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Non-reactive sponge cake formulated with starch and cellulose derivatives: effect of process to design various cellular crumb structures

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Context: improvement of nutritional and organoleptic quality of cereal products by determining the different pathways of Maillard and caramelization reactions

Strategy :

1st step

- Development of a **realistic non-reactive model sponge cake** (solid + cellular structure) **replacing the reactive species** by non-reactive one having **the same functional properties**
- Check of the model sponge cake non-reactivity

2nd step

- Introduction of reactant species one by one (glucose, fructose, amino acids,...)
- Exploration of the range of cellular structure variations **playing on composition and process parameters**



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1. **Functional properties of cellulose derivatives and their effects on the model sponge cake cellular structure through the process**
2. **Effect of starch mixing time on sponge cake cellular structure**

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Functional properties to mimic :

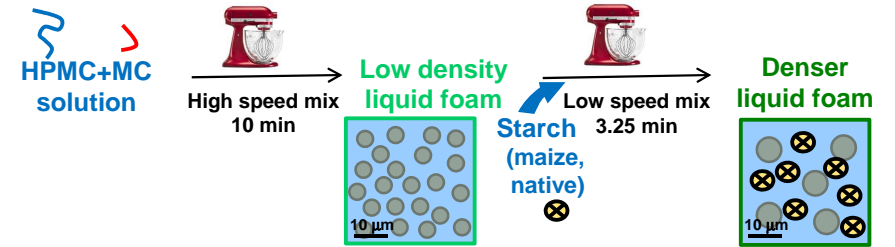
- thickening at room temperature,
- gelling upon heating,
- foaming.

=> Cellulose derivatives were good candidates

		Intrinsic viscosity (dL/g)	Gelation temperature (°C)	Air/water surface tension at equil. (mN/m) at 0.05 g/L
HPMC		10.1	~80 °C Weak gel	47.1 ± 0.1
MC		4.3	~40 °C Strong gel	50.7 ± 0.1

Same process as the reference sponge cake

From ingredients to liquid aerated batter (foam)



From liquid foam to cellular solid

Liquid foam $\xrightarrow[170\text{ °C, 30 min}]{\text{Baking}}$ cellular solid = Model sponge cake



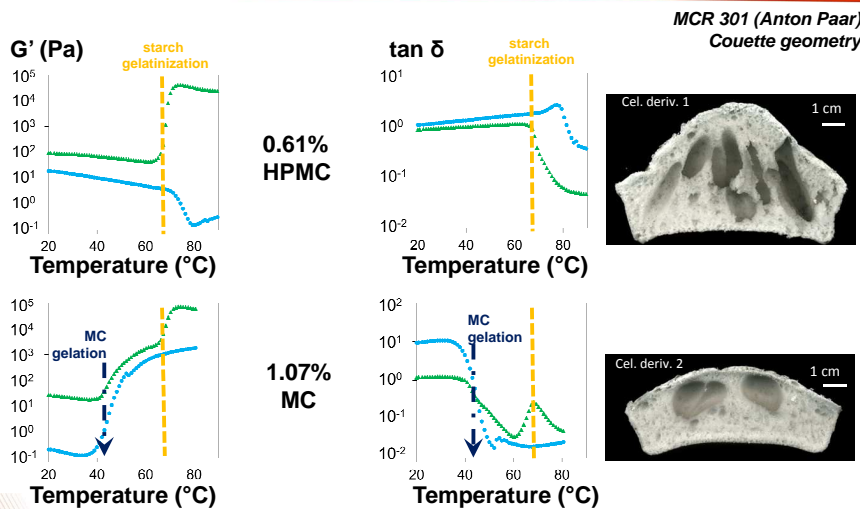
Reference sponge cake

$$\rho_{\text{cake}} = 284 \text{ kg/m}^3$$

$$\eta_{\text{batter}} = 1.4 \text{ Pa}\cdot\text{s at } 270 \text{ s}^{-1}$$



Gelling properties of HPMC and MC

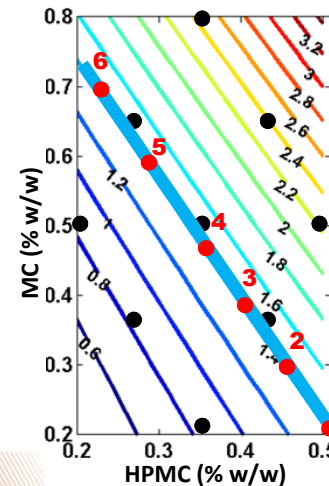


HPMC or MC solutions (●) (HPMC or MC) + starch batter (▲)

1 rad/s, 2 °C/min ; γ_0 HPMC+MC = 3% ; γ_0 HPMC+MC+starch = 0.2%

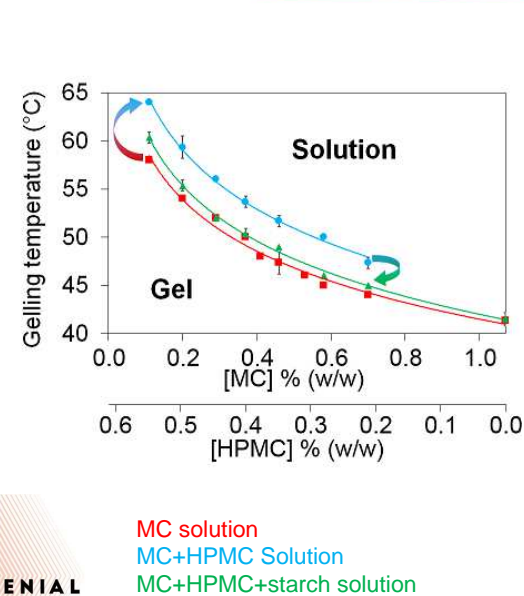
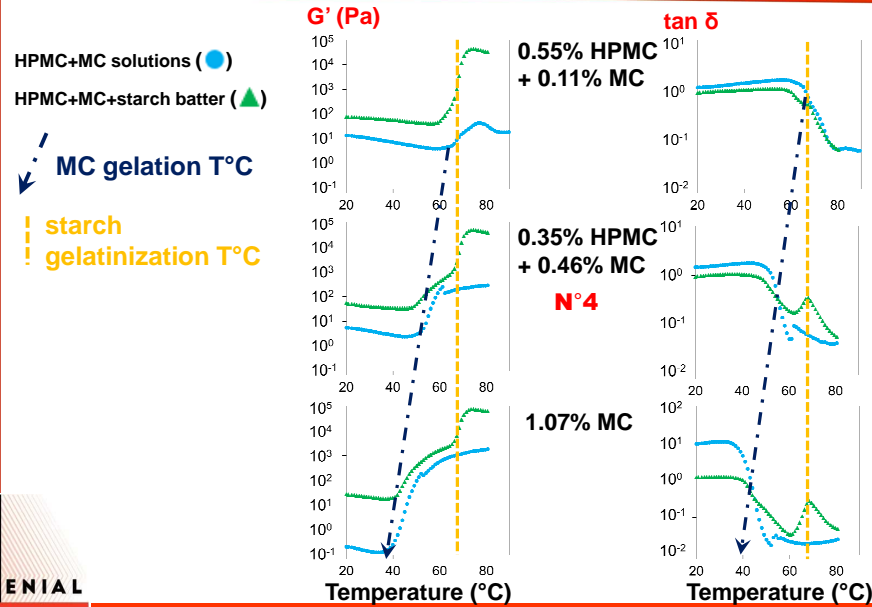
HPMC and MC concentrations

Central composite experimental design & response surface analysis



iso-viscosity curve (1.4 Pa.s at 270s⁻¹) $[MC] = -1.74[HPMC] + 1.07$

Bousqières et al. Gums and stabilisers, 2015; Submitted to Food Hydrocolloids



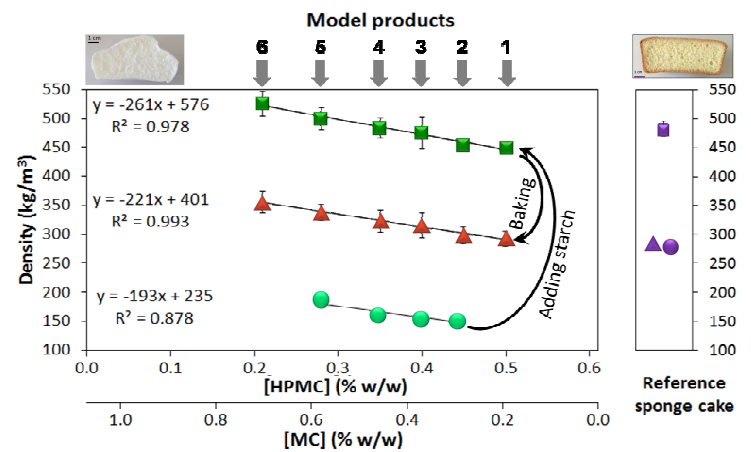
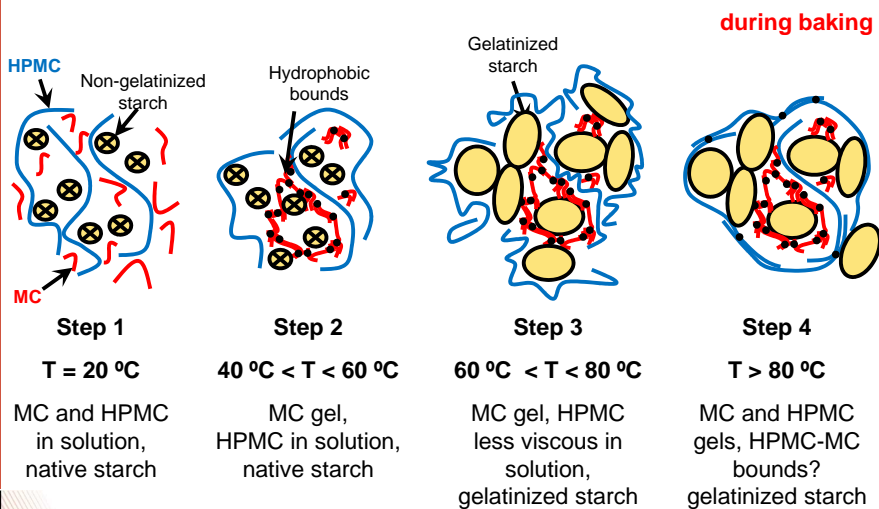
Shift of gelling T to higher values by addition of HPMC

→ MC manage the gelling of the system

→ HPMC hinders the MC gel formation

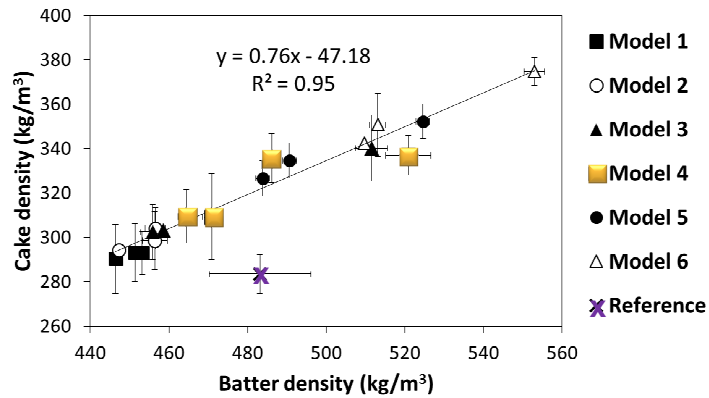
Shift of gelling T to lower values by addition of starch

→ Concentration effect due to water absorption by starch



[HPMC] ↗ → density ↘

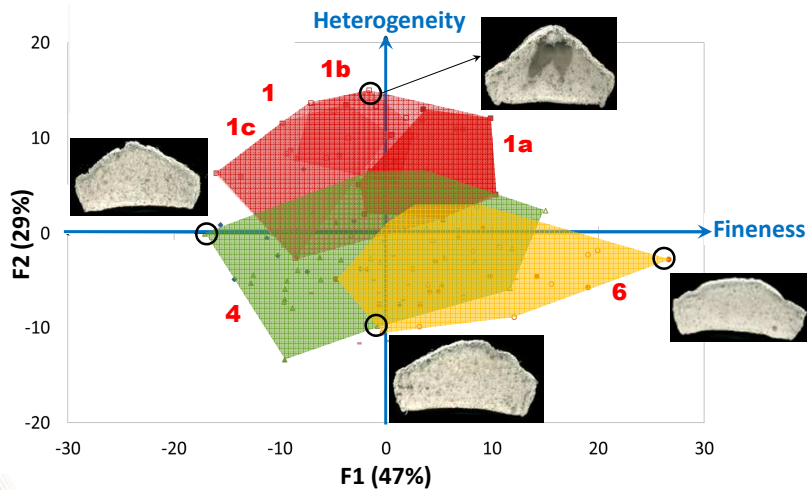
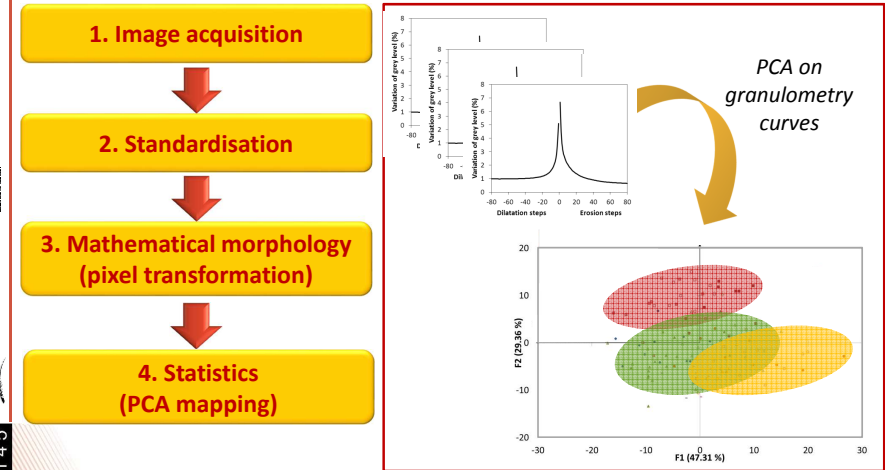
... in our process conditions



4 repetitions of model 4 => different batter density with different model sponge cake density but keeping the proportion of air loss

What about the resulting cellular structure ????

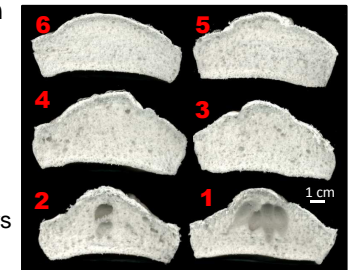
Image processing for crumb structure classification



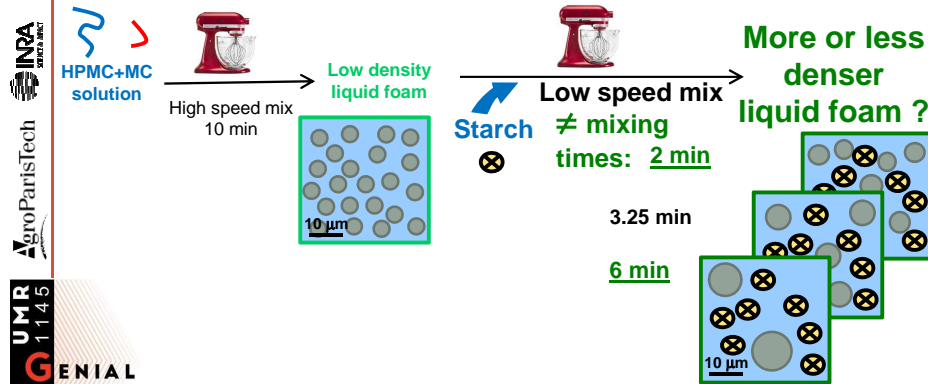
Recipe 1 cellular structure variations
=> not-standardized enough addition of starch?

Functional properties of HPMC and MC in the model sponge cake

- **MC** governs the **gelling properties**
- **HPMC**
 - Governs the **air incorporation** in batter and in sponge cake
 - Increases the gelation temperature (hinders the MC gel formation)
- **Starch**
 - Decreases the gelation temperature (↗ [MC] by small absorption of water even in native form)
 - Absorbs a lot of water at the gelatinization temperature (↗ [HPMC] and [MC] all around)
 - Plays a **major role in the air loss during bater formation and on bubble size**



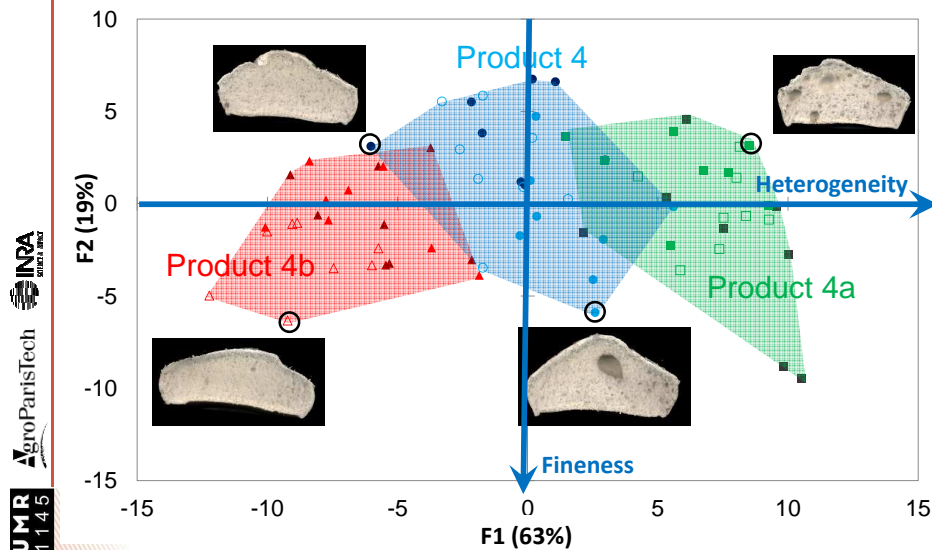
1. Functional properties of cellulose derivatives and their effects on the sponge cake cellular structure through the process
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Camille Michon - 13th International Hydrocolloids Conference - Guelph, Canada - 05/19/2016

2. Starch mixing time and sponge cake cellular structure

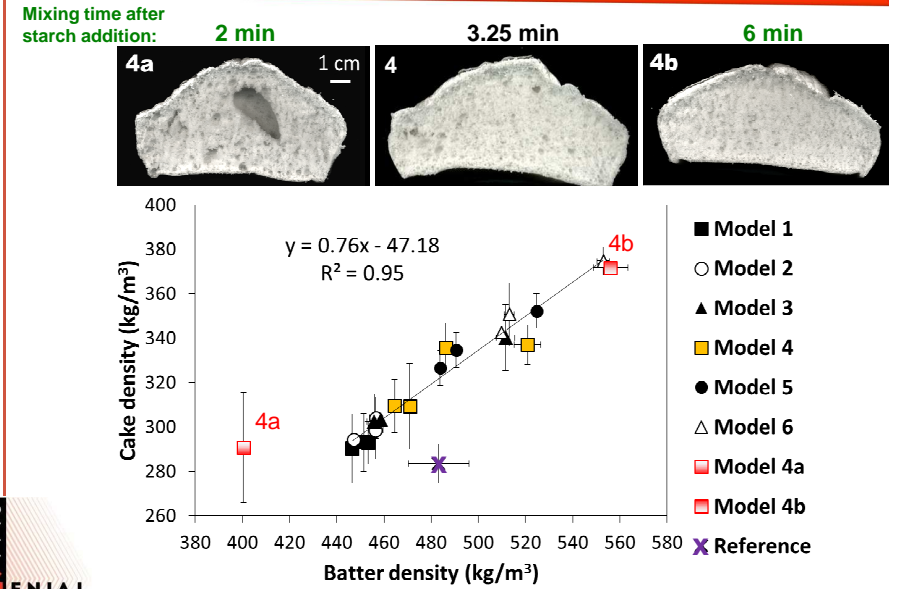
Structure analysis



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2. Starch mixing time and sponge cake cellular structure

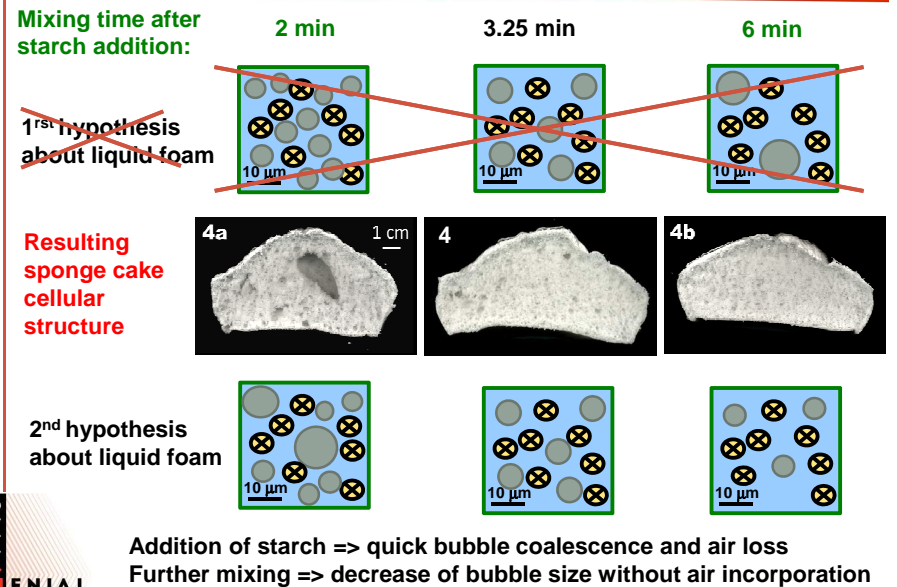
The batter density governs the cake density only in a given range...!



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2. Starch mixing time and sponge cake cellular structure

Conclusion 2



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- ❑ **A lovely model sponge cake was designed**
 - ✓ NON-reactive=> useful for Maillard and caramelization reaction studies
 - ✓ Cellular structure mimicking real sponge one
 - ✓ Rational design based on functional properties of HPMC, MC and starch
 - ✓ Functional properties used at different step of the process
 - illustration through MC gelling and starch gelatinization versus [HPMC]/[MC]
- ❑ **A complex model system to play with to create a great variety of cellular structures and properties**
 - ✓ Formulation
 - Changing starch botanical source => rice is a catastrophe !! But modified maize starch is OK
 - Addition of saccharose
 - ✓ Process
 - 1st step mixing: foaming time, speed, rest time before starch addition
 - 2nd step of mixing : mixing time, speed, starch addition
 - Baking : moisture in the oven, temperature
- ❑ **A model sponge cake useful for further understanding**
 - ✓ Water repartition evolution during the process – Starch contribution
 - ✓ Solid foam texture : link between structure and mechanical properties. Evolution of starch, variety of starch swelling, contribution of damaged starch,...

Work founded by
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