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LIFE SUPPORT SYSTEM
ALTERNATIVE

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A CIRCULAR
FUTURE

3DMedLowG

3D printing in low-gravity: Challenges in development of hardware and food compatible printing ink for personalized supplements

IN COOPERATION WITH

European Space Agency

3DMedLowG

3D printing in low-gravity: Challenges in development of hardware and food compatible printing ink for personalized supplements

Toulouse, November 2022

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University of Ljubljana
Biotechnical Faculty
seventy-five years

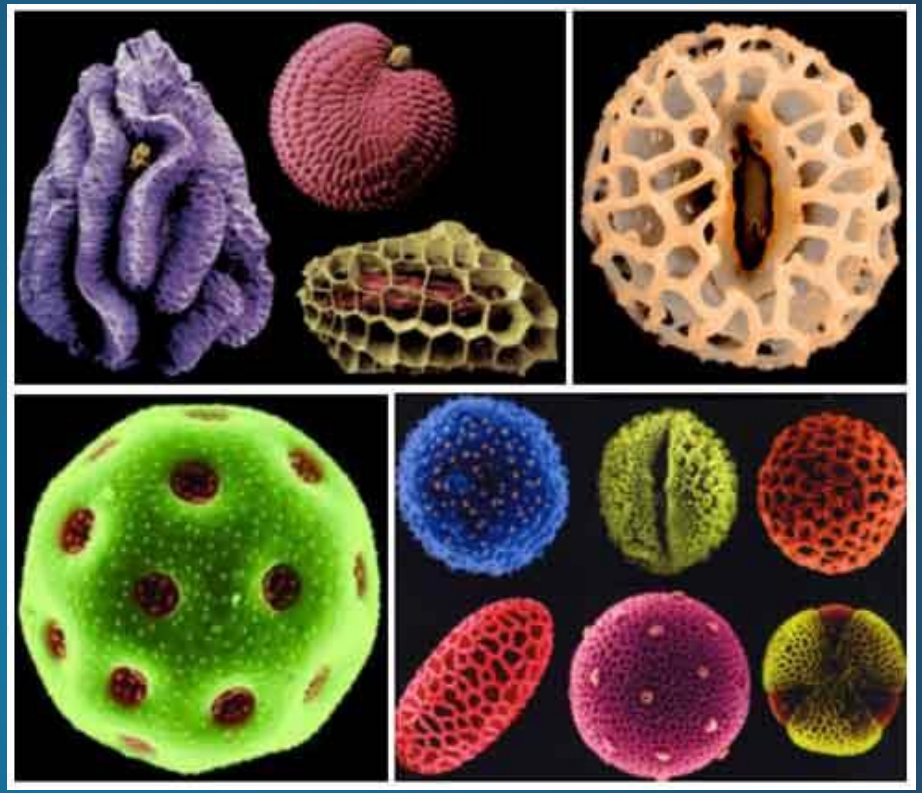
VESOLJE·SI
CENTER ODLIČNOSTI VESOLJE, ZNANOST IN TEHNOLOGIJE

Technology

Development of a responsive device capable of producing personalized nutritional (and pharmaceutical) forms in suitable for consumption in zero-gravity space.

REMARK: Not the actual 3DMedLowG technical solution - unfortunately :)

Encapsulation natural solutions

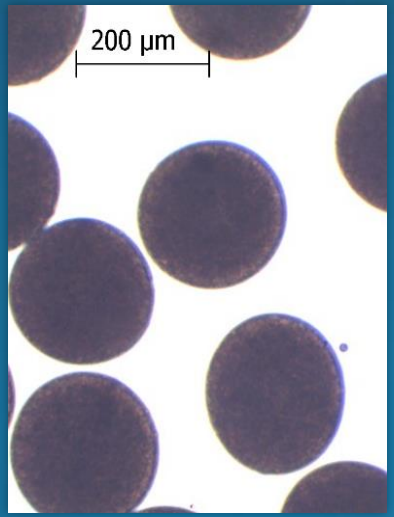


http://www.world-mysteries.com/science-mysteries/cosmic-blueprints/

Emulsions,hydrogels and liposomes are most common.

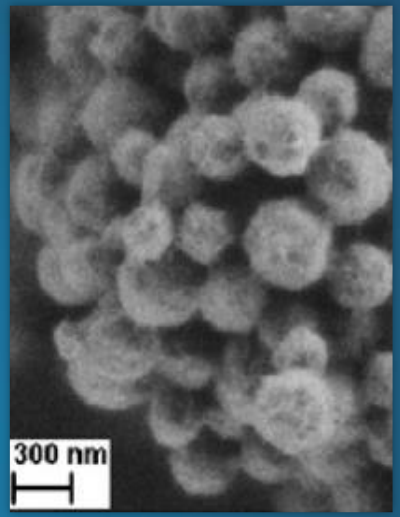
Encapsulation for food applications

Vitamins



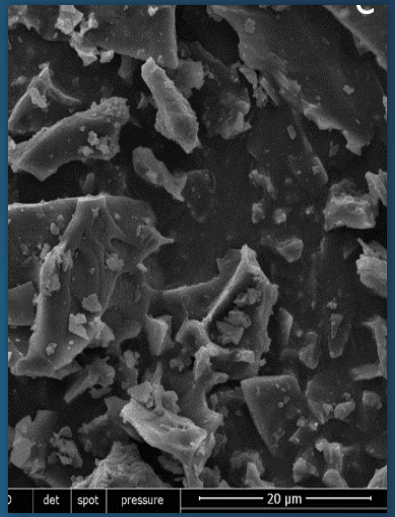
Folic acid (vitamin B9) in proliposome/alginate beads
Osojnik et al., 2020.

Polyphenols



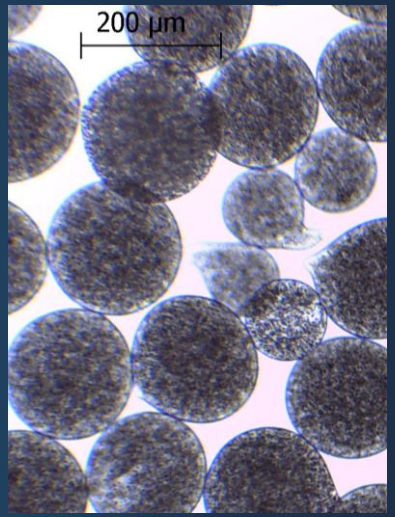
Submicron polisah. beads (W/O template) with resveratrol.
Istenič et al., 2015

Extracts



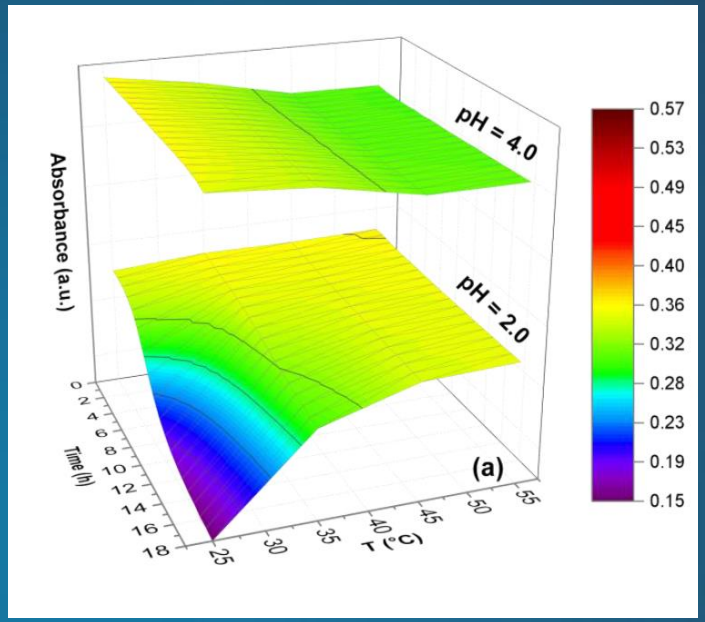
Freeze-dryed complex propolis:gumi arabic.
Šturm et al., 2020

Microorganisms

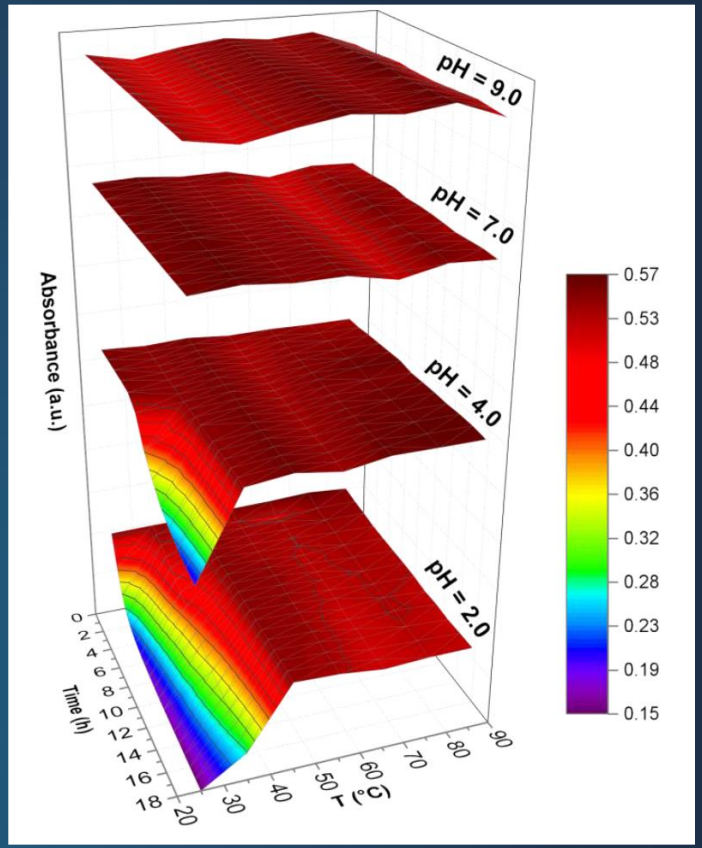


S. cerevisiae self-agglomeration in chitosan and β-CDX matrix.
Osojnik et al.

Encapsulation vitamins



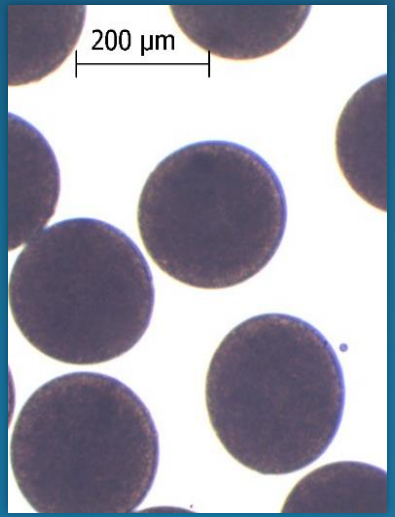
15 µM folic acid,
pH 2-4, 25-55 °C, in the dark



25 µM folic acid,
pH 2-9, 25-85 °C, in the dark.

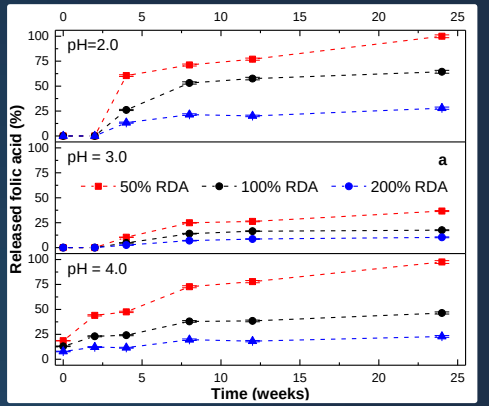
Encapsulation vitamins

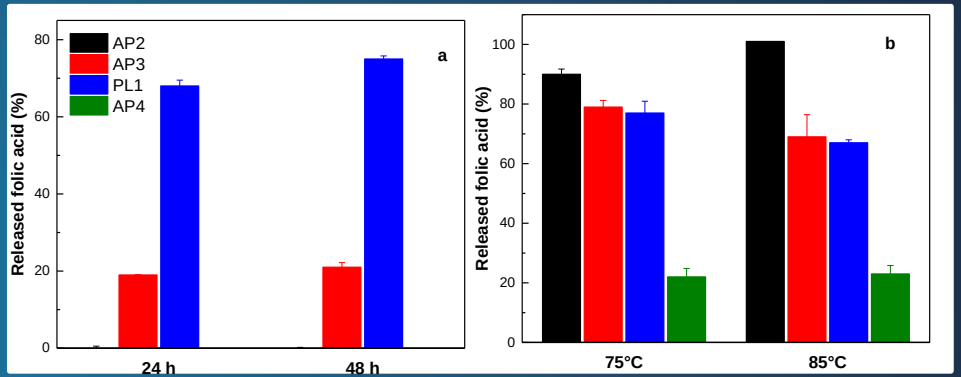
Vitamins



Folic acid (vitamin B9) in proliposome/alginate beads
Osojnik et al., Food&Function, 2020.

Long-term release of folic acid from alginate-pectin microbeads (AP2) at 25 °C and 50–200% dosed recommended dietary allowance (RDA).

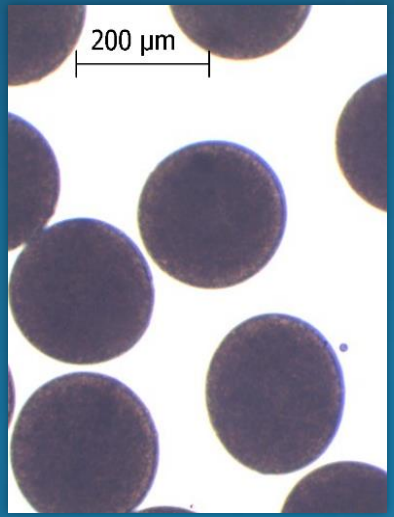




Release of folic acid form various carriers (AP2–4, PL1) in water at 100% RDA and 24 and 48 hour long exposure at 25 °C (left) and 10 min exposure at 75 °C/ 5 min exposure at 85 °C (right).

Encapsulation for food applications

Vitamins



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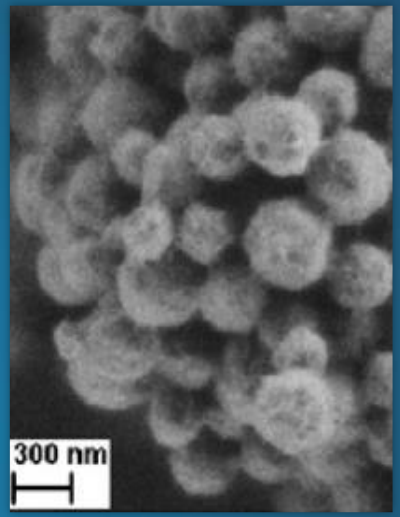

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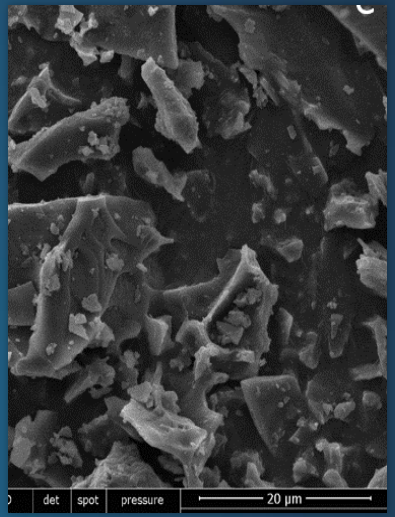

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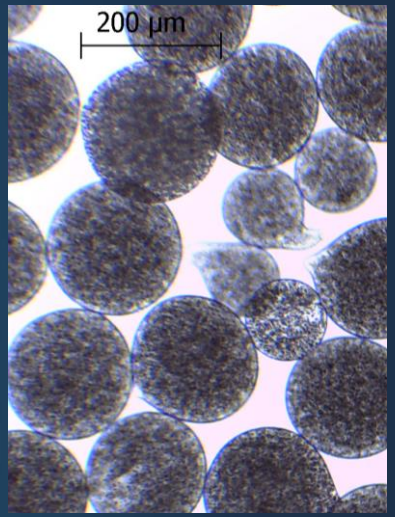
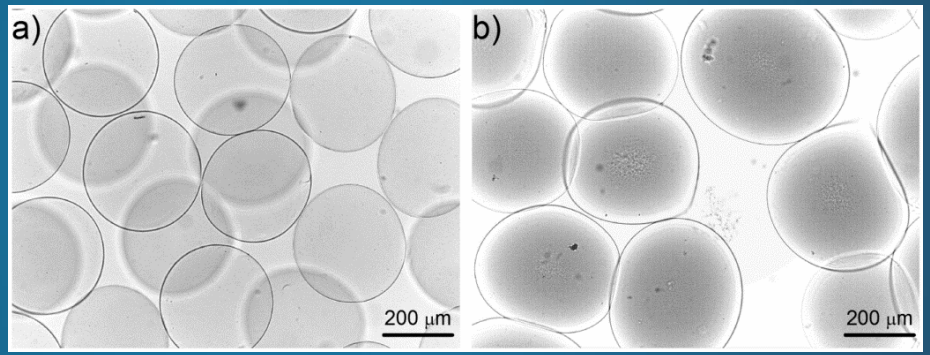


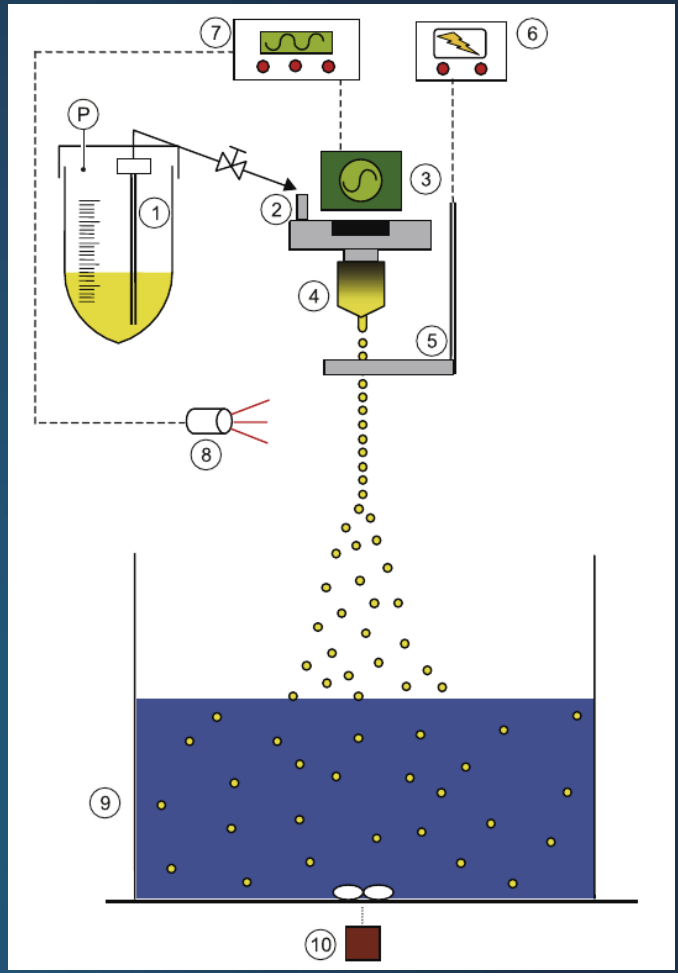
S. cerevisiae self-agglomeration in chitosan and β-CDX matrix.
Osojnik et al.

Hydrogels

Polisaccharide solution is introduced into the corresponding hardening solution containing crosslinking ions.

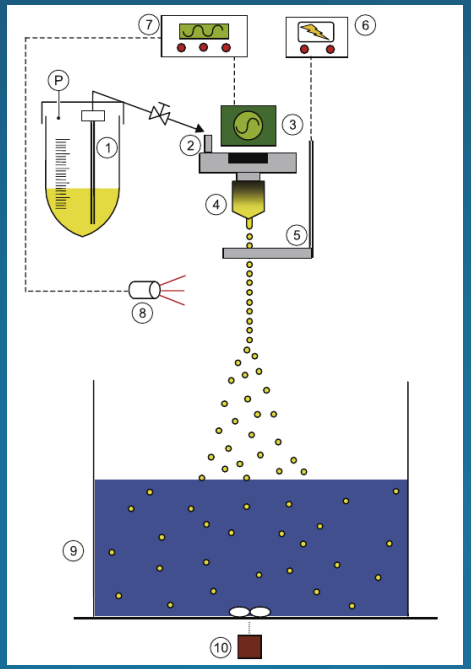
Vibration nozzle and electrode enable the formation of microbeads.

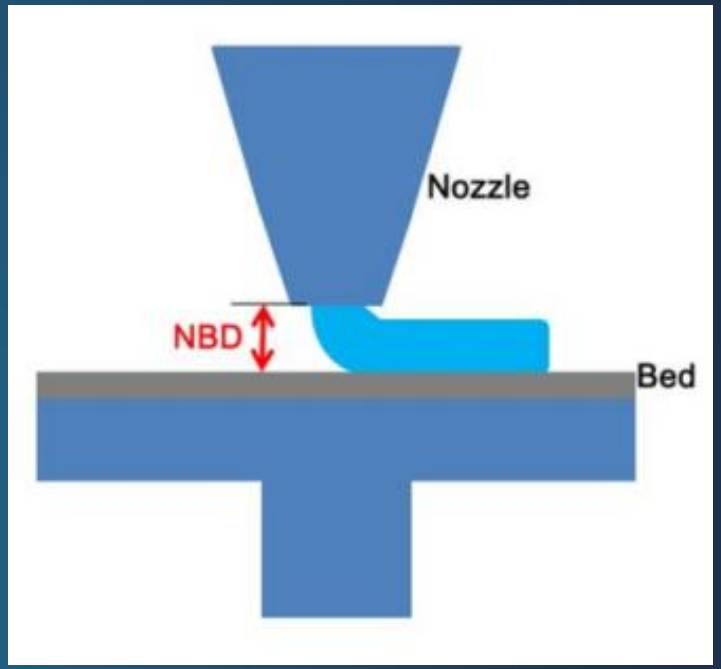




Why 3D printing?

Hydrogels in (low) gravity





3D printing in space

Deep space Missions (3-5 years)

Stable food, supplements, medicine

Chemical/microbiological stability

Encapsulation

Precise dosing (3D printing)

Healthy food

Good bioavailability

Personalized beverages

Healthy astronauts

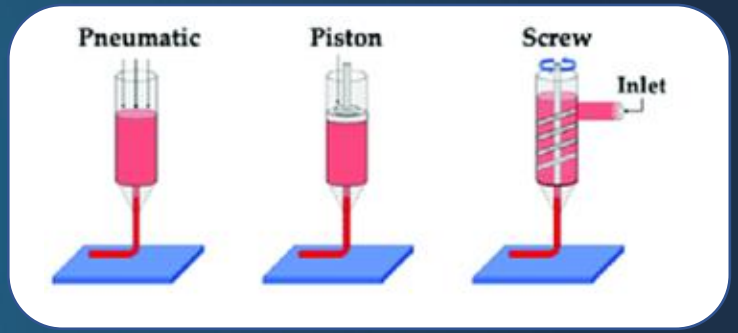
Figure from: Neil Leach (2014): 3D Printing in Space. *Architectural Design*

Technology

3D printing

- Precision extrusion of the ink into an predesigned shape
- Different types of extrusion types and printing strategies
- Allows for deposition of different inks into the same form
- Dissolution can be controlled with ink types (doseage, concentration, wrapper forms)

Coaxial needle for simultaneous dual extrusion



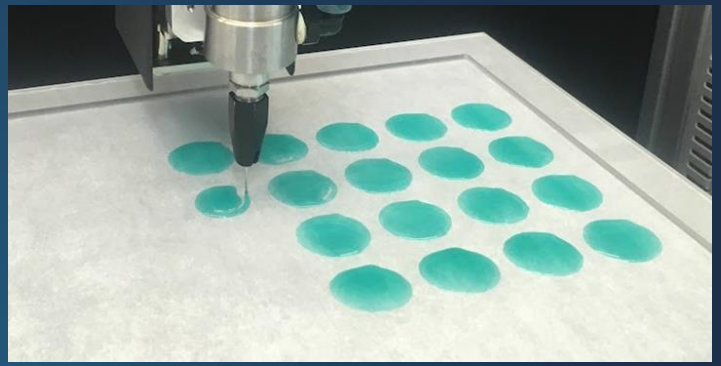
Examples of extrusion type 3D printing

Technology

Goals of the project

Demonstrate the 3D printing in an experimental printing setup capable of printing gel-type inks.

Ensure precise dosing of different A(P)Is already with mass dispersion of not more than 3%.

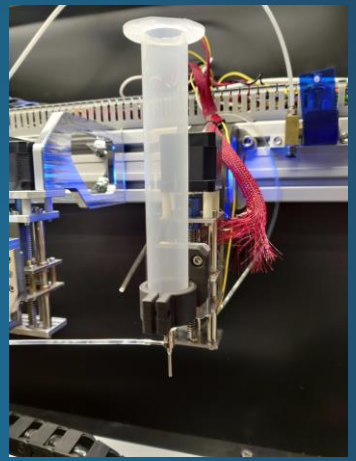


Sublingual printlets

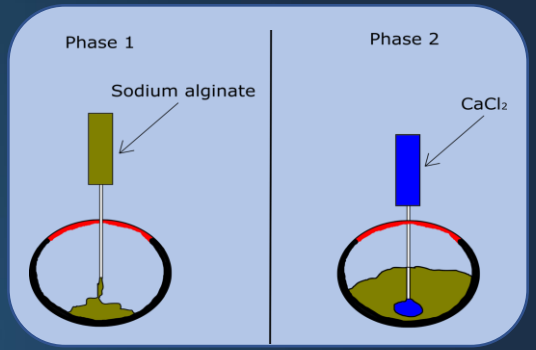
Current 3D printing setup

Project 3DMedLowG

– Personalized medicine / food supplements
– Focus on precise ingredient dosing
(not on shape, although can be templated)
– Easy mixing procedures
– Simple delivery systems
– Manageable dosing and gelation systems
– Long stability of nutrient content
– Minimum spoilage hazard
– Simple and efficient cleaning/maintenance



Printing nozzle inside the machine



Extrusion steps for the gelation of Na-alginate

Alginate hydrogels after gelation

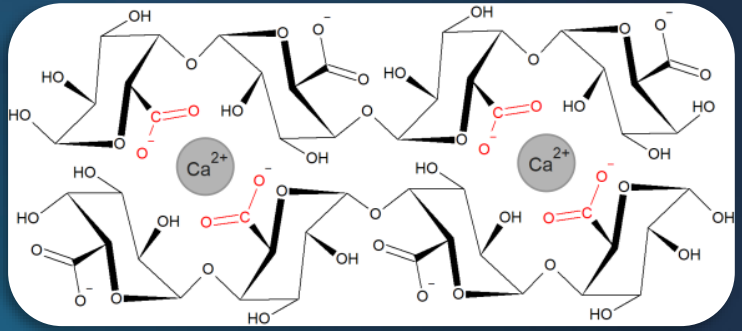
Gelation agent

Alginate-based ink

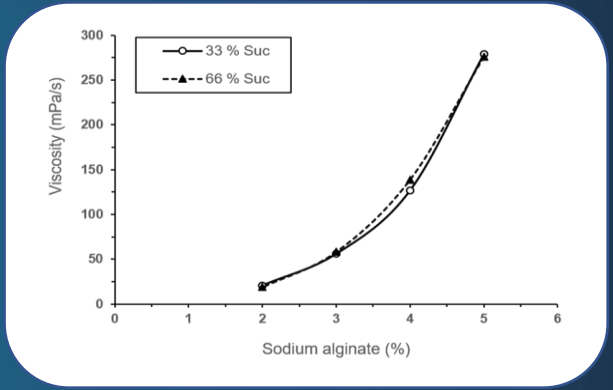
- Good stability in powdered and gel form
- Good encapsulation properties for gut delivery
- Vegan acceptable

Recipe takes in account:

- Fast ion induced gelation (Ca^{2+})
- Fast solubility/hydration period in cold water
  (minutes at no/minimal mixing instead hours at intensive agitation)
- Versatile entrappment
  (also hydrophobic instead of only hydrophillic)
- All materials EFSA and FDA approved for food consumption



Gelation principle of Na - alginate

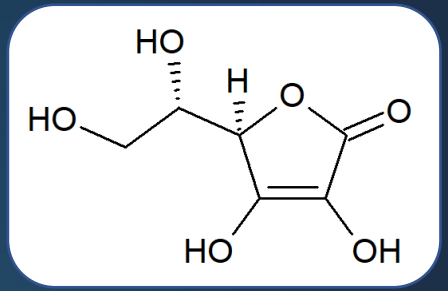


Viscosity of rapidly dissolving alginate matrix

Supplements

Vitamin C

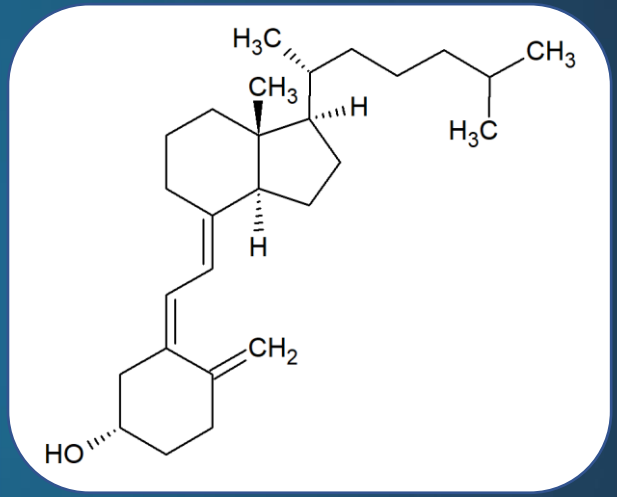
- POC model compound (extrusion, cross-linking, dosing)
- One of the essential vitamins, only obtainable by ingestion
- Perfect water solubility
- Low stability in aqueous systems, good stability in powdered forms
- Different vitamers available



Ascorbic acid (vitamin C)

Other vitamins (vitamin D, K, E, …)

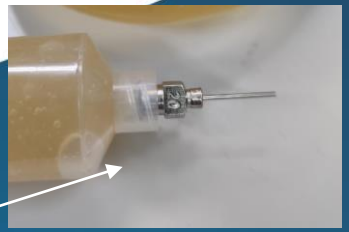
- Further work
- Low water solubility
- Mixing doses

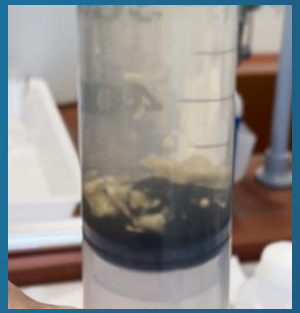


Vitamin D

Challenges

- Extrusion technique
- Printing nozzle
- Hydrocolloid and gelation type
- Stability of the extruded system
- Cleaning
- Mixing procedure
- Minimizing waste output
- Microbiological spoilage
  (none for fresh gels)





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THANK YOU.

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