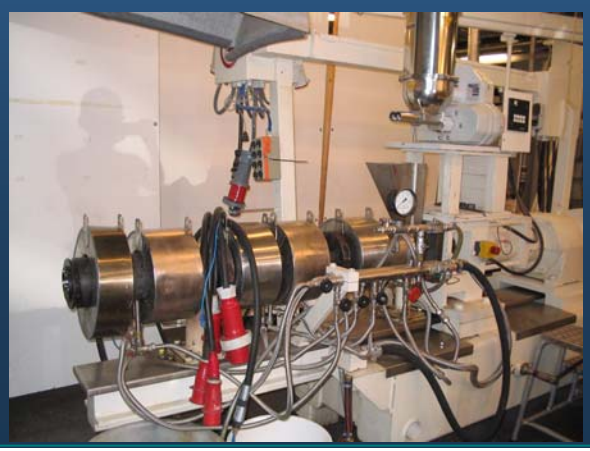
Requires a combination of specific expertise

Outline

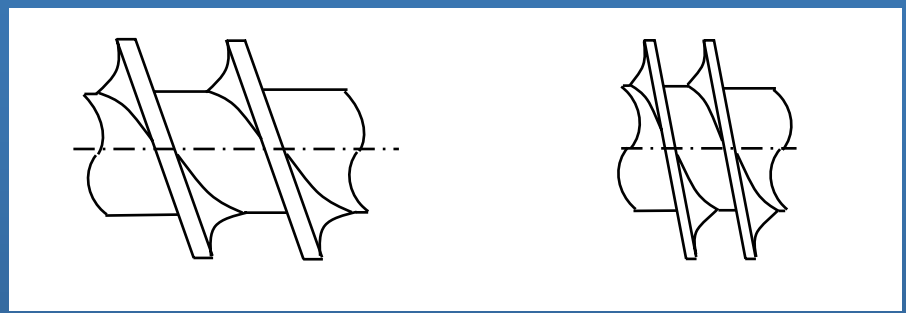
- Introduction to extrusion technology
- Processing issues for encapsulation
- Products & applications
- Future prospects

Extruders

- Thermo-mechanical mixers with one or more screws in a barrel
- Transfer of material usually by rotation of the screws
- Barrel/screws can be heated/cooled
- Energy input: Mechanical energy via shearing
  Heat transfer through the barrel wall

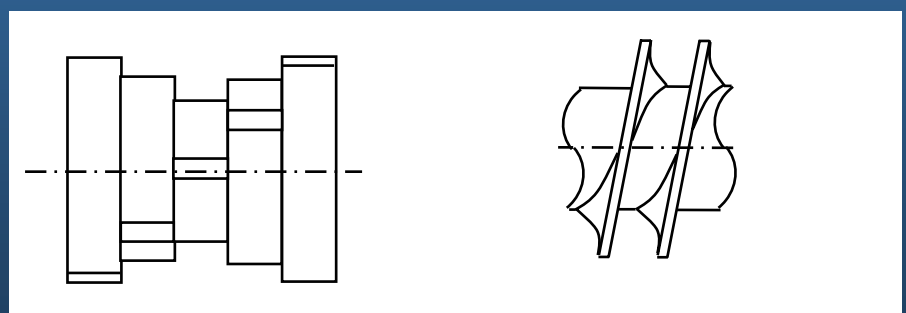


Screws



Large pitch Small pitch

Conveying/ transport elements



Kneading

Mixing elements **Reverse element**

Die

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 for encapsulation

5 integrated processes and zones of the extruder

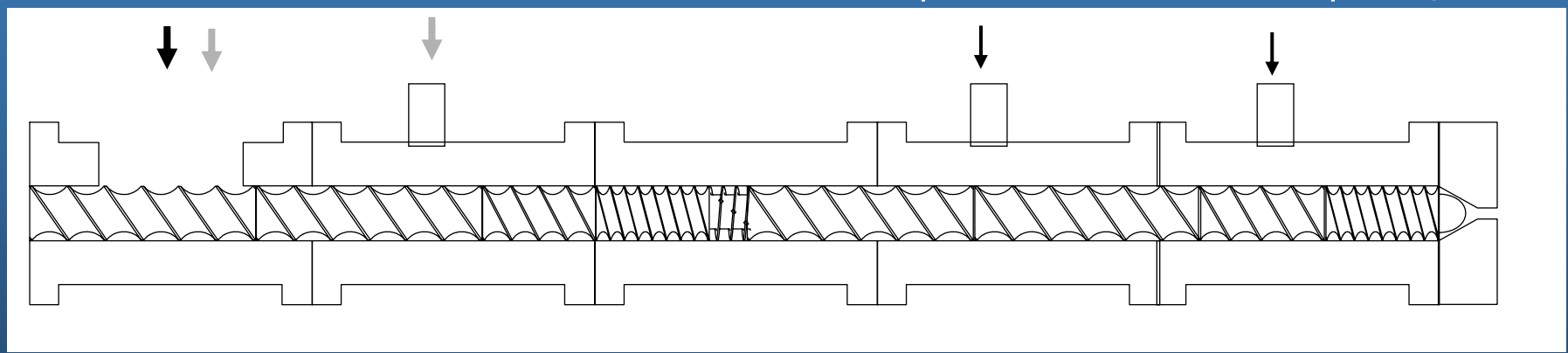
- The feeding zone
- The melting, dissolving / conveying zone
- The mixing / dispersing zone
- The conveying / compression zone
- The end-zone, or the die

Schematic representation

Feed
(matrix materials)

Optional inserts for the encapsulants

Die



Feeding

Melting/Dissolving

Dispersing/Mixing

Compre

When performing encapsulation via extrusion

- Consider Sensitivity
  - T, O_2, shear, pressure, light, moisture
- Stability may a problem
  - Further processing, application, storage or consumption
- Controlled release should be possible for some applications

Processing issues

Good control of T, pressure & shear is essential

- Suitable screw (required shear & mixing efficiency)
- Temperature profiles and screw speeds
- Closed system
- Less or more compression
- Modifications on the matrix formulation
- Degree of fill

Matrix materials

Natural polymers	Synthetic polymers
Polysaccharides Starch&modified starches Cellulose&modified celluloses Chitosan *Proteins* Soy protein Wheat protein Collagen Gelatin Keratin Whey protein	*Polylactide* *Polyglycolide* *Polylactide-co-glycolide* *Poly vinyl alcohol* *Polyvinyl acetate* *Polyethylene vinyl acetate* *Polyethylene glycol* *Polyethylene oxide*

Formulation

- Biopolymers are advantageous:
  - Edible & Biodegradable
  - Usually biocompatible and well tolerated metabolizable
  - Large variety & range of properties
  - Large availability
  - Can be processed at lower temperatures
- Combination with synthetic polymers is an option for tailor made properties
- Processing aids & additives

Encapsulants

Compounds & organisms with or without a certain biological activity

- Numerous 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…

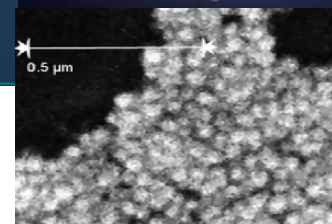
Products

- Shaped articles
- Granules
- Pellets
- Powder
- Gels
- Sheet
- Latexes/nano-particles

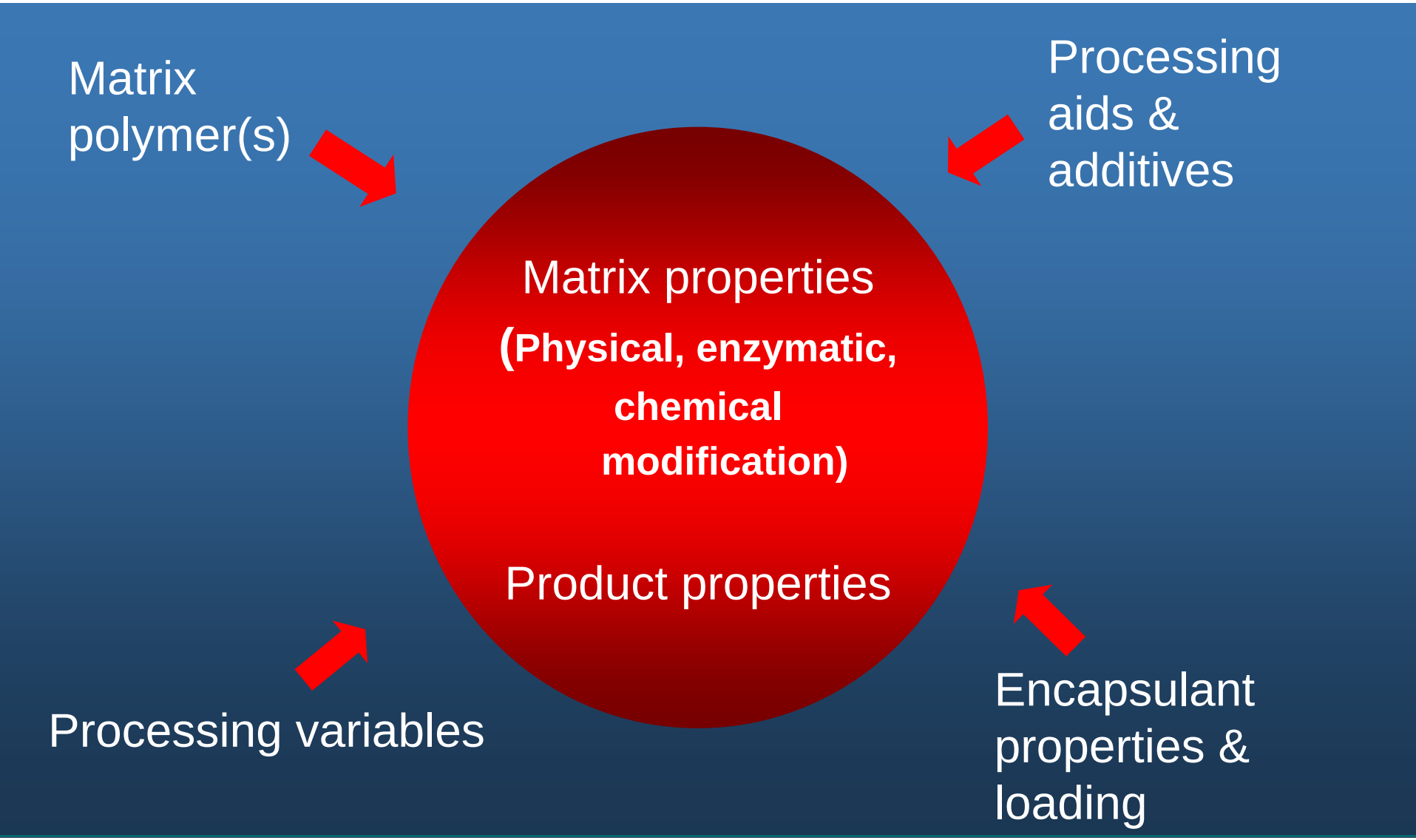








Modifications

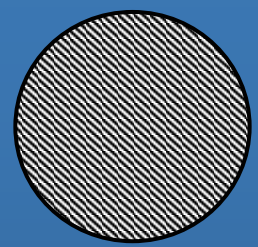


Product Properties

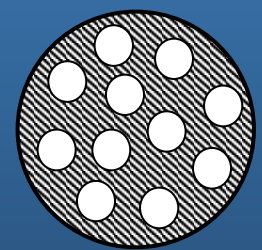
- Morphology
- Crystallinity
- Mechanical properties
- Density
- Release properties (mechanism, rate, profile, kinetics)

Morphology

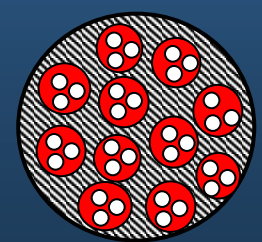
- Single phase
  - Encapsulant dissolves in the matrix



- Two phase
  - Encapsulant is dispersed in the matrix



- Multiple phase
  - Two non-miscible matrix components
  - Encapsulant is dissolved or dispersed in one



Processing issues: Morphology

- For single phase
  - Simple mixing
- For two/multiple phase
  - Very comparable with polymer blending
    - Dispersive and distributive mixing
    - Additives

Release properties

Abundant options:

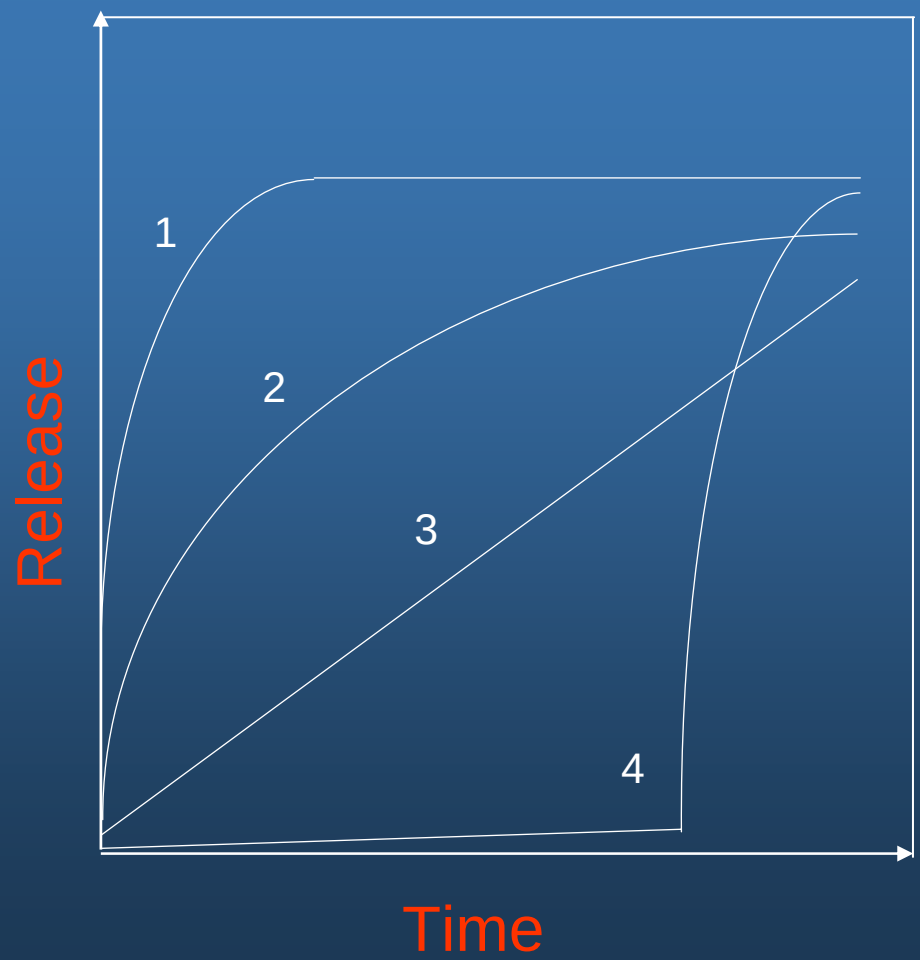
1: Burst release,

2: First-order release,

3: Zero-order release,

4: Pulsed/Triggered release

controlled by diffusion, degradation or combination



Applications

- Food industry
- Pharmacy
- Non-food industries
  - Coatings/paints/inks
  - Agriculture
  - Textile
  - Plastics
  - Packaging
  - Household
  - Cosmetics & personal care
  - Waste water treatment

Applications in the food industry

- Food grade matrices (starch, proteins, fats..)
- **Enhancement of taste**
  - **Mostly for flavors**
  - **Instant food products**
  - **Bakery**
  - **Low fat food**
- Functional foods (vitamins, minerals, probiotics..)
- Taste masking (fish oils)
- Processing aid (salt, enzymes, bacteria)

Applications in the pharmacy

- Various types of matrices (synthetic and bio)
- For controlled or targeted delivery of biologically active compounds
  - Prescription medication
  - OTCs
  - Biomaterials (Implants)

Applications in the non food industries

- Various types of matrices (synthetic and bio)
- Processing aid
- Better compatibility of the actives
- Added functionality
- Controlled or targeted delivery of compounds

Packaging

Additional functionality; improvement of shelf life and/or quality, presentation

- Active packaging
  - Food products (difficult; legislation on migration)
    - Permeation control (scavengers, antioxidants, absorbents)
    - Encapsulated anti-microbial/fungal agents
  - Plants / cut flowers
    - Release of growth regulators
    - Disease elimination
    - Improved presentation with perfumes
- Indicator systems
- Marketing tool

Agriculture

Focus on controlled release and agricultural films

- Release of biologically active compounds
  - Herbicides, pesticides, fertilizers...
- Influence of the biodegradability
  - Triggered biodegradation
  - Extension of the biodegradation
  - Soil enhancement
  - Soil disinfection

Other non food applications

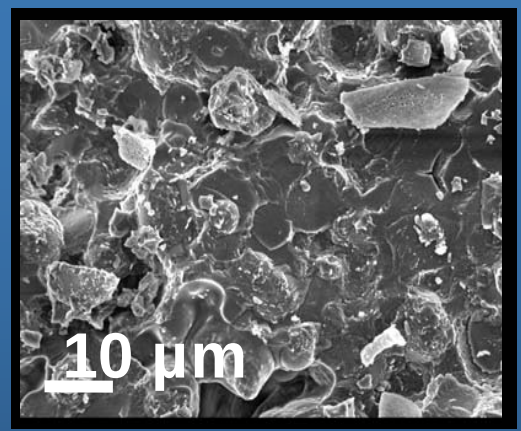
- Coatings/paints/inks
  - Self healing
  - Functional (antifungal, anti graffiti..)
  - Better adhesion/drying (curing agents)
- Textile
  - Added functionality (anti fungal, nice smell, cosmetic..)
- Plastics
  - Durability (controlled degradation, color stability, UV stability..)
  - Processing aid (catalysts, crosslinker, mold release agents..)
- Household
  - Long lasting effect (smell, pest control, antimicrobial)
  - Protected actives (longer shelf life)
- Cosmetics & Personal care
  - Vitamins, cosmeceuticals
  - CR effect
  - Tailored functionality (acne treatment, anti age, scar healing..)

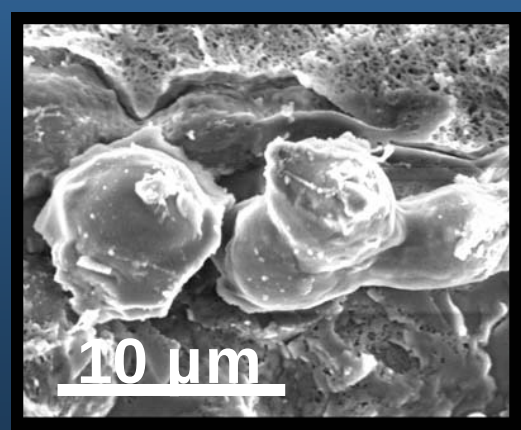
Intellectual property

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

Examples:

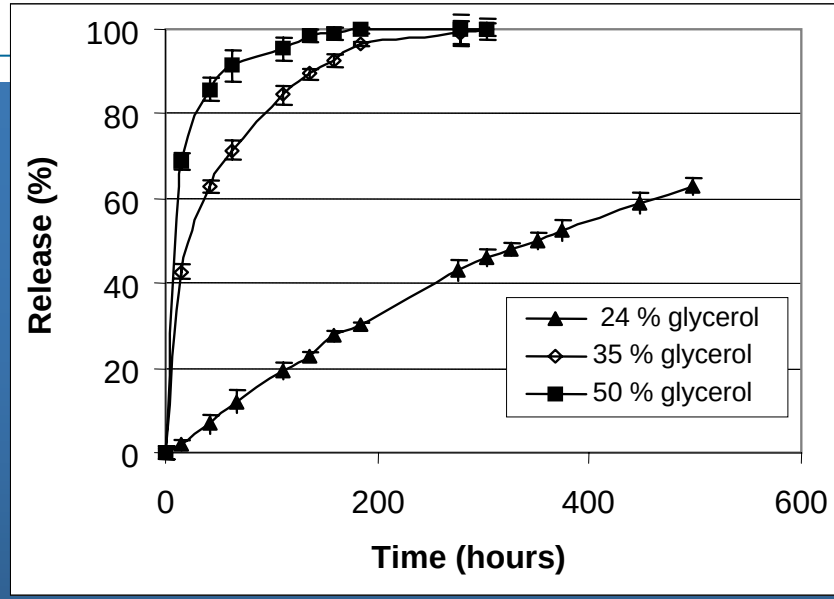
- **Encapsulation of bioactive organisms** (Lactic acid bacteria, bakers yeast, bifidobacteria)
- Processing at ambient temperature
- Survival ratio up to 97%
- Good stability first 2 weeks of storage
- Good stability at elevated temperatures

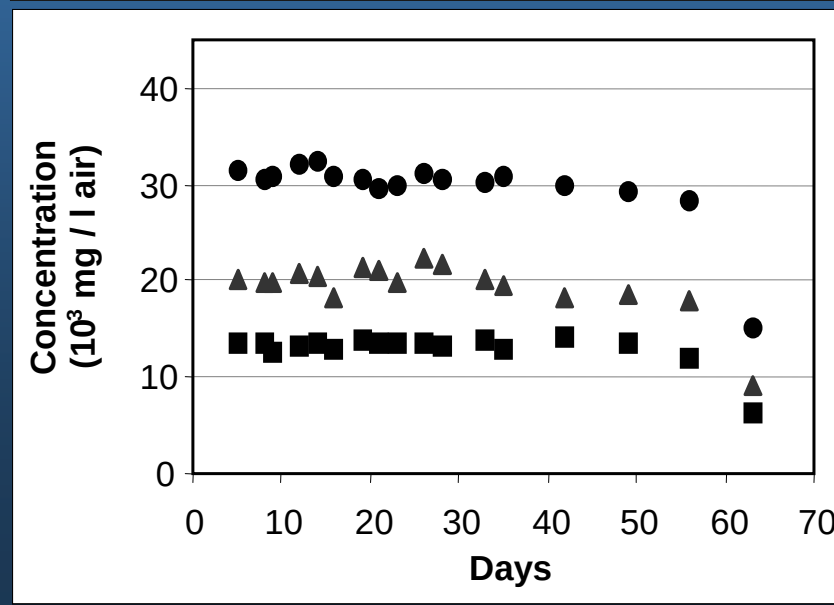




Examples:

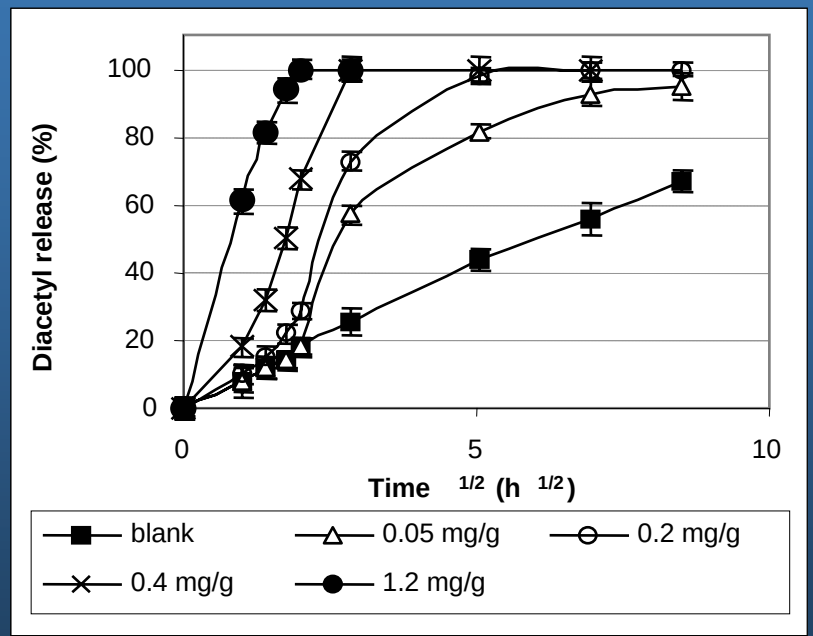
- **Encapsulation and slow release system for a volatile compound**
- Processing at ambient temperatures
- Multi component matrix system providing zero - order release of the active which can be extended for months





Examples:

- **Encapsulation and triggered release of biologically active compounds**
- Triggered upon increase in the RH
- Extent of release can be controlled

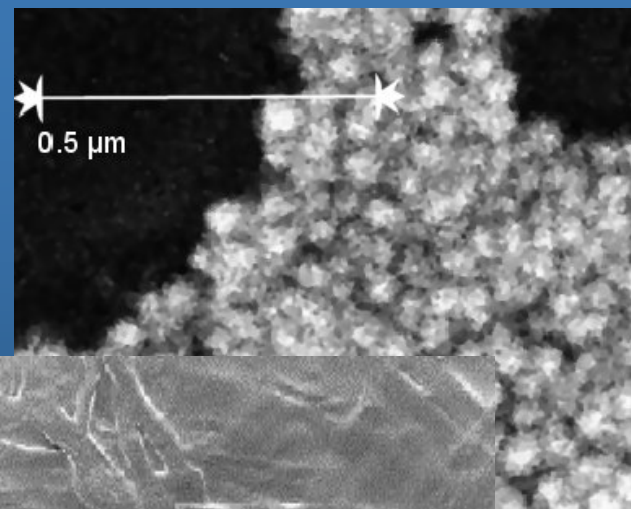


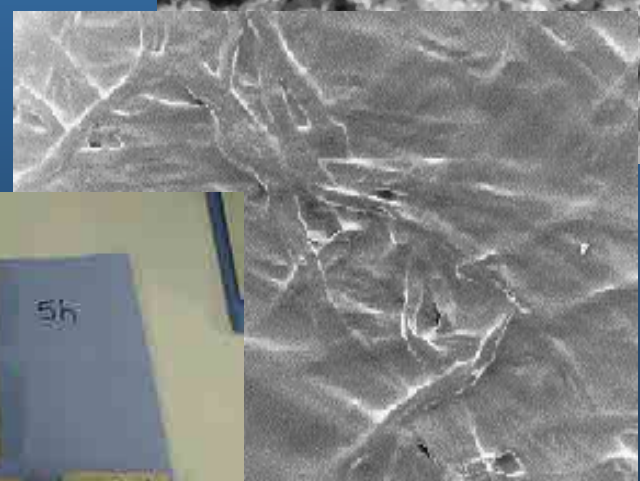
Examples:

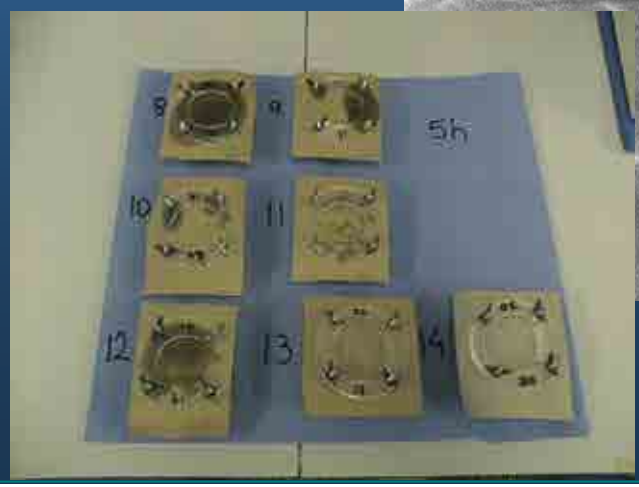
- **Encapsulated fertilizers formed into shaped articles**
- Biodegradable pots
- Release occurs upon contact with water

Examples:

- Latex systems
  - Colloidal stability in water
  - Economically feasible production methods
  - Tuneable water absorption and binding
  - Barrier
  - Protective
  - Gloss
  - Antimicrobial
  - Responsive
  - Self curing







Application examples

- Encapsulated active compounds for oral hygiene
- Stabilized flavors for food products
- Vitamin delivery
- Probiotics/prebiotics delivery
- Oral delivery of pharmaceutically active compounds for domestic animals
- Oral vaccination of animals
- Responsive antimicrobial packaging material
- Responsive freshness indicator
- Triggered fungicide release
- Protected colorants & dyes
- Fast drying ink
- Soil disinfecting foils
- Slow release agrochemicals
- …..

Concluding remarks

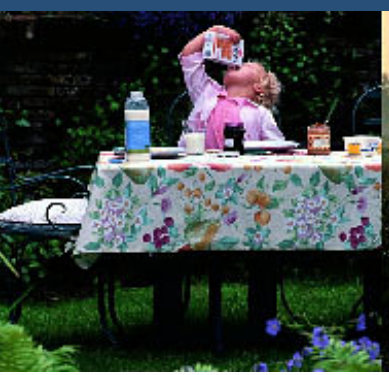
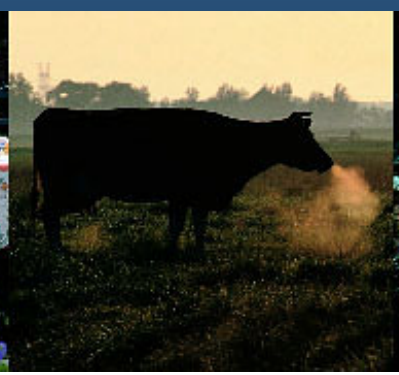
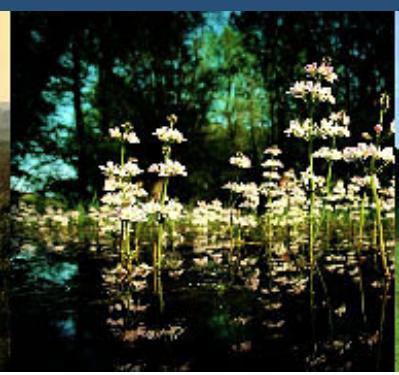
Encapsulation via extrusion technology enables

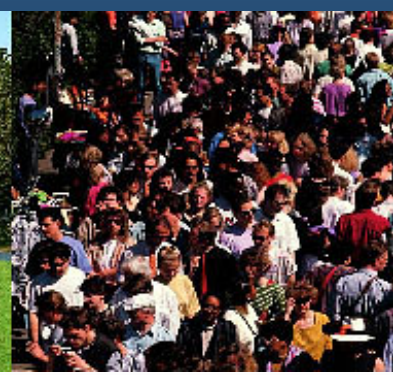
- Encapsulation of wide range of compounds
- Process flexibility
- Efficient and economically feasible processing
- Tailor made properties of the products

Future prospects

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

Thank You!



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