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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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2nd step

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Functional properties to mimic :

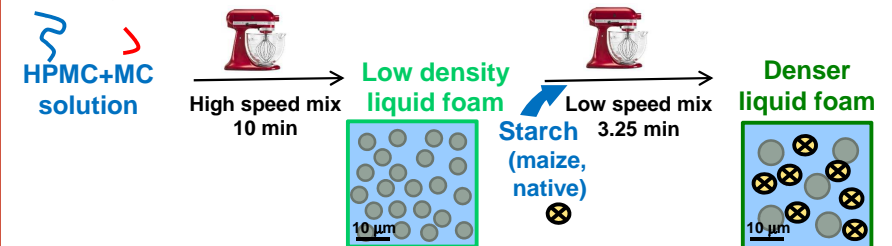
- thickening at room temperature,
- gelling upon heating,
- foaming.

=> 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



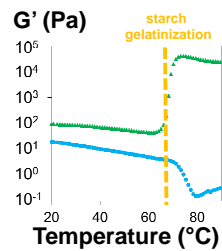
Reference sponge cake

$\rho_{\text{cake}} = 284\text{ kg/m}^3$
 $\eta_{\text{batter}} = 1.4\text{ Pa.s at } 270\text{ s}^{-1}$

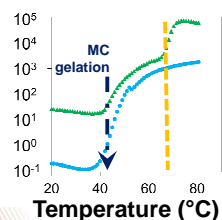
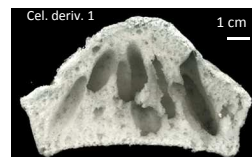
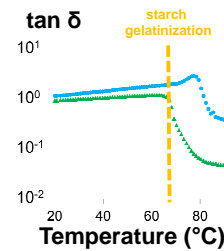


Gelling properties of HPMC and MC

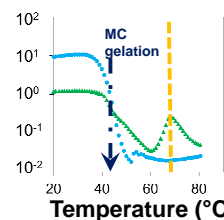
MCR 301 (Anton Paar)
Couette geometry



0.61%
HPMC



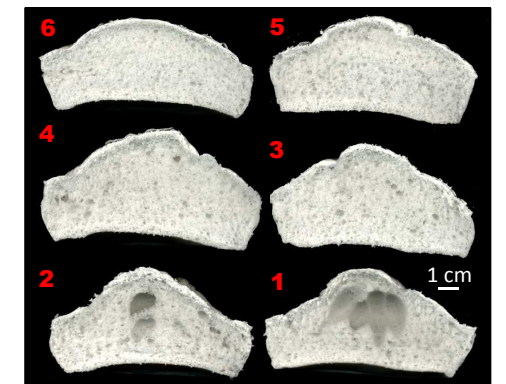
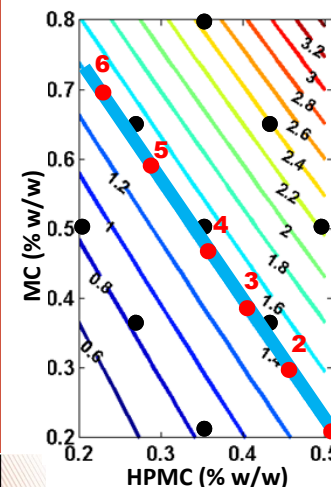
1.07%
MC



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%

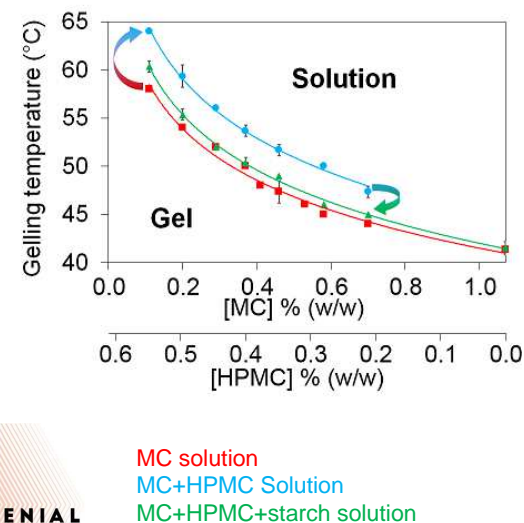
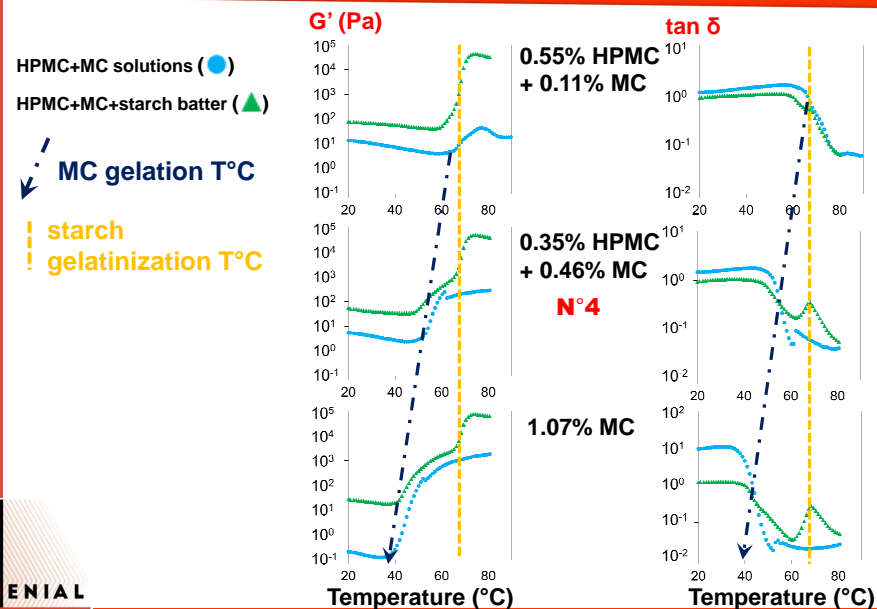
HPMC and MC concentrations

Central composite experimental design & response surface analysis



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

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



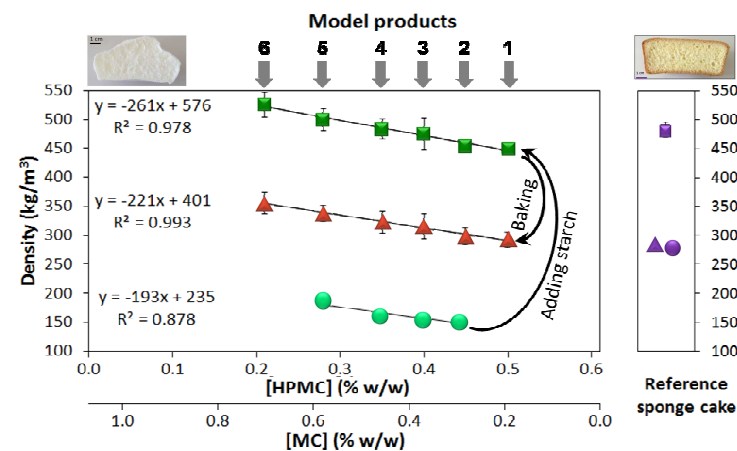
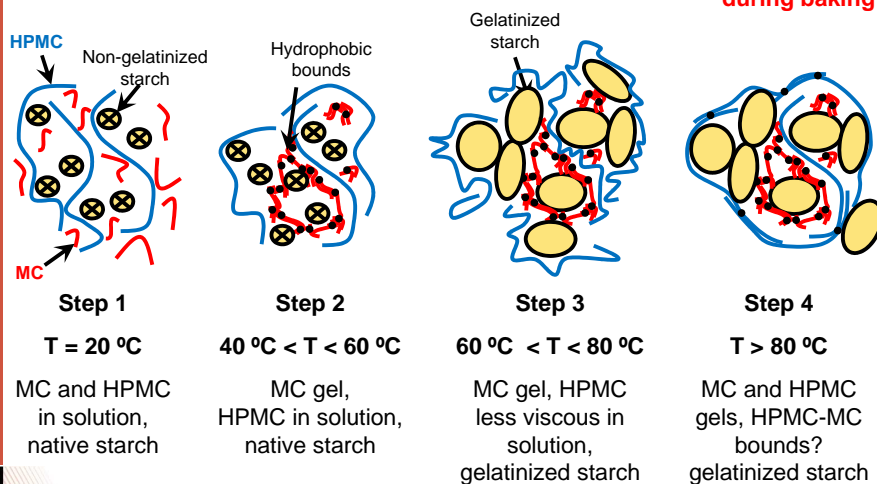
Shift of gelling T to higher values by addition of HPMC

→ MC manage the gelling of the system

→ HPMC hinders the MC gel formation

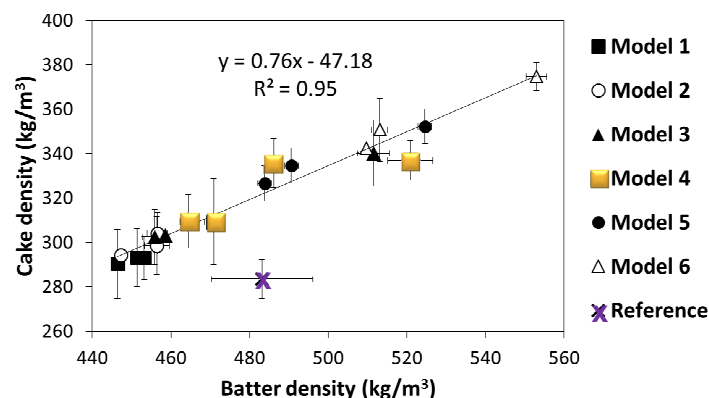
Shift of gelling T to lower values by addition of starch

→ Concentration effect due to water absorption by starch



[HPMC] ↑ → density ↓

... in our process conditions



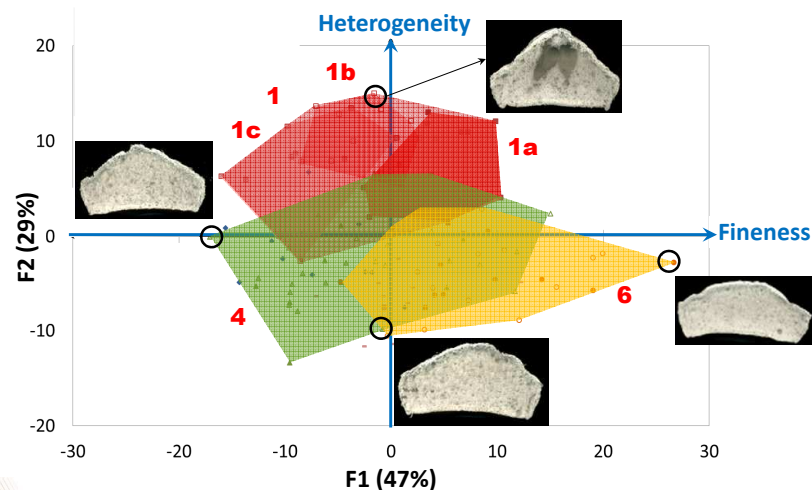
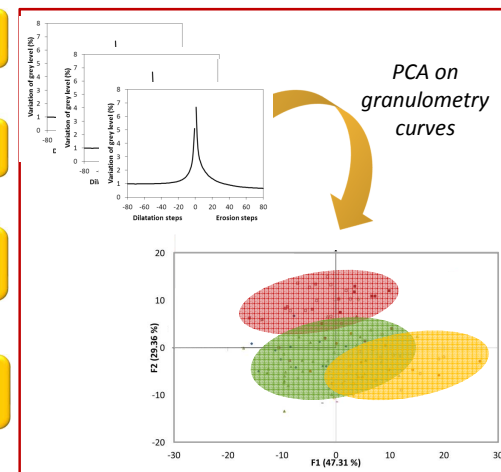
4 repetitions of model 4 => different batter density with different model sponge cake density but keeping the proportion of air loss

What about the resulting cellular structure ????

Image processing for crumb structure classification

1. Image acquisition

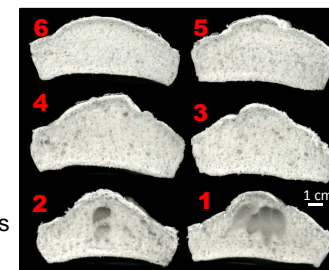
2. Standardisation

3. Mathematical morphology
(pixel transformation)4. Statistics
(PCA mapping)

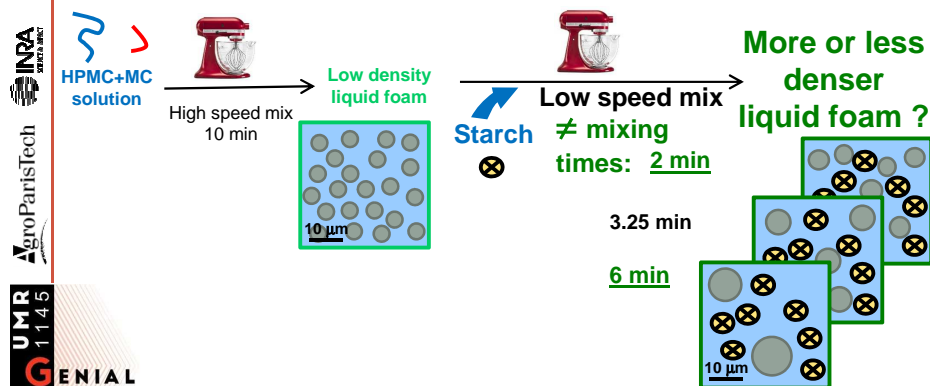
Recipe 1 cellular structure variations
=> not-standardized enough addition of starch?

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 batter formation and on bubble size



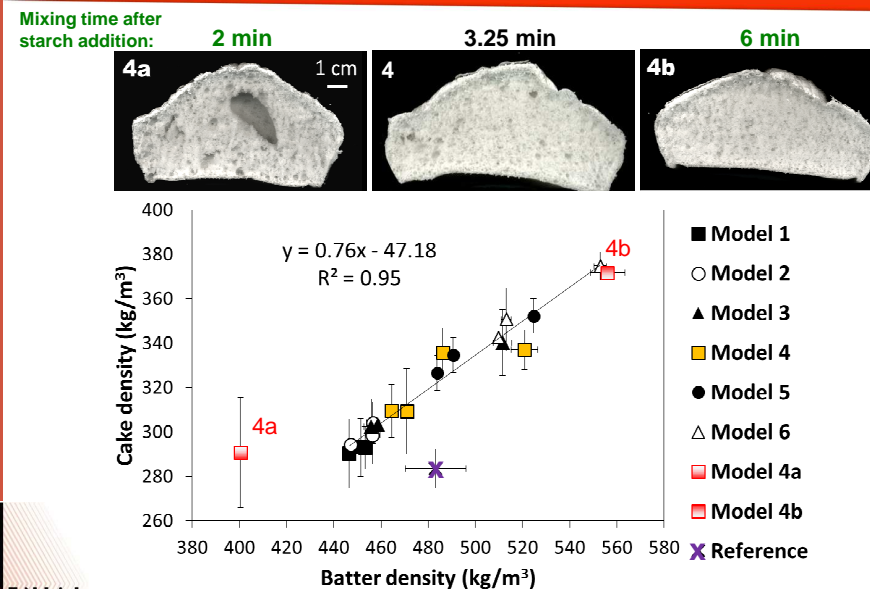
1. Functional properties of cellulose derivatives and their effects on the sponge cake cellular structure through the process
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2. Starch mixing time and sponge cake cellular structure

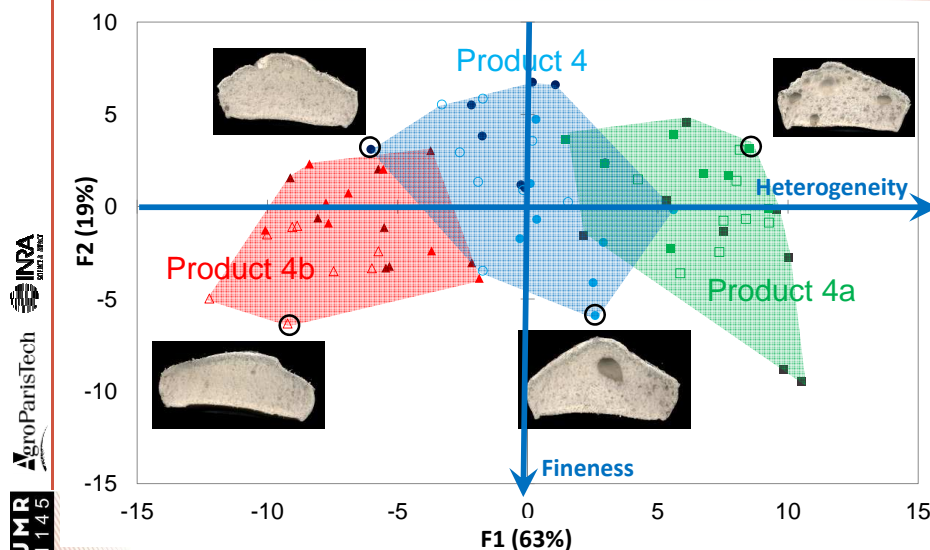
The batter density governs the cake density only in a given range...!



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2. Starch mixing time and sponge cake cellular structure

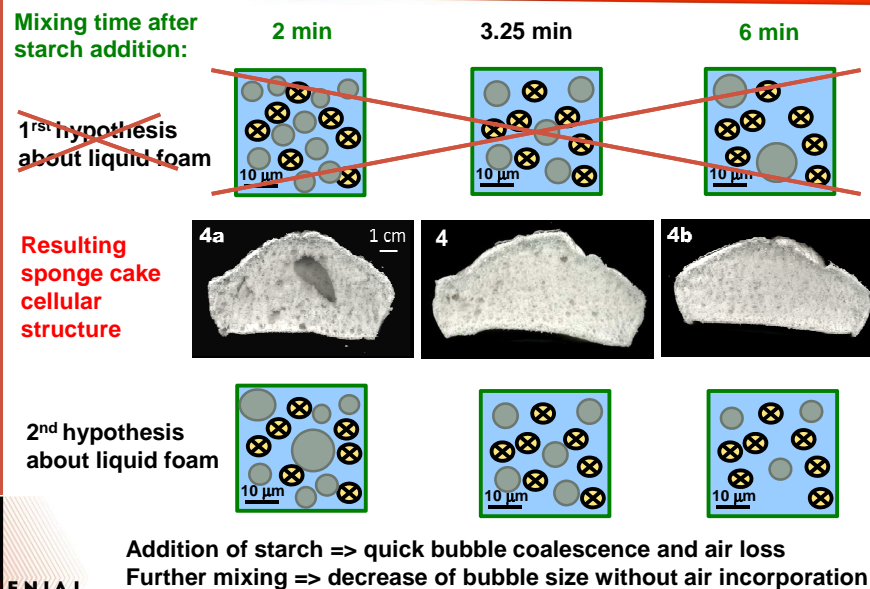
Structure analysis



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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
Région Ile-de-France



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Massy, France

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