

Adapting the curdling process of cheese for 3D printing of protein-fortified milk.

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Milk proteins in 3D food printing (3DFP)



Milk proteins can form self-standing structured foods (i.e., cheese) under specific conditions



Milk protein powders are good sources of milk proteins. Therefore, they are **potential materials for 3D food printing.**

Milk protein functionalities

Gelation

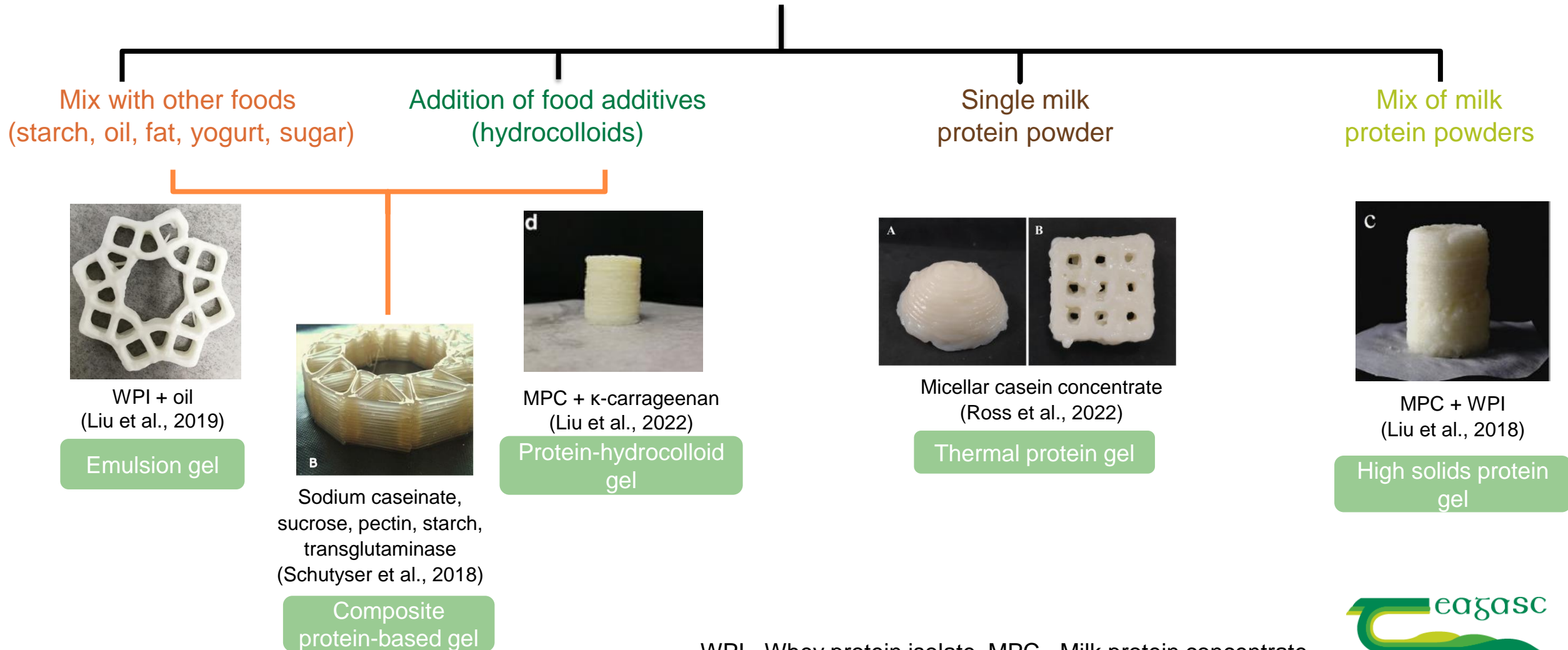
Thickening

Emulsification



Milk protein powders in 3DFP

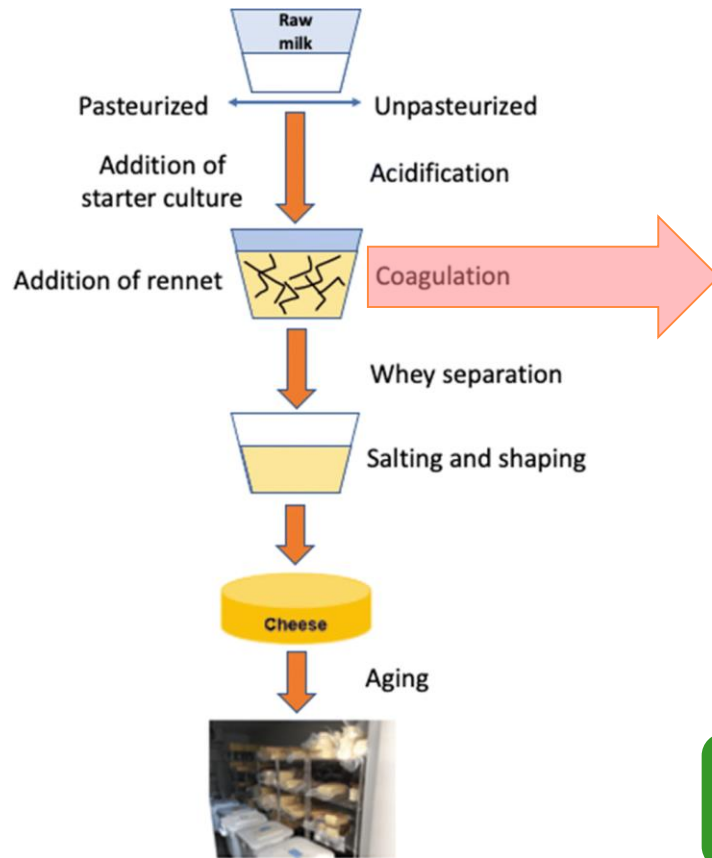
Common approaches for using milk protein powders in extrusion-based 3D printing



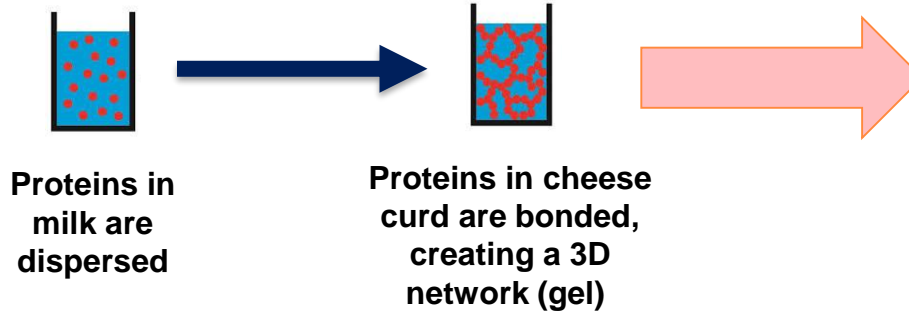
WPI= Whey protein isolate, MPC= Milk protein concentrate

Rennet gelation in cheese making

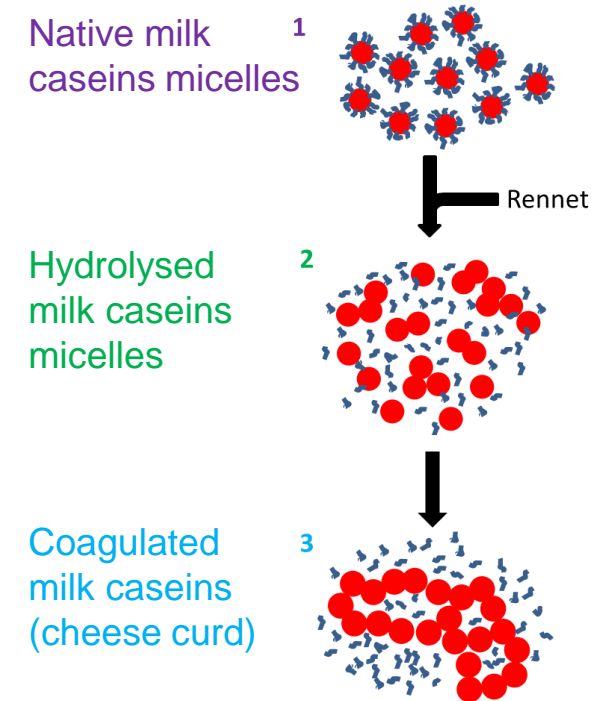
Cheese making steps



Curd formation



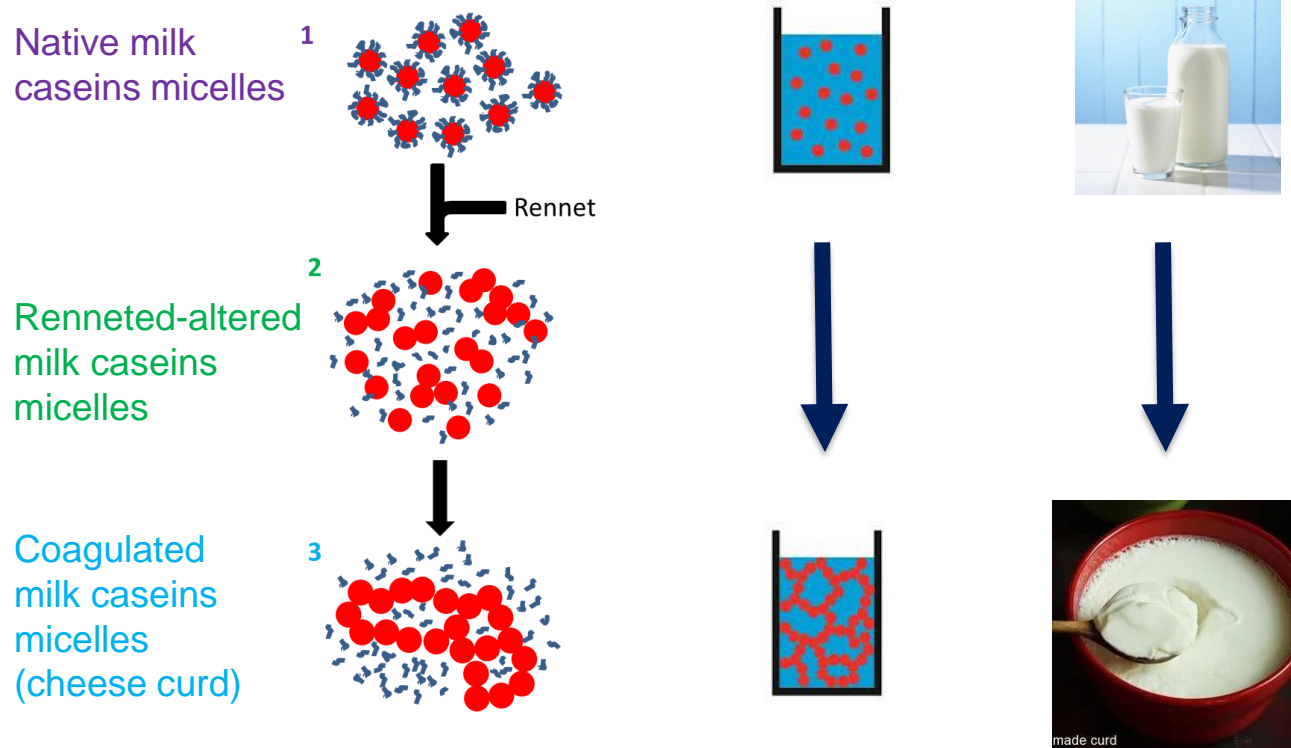
Rennet gelation steps



Rennet gelation is a potential method to produce structured 3D printed dairy products

Objective

Adapt rennet gelation (from the curdling process of cheese-making) to produce 3D printed dairy snacks



Challenge

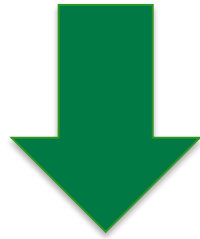
Adapt conditions to extrusion-based 3D food printing

1. **Behave as a liquid** to allow extrusion
2. **Behave as a solid** after deposition
3. **Binding mechanism** to fuse layers

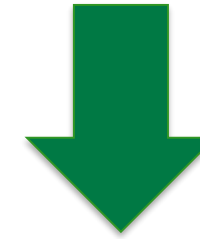


Approach

- Development of a printable dairy formulation
- Determine suitable 3D printing parameters and conditions

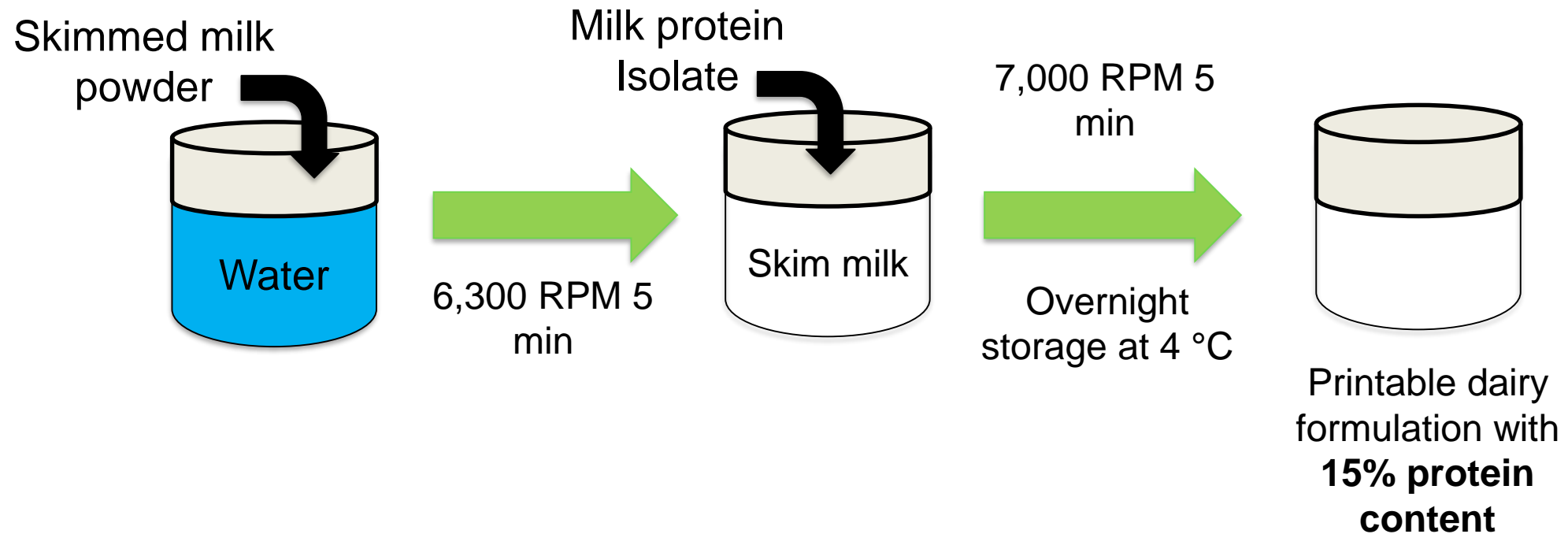


Obtain a "cheese curd" (milk gel) with self-standing capability



Control the rennet gelation process using 3D printing

Preparation of a dairy printable formulation



Evaluation of rennet gelation properties

Rheological evaluation

Factors:

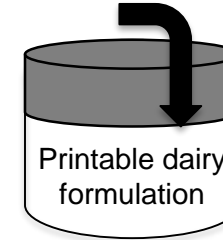
- Temperature (31 & 40 °C)
- pH (6.4 & 6.0)
- [Ca²⁺] (1.5mM & 5.7mM)

Parameters:

- Strength of the final gel (G')
- Maximum gelation rate ($\Delta G'/\Delta t$)
- Time to maximum gelation rate ($t_{\Delta G'/\Delta t}$)

Strain= 0.025 & Frequency=1 Hz

Rennet
(15 IMCU / 100g)

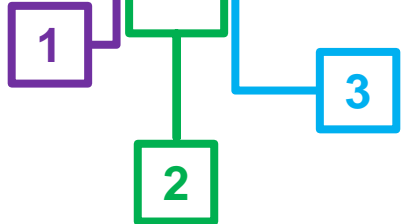
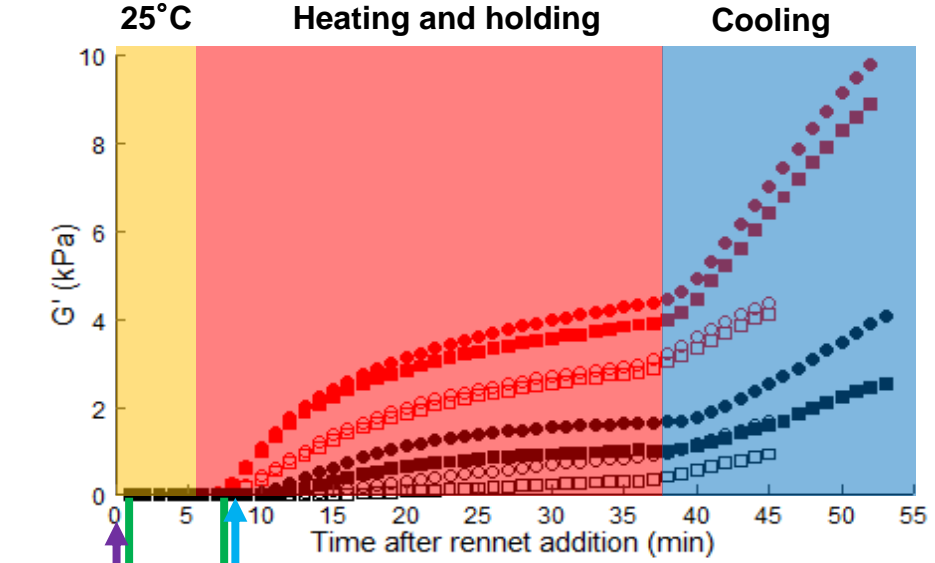
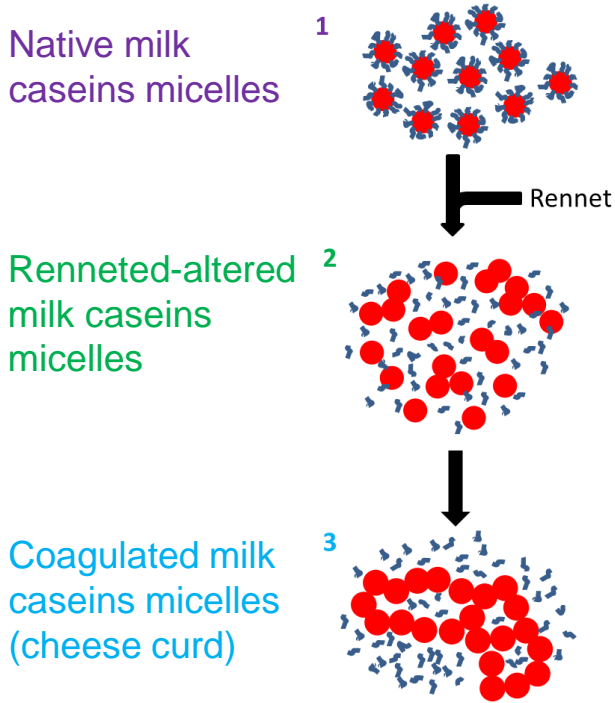


Three stages:

- Start at 25°C and hold for 2 min.
- Heat to 31 or 40 °C at a rate of 5°C min⁻¹, hold at for 30 min.
- Cool to 15°C at a rate of 1.8°C min⁻¹.

Simulate temperature profile during 3D printing process

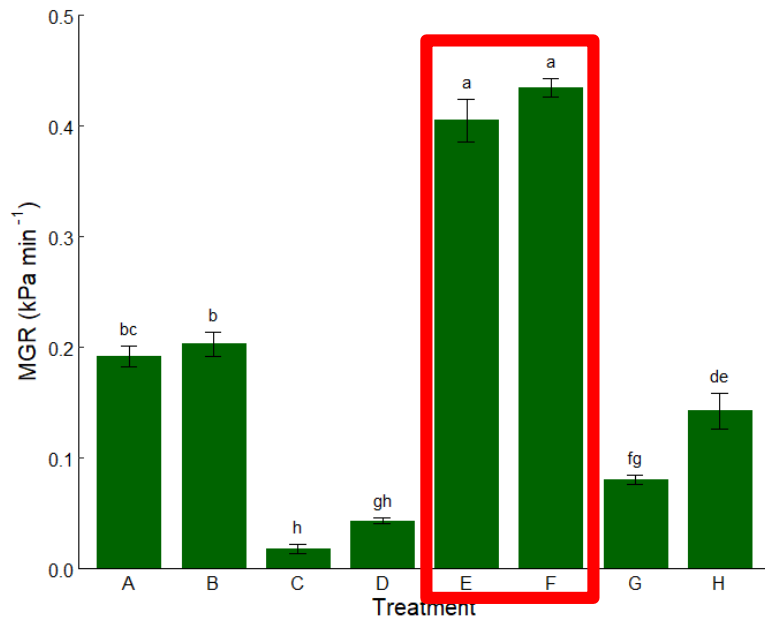
Determining ideal conditions for 3DFP



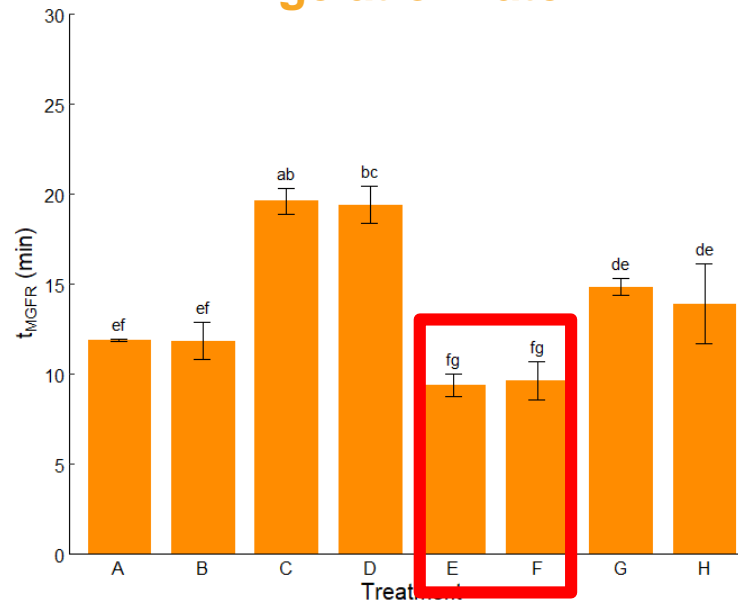
	□	○	□	○	■	●	■	●
Temperature	31°C	31°C	31°C	31°C	40°C	40°C	40°C	40°C
pH	6.00	6.00	6.40	6.40	6.00	6.00	6.40	6.40
[Ca ²⁺]	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM

Determining ideal conditions for 3DFP

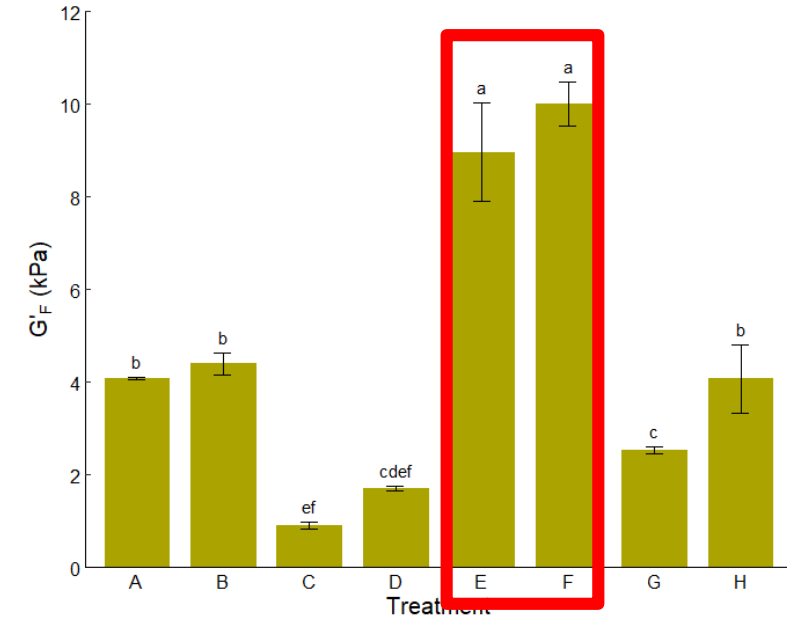
Maximum gelation rate



Time to maximum gelation rate



Gel strength




Treatment	A	B	C	D	E	F	G	H
Temperature	31°C	31°C	31°C	31°C	40°C	40°C	40°C	40°C
pH	6.00	6.00	6.40	6.40	6.00	6.00	6.40	6.40
[Ca ²⁺]	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM

- Fastest gel rate
- Firmer gel



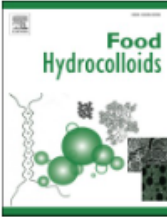
Determining ideal conditions for 3DFP



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Evaluation of rennet-induced gelation under different conditions as a potential method for 3D food printing of dairy-based high-protein formulations



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Treatment	A	B	C	D	E	F	G	H
Temperature	31°C	31°C	31°C	31°C	40°C	40°C	40°C	40°C
pH	6.00	6.00	6.40	6.40	6.00	6.00	6.40	6.40
[Ca ²⁺]	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM	1.5mM	5.7mM

- Fastest gel rate
- Firmer gel

Adaptation of rennet gelation for 3DFP

- This content is soon to be published.

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**MTU Department of Manufacturing,
Biomedical and Facilities Engineering**

Thank You!



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