L'huile ne rentre pas en cours de friture !!!

Réduire les matières grasses dans les produits frits

Olivier Vitrac, Maxime Touffet

UMR 1145 GENIAL, I2MC, AgroParisTech site de Massy

olivier.vitrac@agroparistech.fr

1994

Carrefours de l'Innovation Agronomique

Améliorer la qualité nutritionnelle des aliments

5 novembre 2019 | Espace IRIS | Paris

AgroParisTech

INRA SCIENCE & IMPACT

L'histoire rapidement racontée de la friture

Keros-Syros Culture
2800-2300 BC

The Prehistoric Collection> ΕΑΜΠ4974

Friture plate

1775

CAUSES
CÉLEBRES,
CURIEUSES ET INTÉRESSANTES
DE TOUTES LES COURS
SOUVERAINES DU ROYAUME;
AVEC LES JUGEMENS

CÉLEBRES. 81

verbal même que nous allons copier.

« Après avoir fait lever les scellés en présence de tous les susnommés, nous avons trouvé, dans la cassette, une écuelle, dans laquelle il y avoit de la soupe, & deux plats d'étain, dans l'un desquels étoient des haricots fricassés, dans l'autre quelques morceaux de pommes de terre frites; & attendu que lesdits sieurs Girardet & la Boulaye sont ici présens, nous avons pris & reçu leur serment sur

Pommes de terre frites

1898

HISTOIRE
DE
LA POMME DE TERRE
TRAITÉE AUX POINTS DE VUE
HISTORIQUE, BIOLOGIQUE, PATHOLOGIQUE,
CULTURAL ET UTILITAIRE
PAR
Ernest ROZE

En général, on peut dire que sans les *Pommes de terre*, on auroit vu périr de faim dans toute l'Allemagne, dans les pays du Nord, en Suisse, etc., des cent mille personnes, peut-être des millions, vu la disette extrême des bleds qu'on ne pouvoit pas se procurer en quantité nécessaire, même pour de l'argent : chacun demandoit du pain, on n'en avoit pas et les *Pommes de terre* y suppléerent...

» En Allemagne, on se sert des *Pommes de terre* pour toute espèce d'animaux, chevaux, brebis, chèvres, cochons, volailles, les poissons même et les écrevisses s'en engraissent dans les réservoirs... Le commun du peuple les mange simplement bouillies à l'eau avec du sel, ou cuites au lait qui font une nourriture agréable aux personnes de condition même ; grillées, frites au beurre, en beignets et de tant d'autres manières... »

Pommes de terre = nourriture unique du "peuple"

L'histoire rapidement racontée de la friture

1867


REPORTS

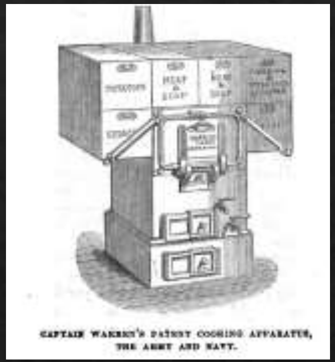
ON THE

PARIS UNIVERSAL EXHIBITION,

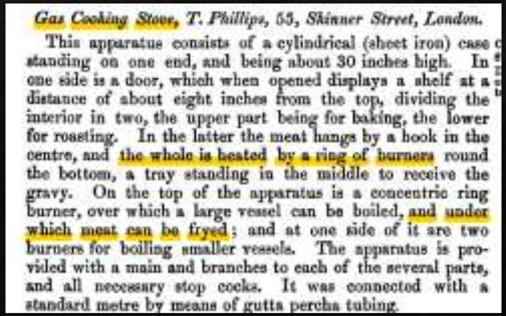
1867.

VOL. IV.

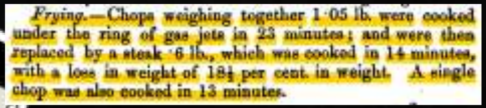
CONTAINING REPORTS ON



Friteuse chauffée par brûleur à gaz


Gas Cooking Stove, T. Phillips, 55, Skinner Street, London.

This apparatus consists of a cylindrical (sheet iron) case standing on one end, and being about 30 inches high. In one side is a door, which when opened displays a shelf at a distance of about eight inches from the top, dividing the interior in two, the upper part being for baking, the lower for roasting. In the latter the meat hangs by a hook in the centre, and the whole is heated by a ring of burners round the bottom, a tray standing in the middle to receive the gravy. On the top of the apparatus is a concentric ring burner, over which a large vessel can be boiled, and under which meat can be fryed; and at one side of it are two burners for boiling smaller vessels. The apparatus is provided with a main and branches to each of the several parts, and all necessary stop cocks. It was connected with a standard metre by means of gutta percha tubing.


Frying.—Chops weighing together 1·05 lb. were cooked under the ring of gas jets in 23 minutes; and were then replaced by a steak 6 lb., which was cooked in 14 minutes, with a loss in weight of 18½ per cent. in weight. A single chop was also cooked in 13 minutes.

1929

Friteuse continue “tunnel”

Freeman McBeth, J.D. Ferry Co.

1930-1945

Espace de stockage des pommes de terre

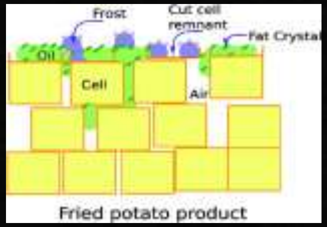
L'histoire rapidement racontée de la friture

1955

Fast Food

1960-aujourd'hui

Pommes de terre préfrites congelées



Credit Ruud-van-der Sman

1967

Friteuse électrique "fermée"

Projet Fry'In (2014-2018) : produits frits plus sains

Moins oxydé, moins d'odeur, matières grasses plus insaturées

Réduction de la valeur nutritionnelle
Scission: composés volatiles, odeurs, composés cytotoxiques
Polymérisation: encrassement
Cyclisation: composés toxiques

Table 1–Moisture and oil content of frozen par-fried French fries, finish-fried in palm olein.

Sample	Moisture content (%)	Oil content: Notation (%, fat-free dry basis)	Oil content: Value (%, fat-free dry basis)	Oil content: % based on the mass of French fries
Initial par-fried material	61.61 ± 0.87[a]	$(X_{pp})_i$	28.50 ± 1.69[a]	8.51 ± 0.90
Finish-fried product[1]	31.85 ± 2.87[b]	$(X_f)_1$	51.66 ± 1.04[b]	23.21 ± 0.87
Finish-fried product[2]	49.93 ± 0.79[c]	$(X_f)_2$	40.17 ± 0.81[c]	14.35 ± 0.55

[1]French fries fried for 3 min at 185 °C in palm olein.
[2]French fries fried for 0.5 min at 185 °C in palm olein.

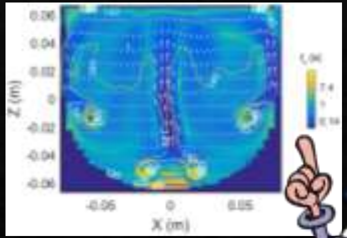
From: J. Food Sci. **2012** 71(1),E32-E36

Echange d'huile, moins gras

L'huile de préfriture est perdue lors de l'étape de reconstitution

*La teneur en matière grasse peu varier de **4 % (w/w) à 25% (w/w)** pour des frites précongelées suivant la technologie utilisée*

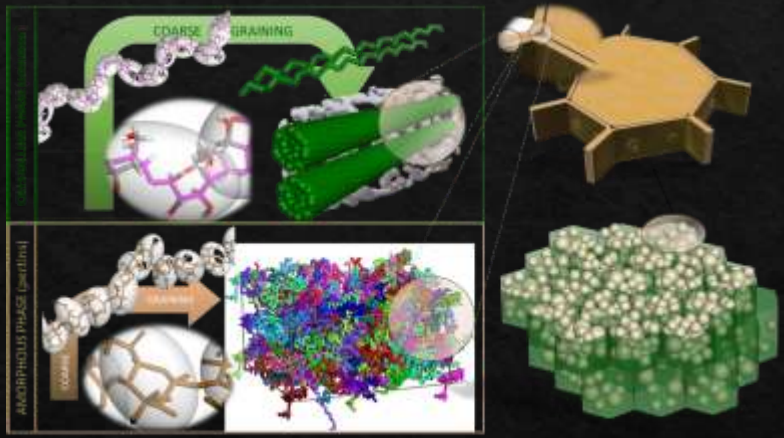
Procédés de friture réinventés

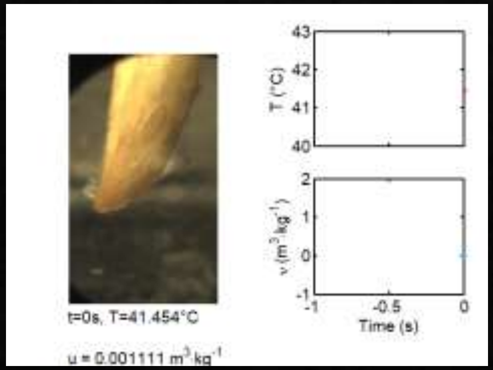


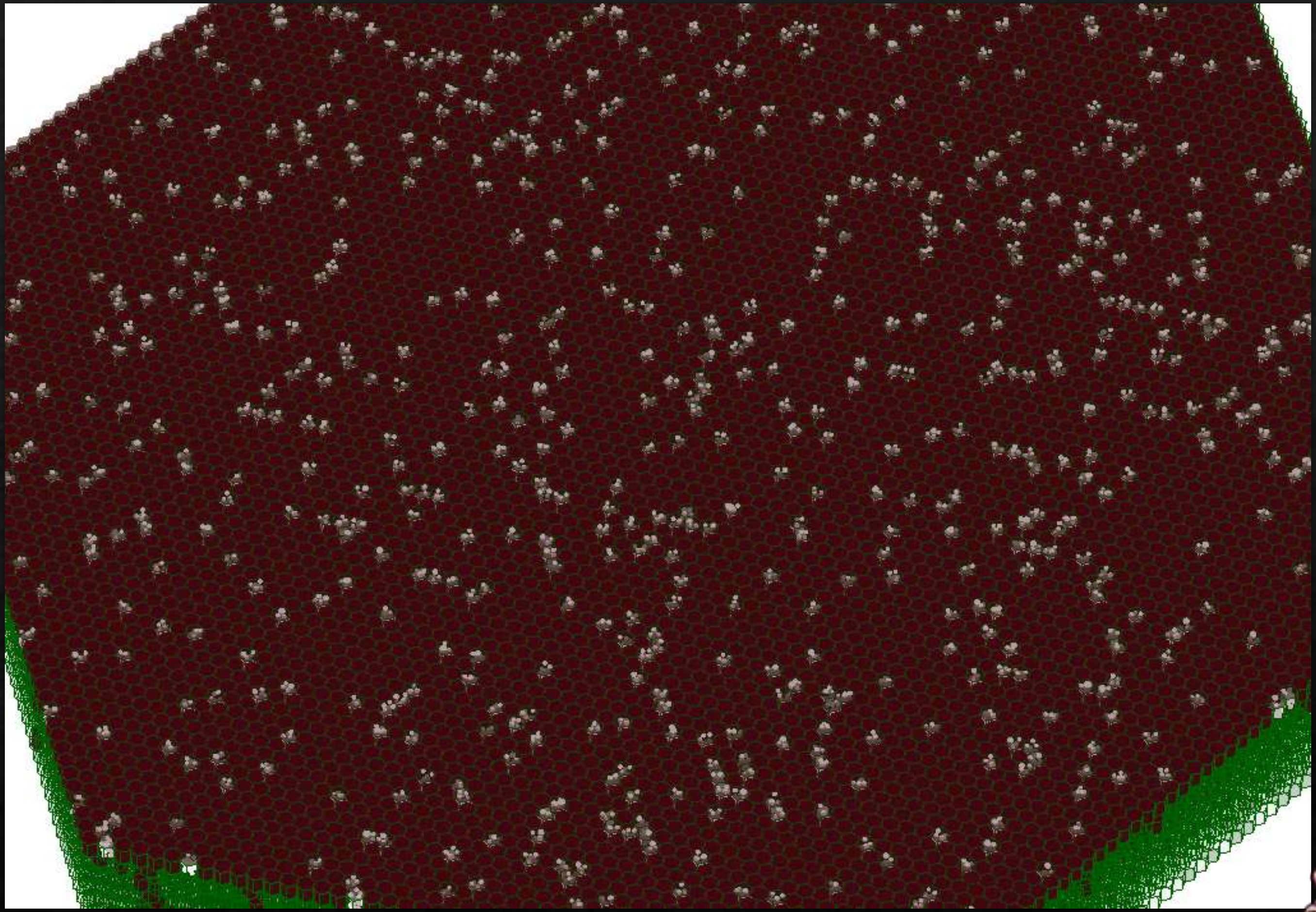
Ajout de nouvelles fonctions à l'opération de friture dont « oil shield »

La friture au XXIe siècle

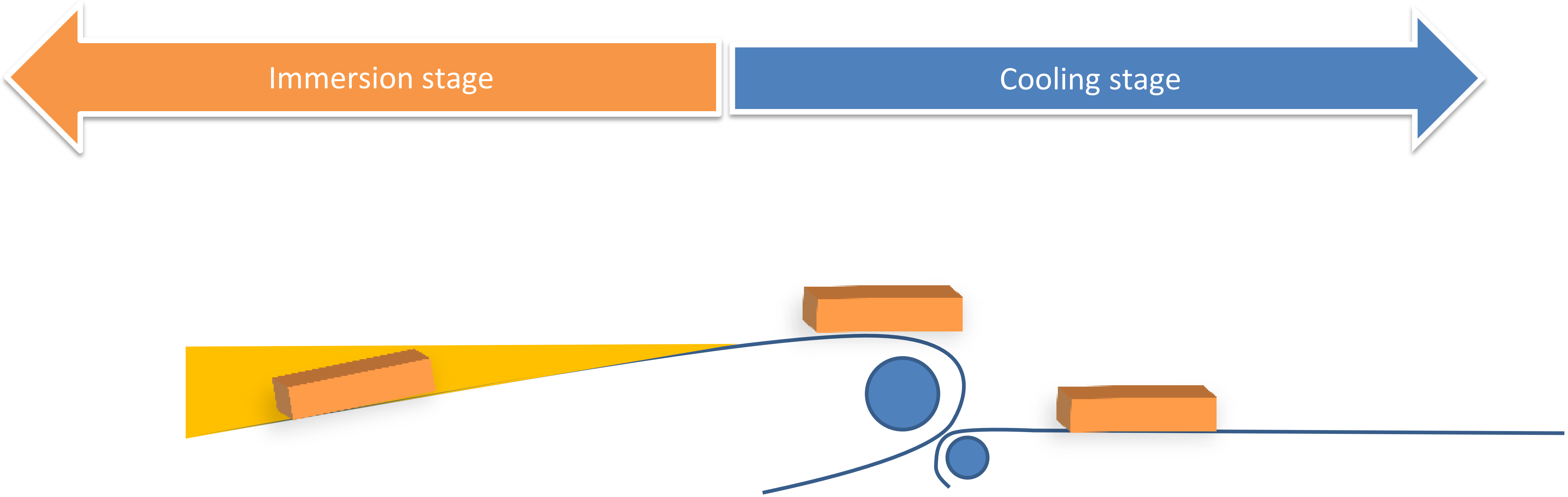
la caractérisation et la modélisation multi-échelle comme source d'innovation



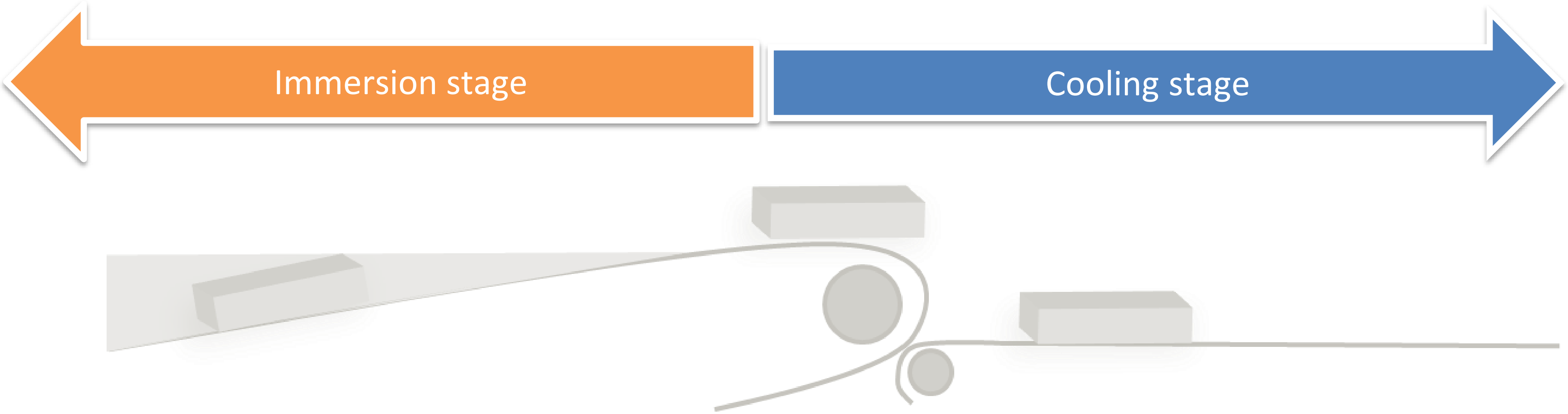




Deep-fat frying overview: two stages



Deep-fat frying overview: two stages



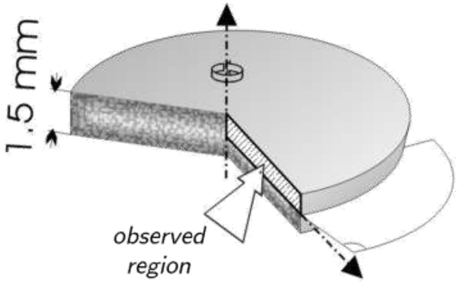
- Solid phases = starch, cell walls (cellulose pectins)
- Liquid phase = **WATER** (almost no oil)
- Gas phase = **PURE STEAM**

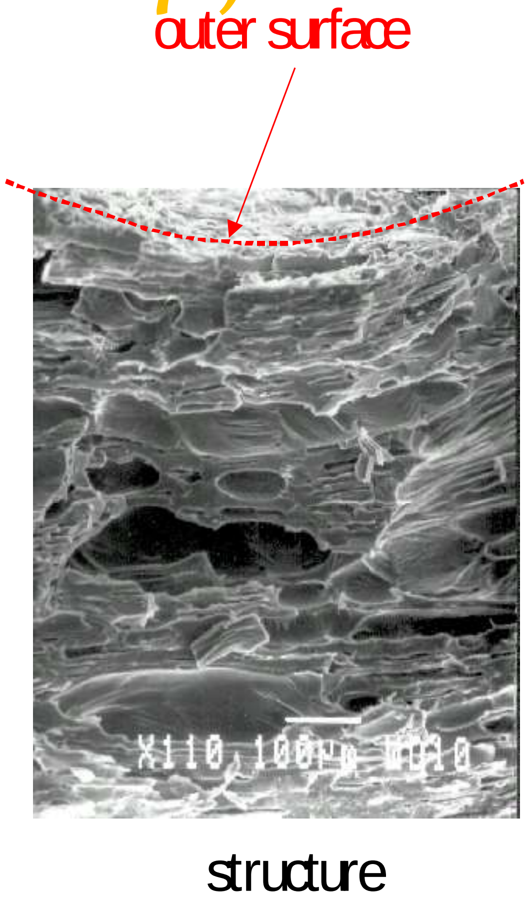
=
≠
≠

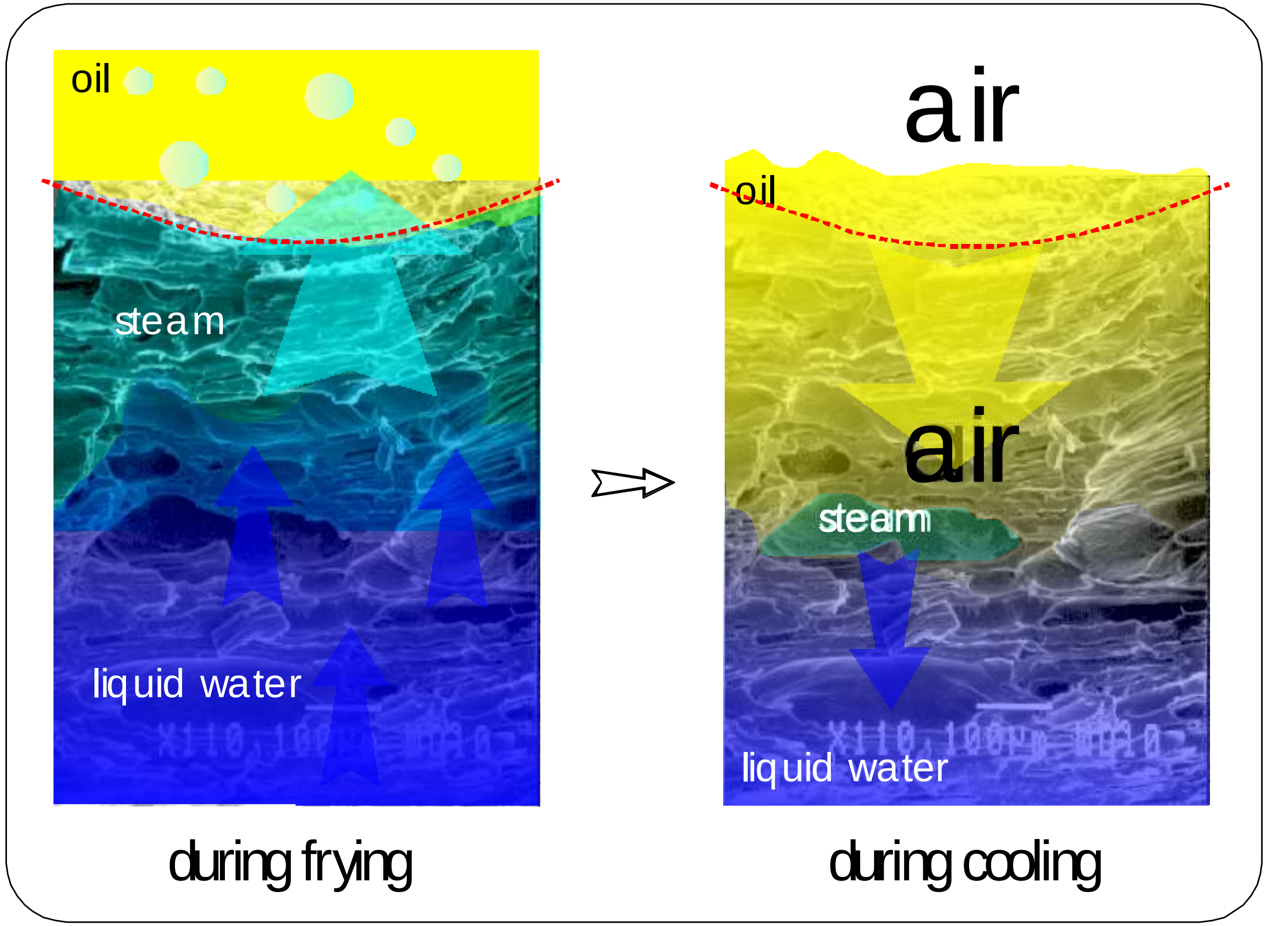
- Solid phases = starch, cell walls (cellulose pectins) + reaction products
- Liquid phases = water + **OIL**
- Gas phase = mixture **AIR** + residual water vapor

Organization of phases during immersion and cooling

(1.5 mm thick cassava chips)

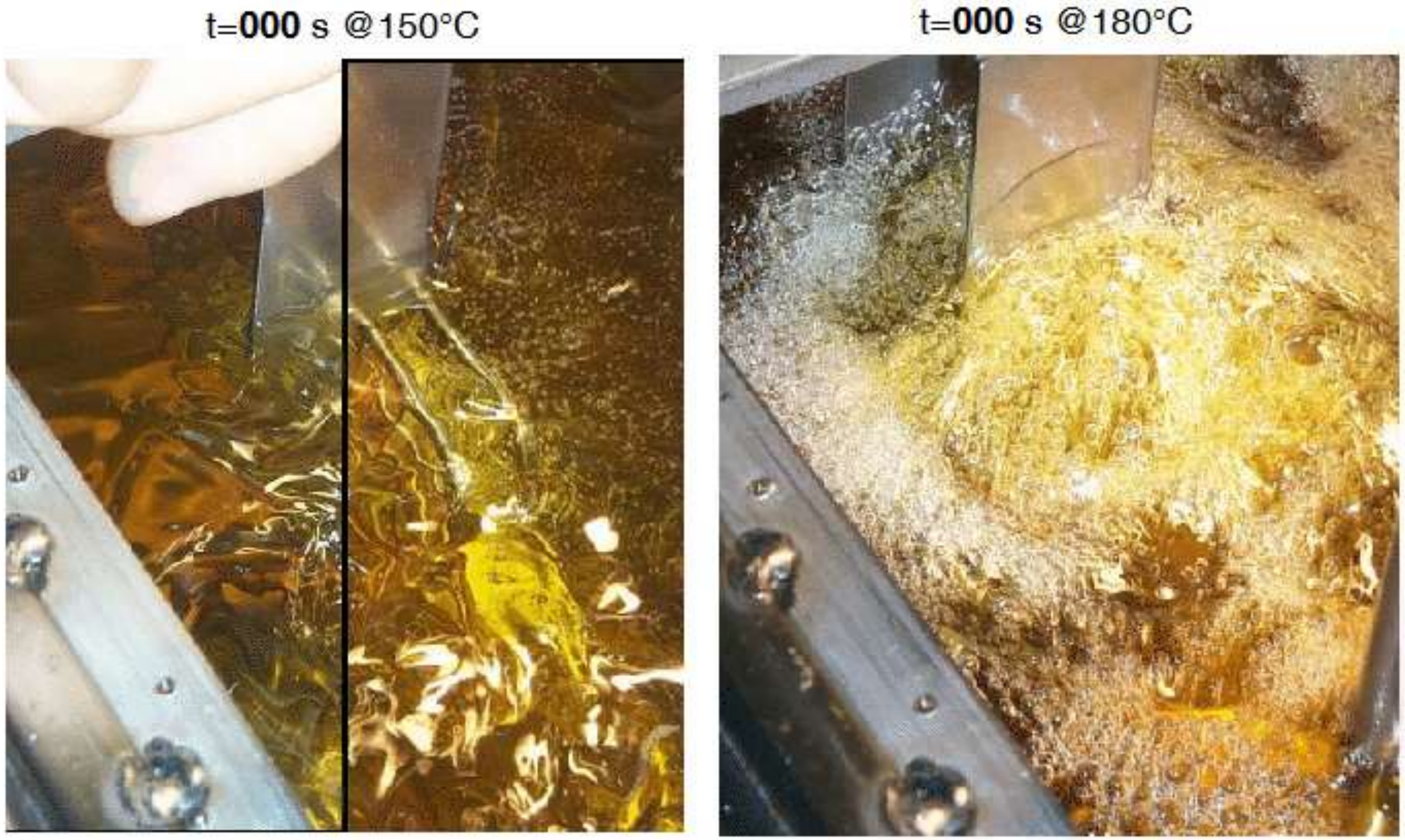






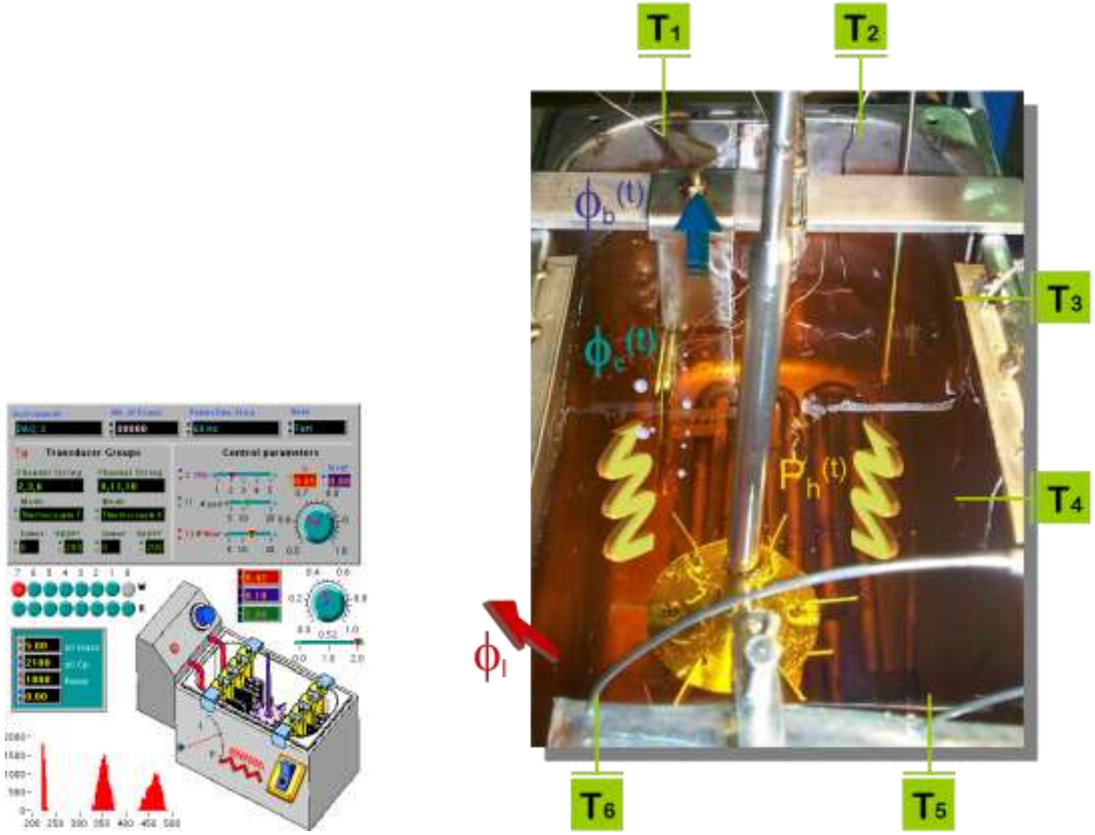
Vitrac, O. et al. (2000). Eur. J. Lipid Sci. Technol. 102 (8-9), 529-538
Vitrac, O. et al. (2003). J. Food Eng. 60 (2), 111-124.

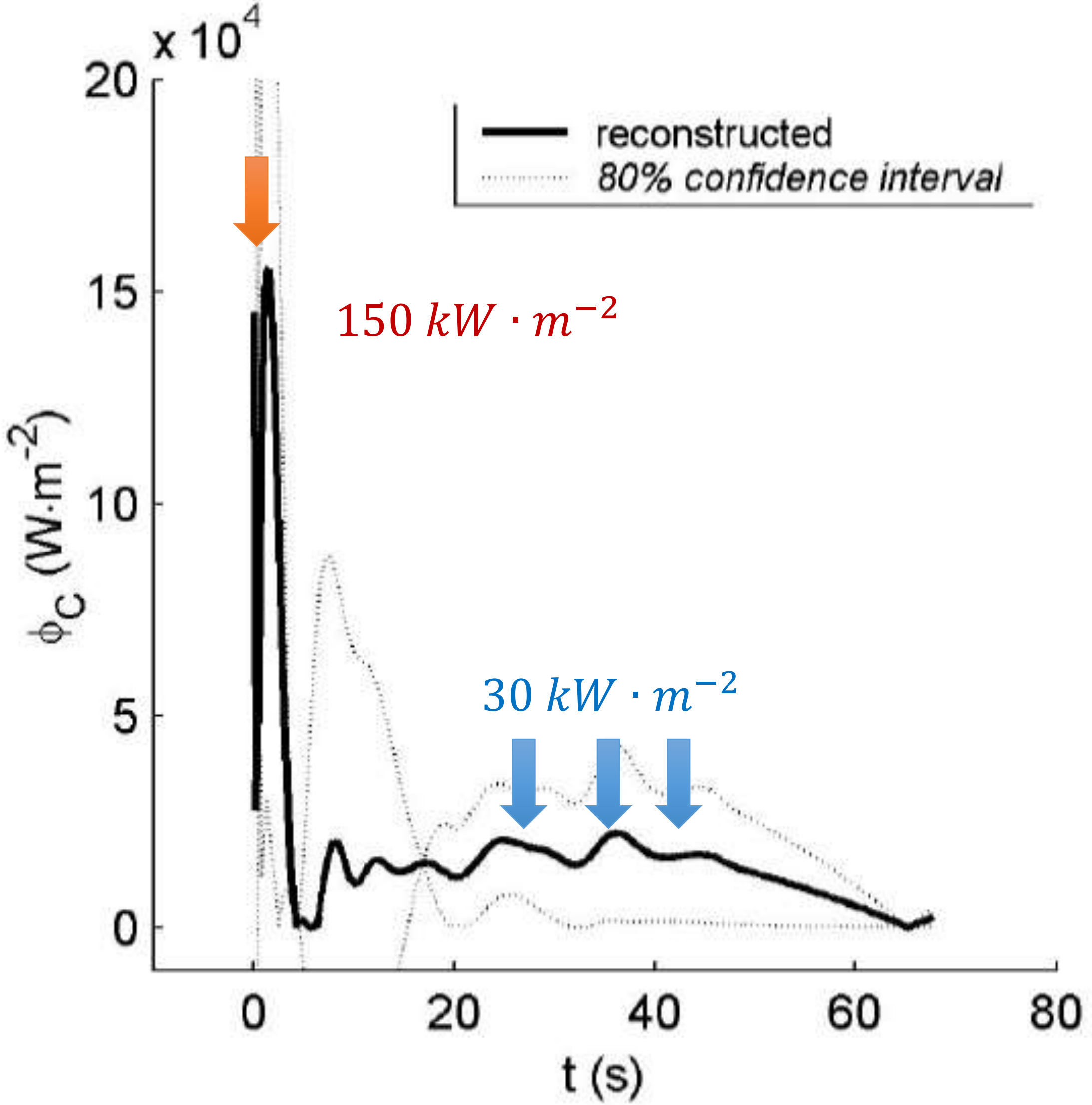
Immersion stage
(e.g., thermostable alginate gel)



Vitrac, O. et al. (2003). J. Food Eng. 60 (2), 111-124.

Immersion stage
(e.g., cassava chips)



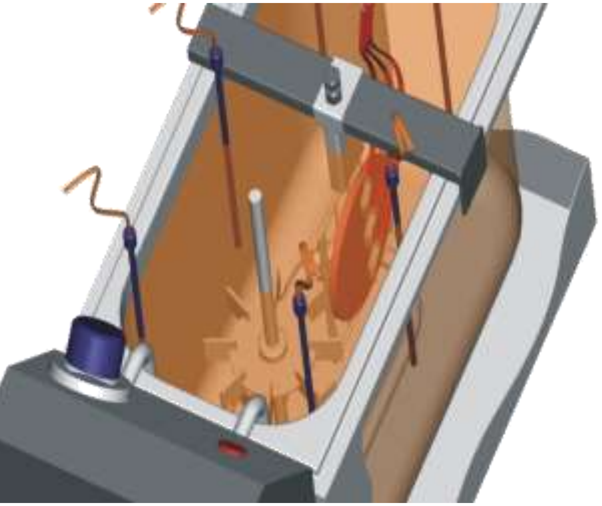


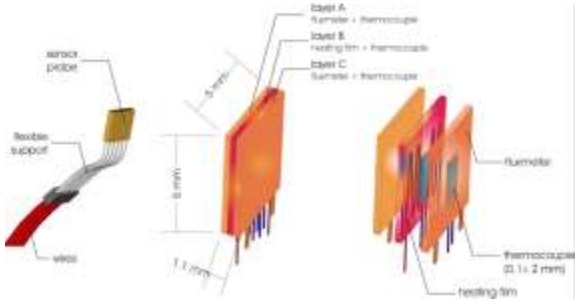
Vitrac, O. et al. (2003). J. Food Eng. 60 (2), 111-124.

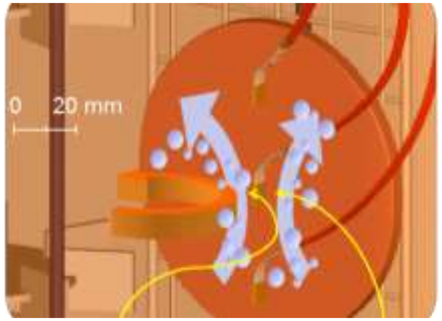
INRA SCIENCE & IMPACT

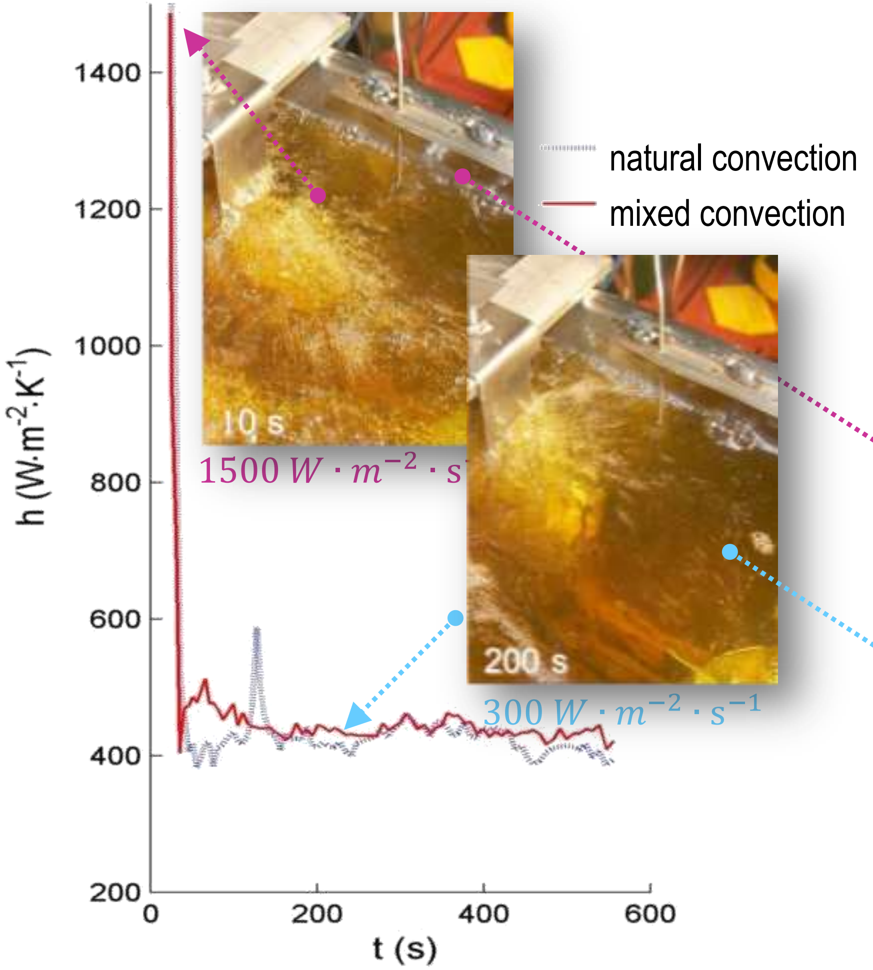
Immersion stage

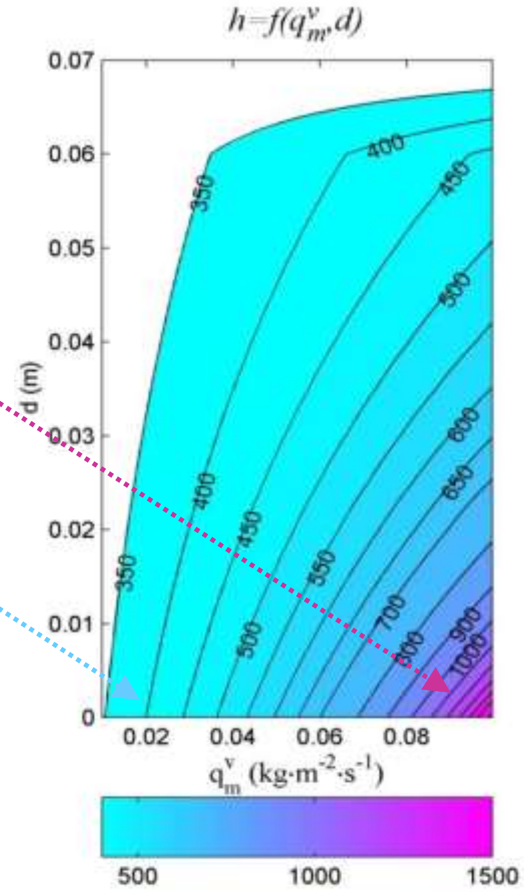
convective heat transfer coefficient: h







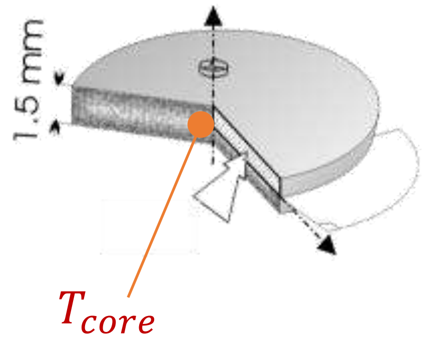


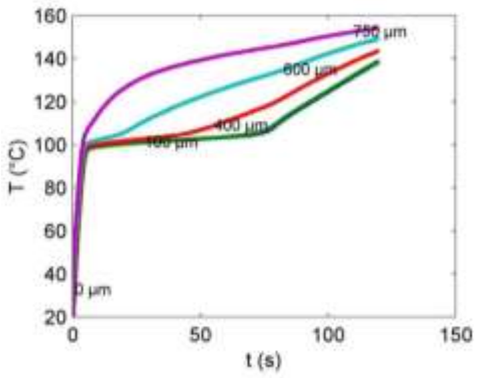


Vitrac, O and Trystram, G. (2005). Chem. Eng. Sci. 60(5), 1219-1236

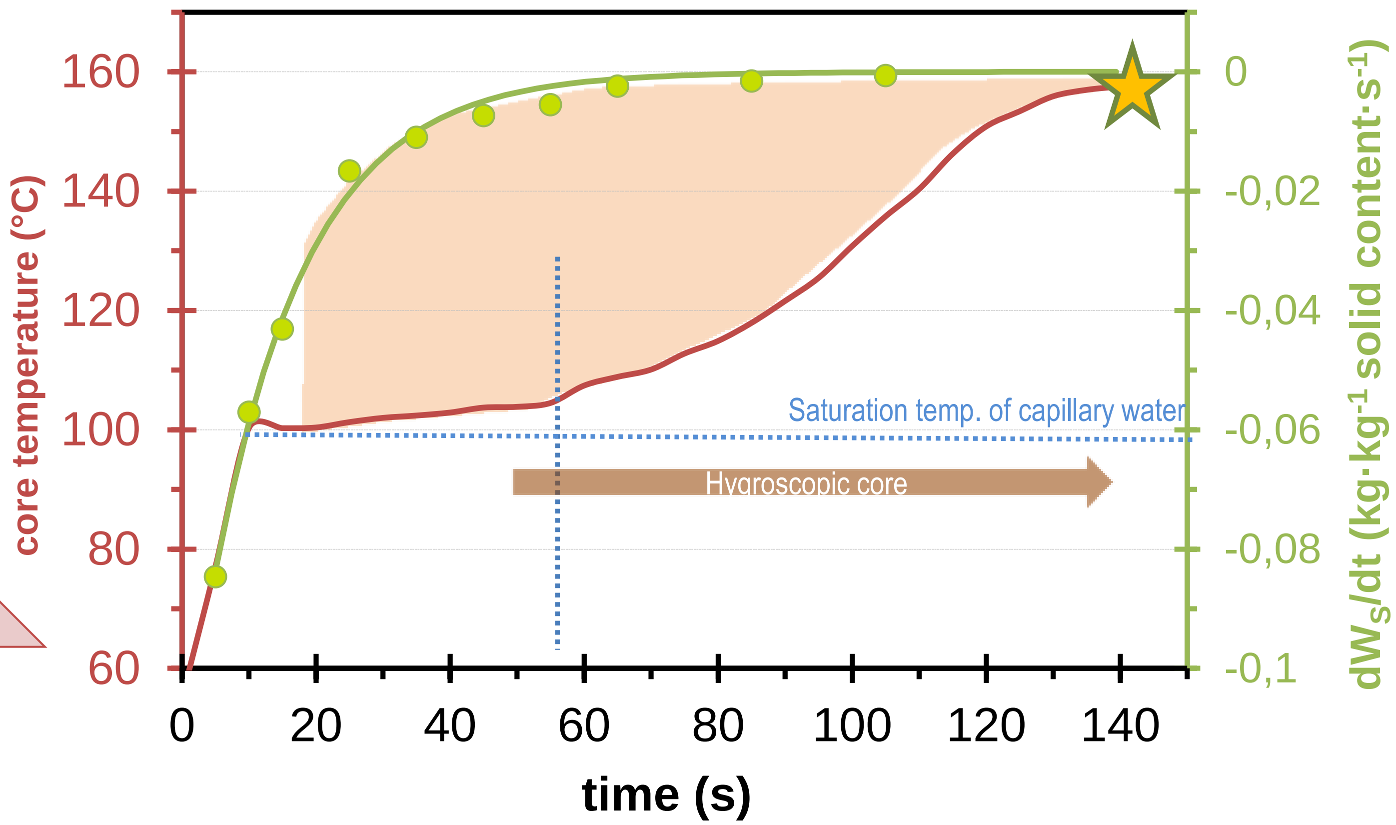
Immersion stage
(e.g., 1.5 mm thick cassava chips)

THERMODYNAMIC EQUILIBRIUM
(can be reproduced using super heated steam)





HEATING

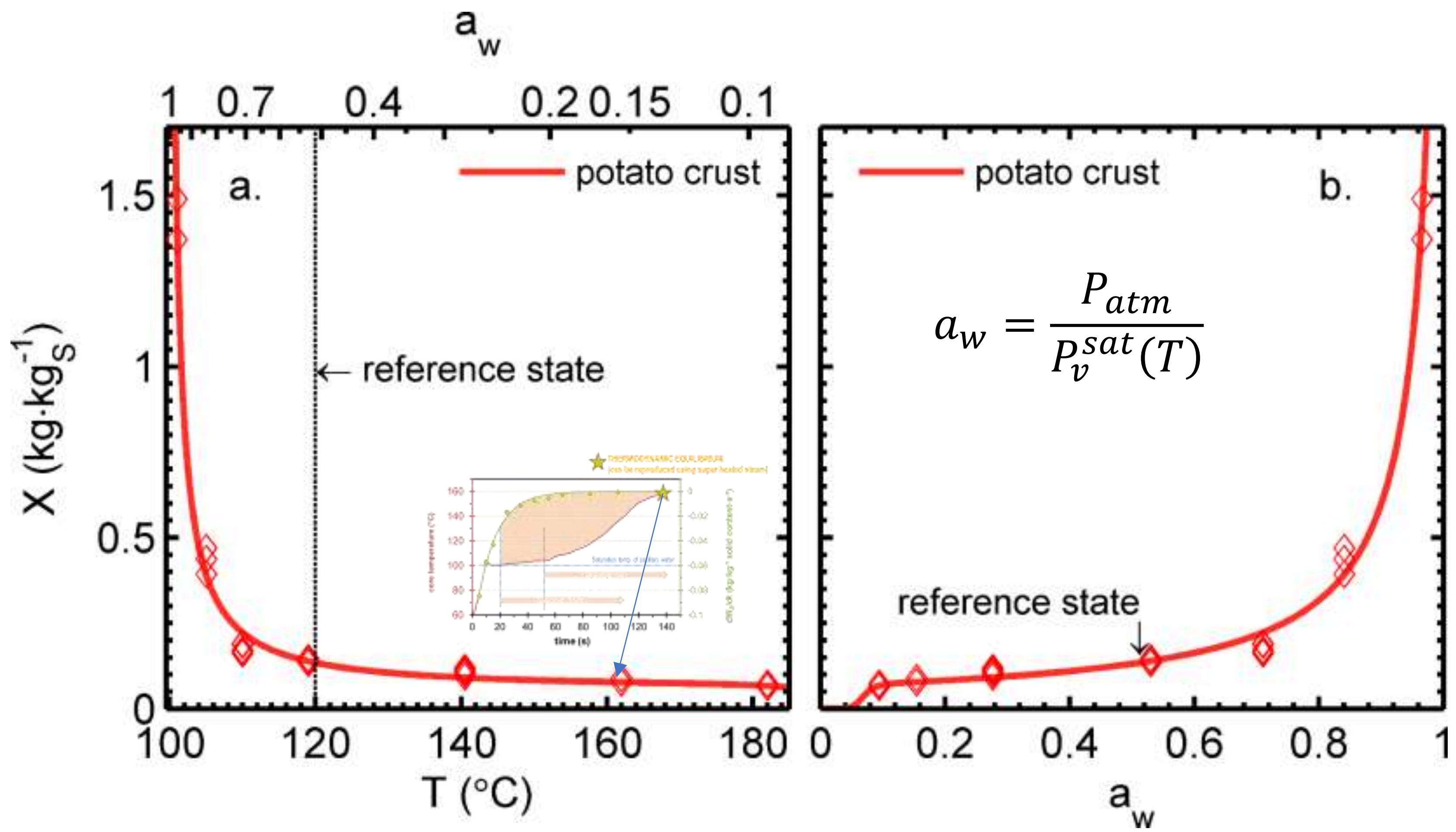


DRYING RATE

Vitrac, O. et al. (2002). J. Food Eng. 53, 161-176.

Immersion stage (no air)

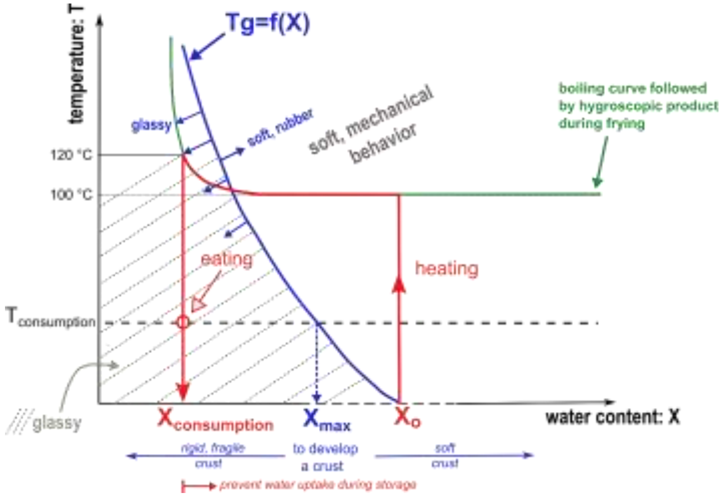
Isobaric sorption curves (crust of French fries)

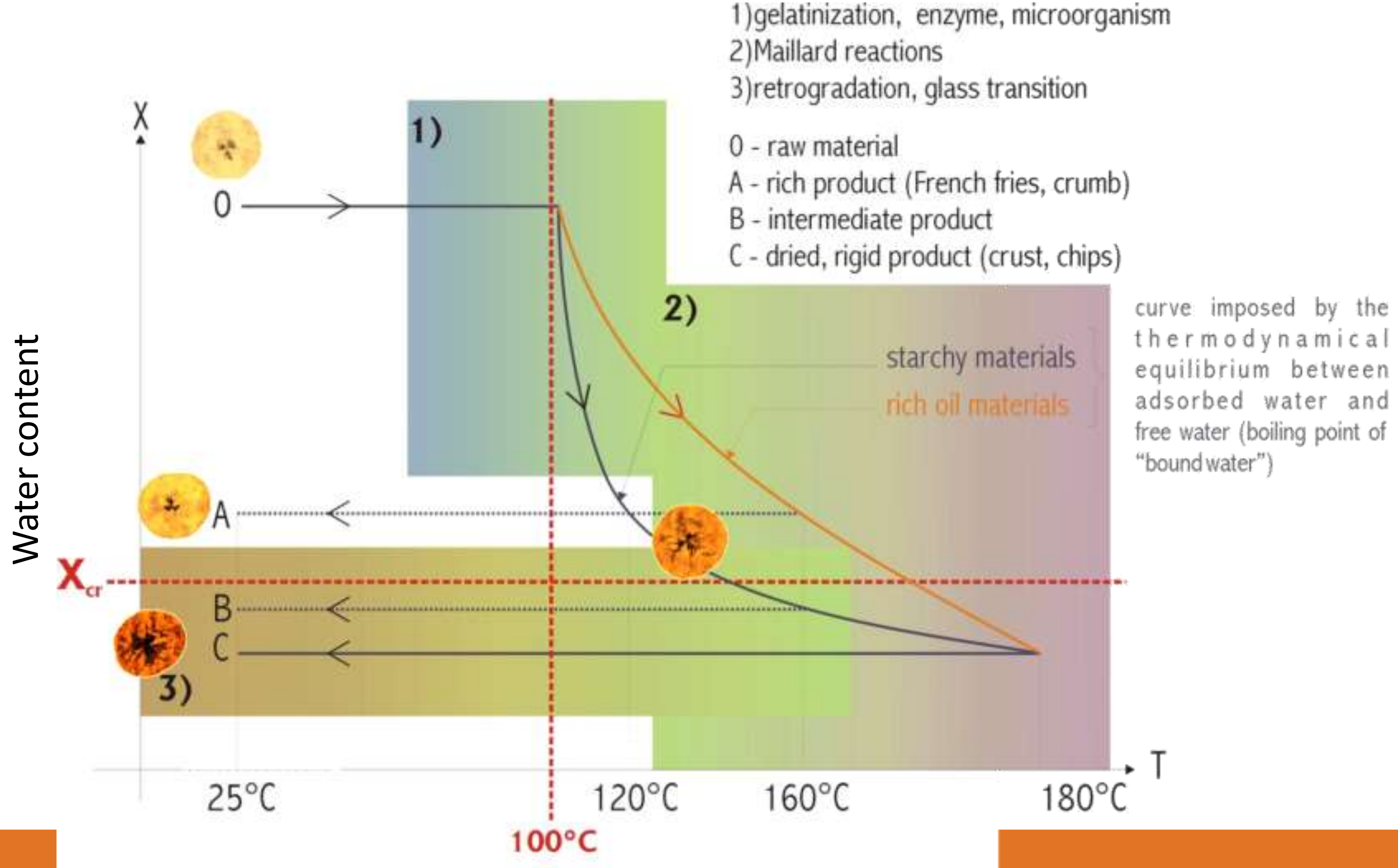


Patsioura, A. et al. (2015). AIChE J. 61(4), 1427-1446.

Without air: a single thermodynamic curve

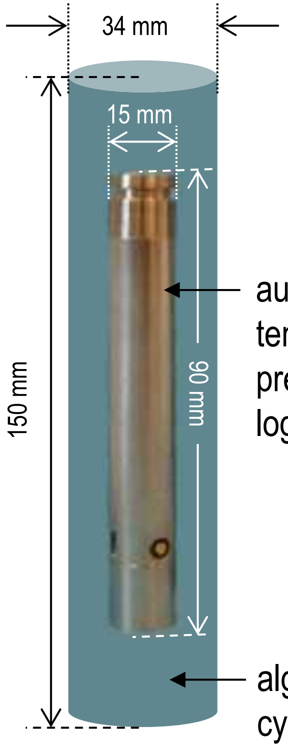
(e.g., for curve for each roaw material)



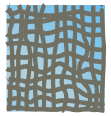


Vitrac, O. et al., In "Transport Phenomena in Food Processing" (2003) 29:445
Achir et al. (2008). Chem Eng Process, 47(11), 1953-1967

Immersion stage
(e.g., thermostable alginate gel)

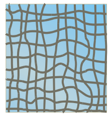


- **Starchy gel**

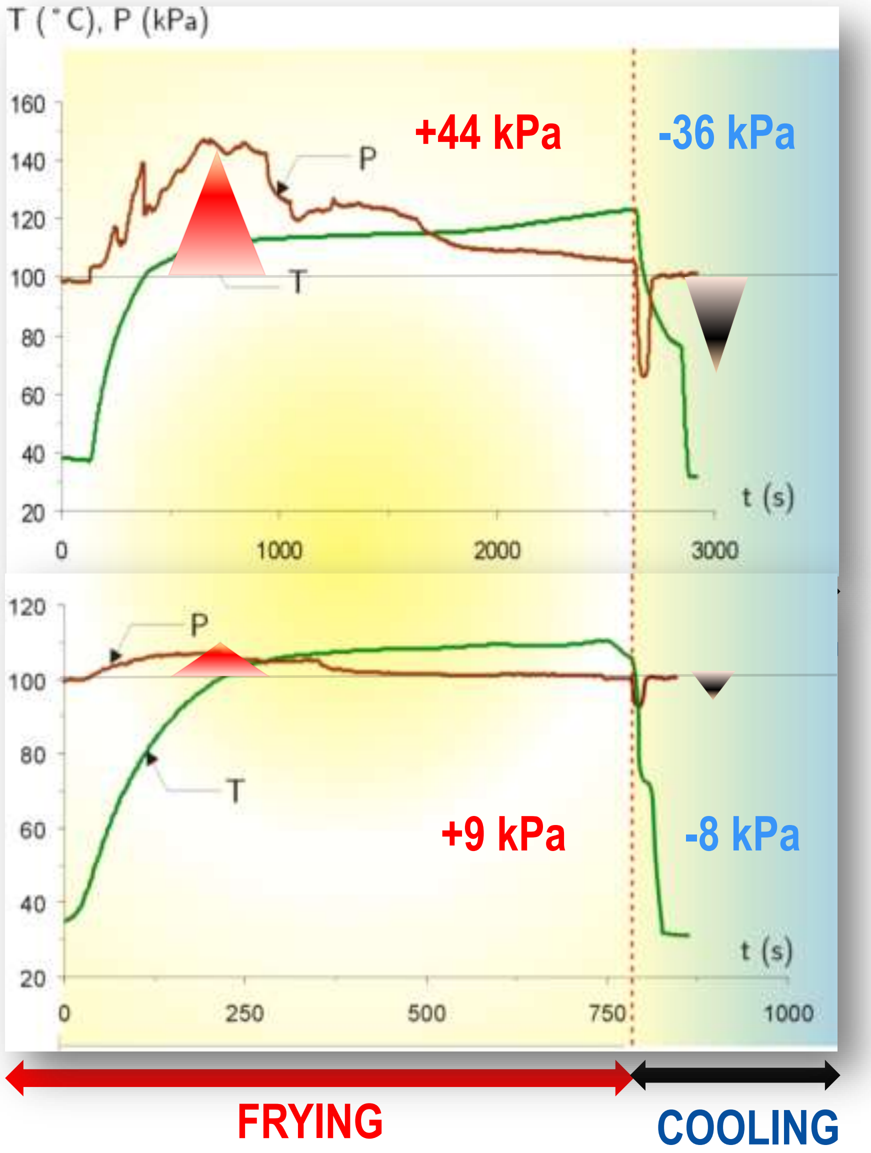


Initial water content = 2.7 kg/kg d.b.

- **Rich-water gel**

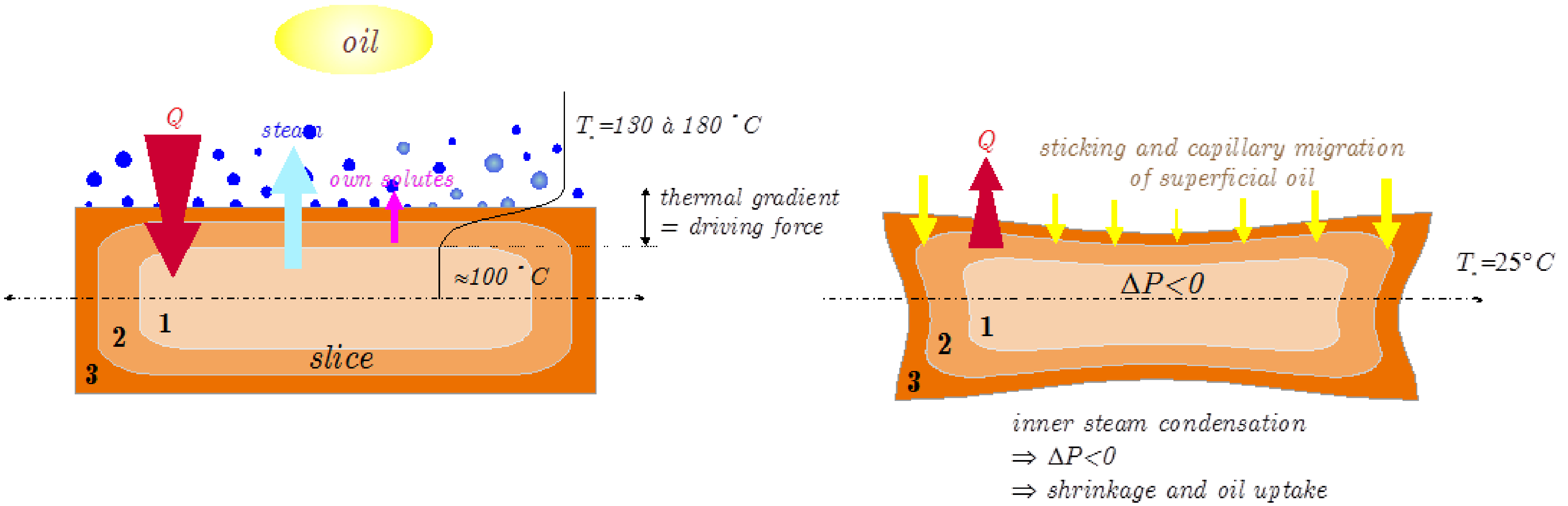


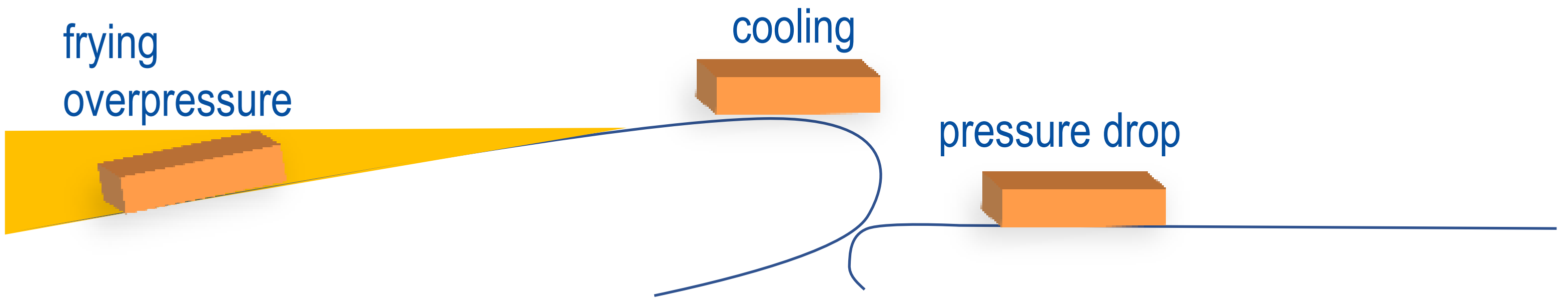
Initial water content = 13.2 kg/kg d.b.



Vitrac et al. Eur. J. Lipid Sci. Technol. (2000) 102:529

Pressure controls oil penetration (forced imbibition)





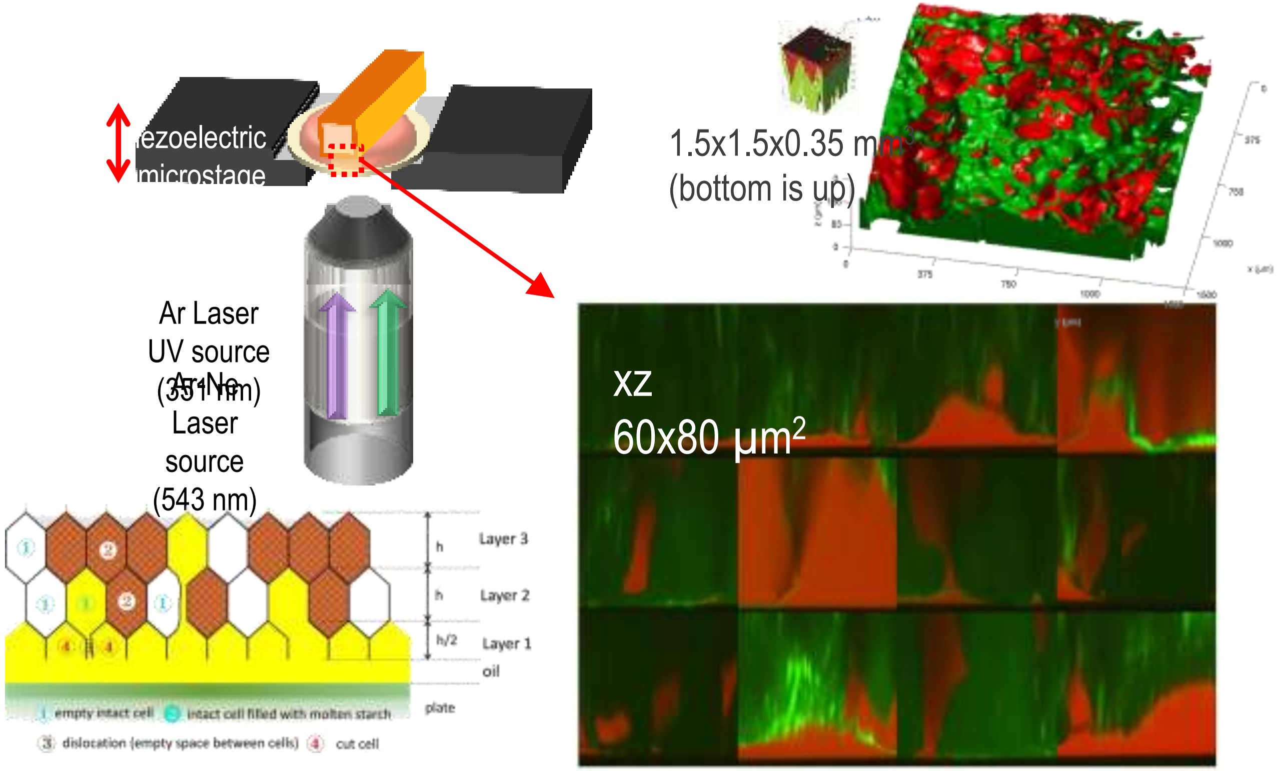
Achir, N., Vitrac, O., Trystram, G., Heat and mass transfer during frying
In "Advances in Deep-Fat Frying", S. Sahin, S.G. Sumunu, (Eds.), CRC Press, Boca-Raton, 5, 2010.

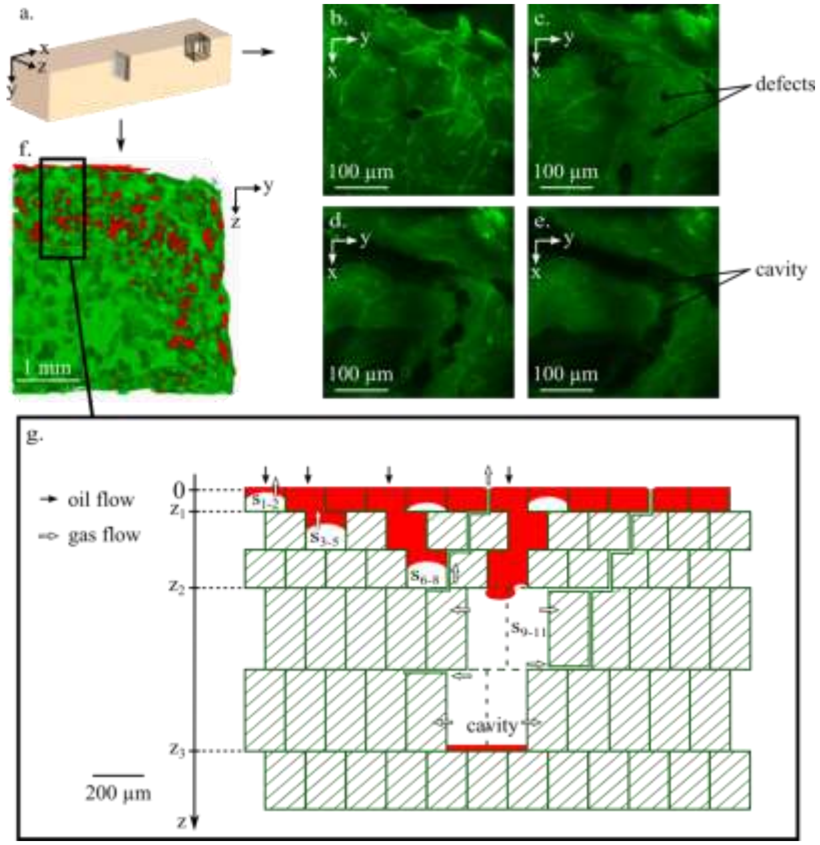
INRA SCIENCE & IMPACT

Difference between fresh and parfried French-Fries

from fresh potatoes

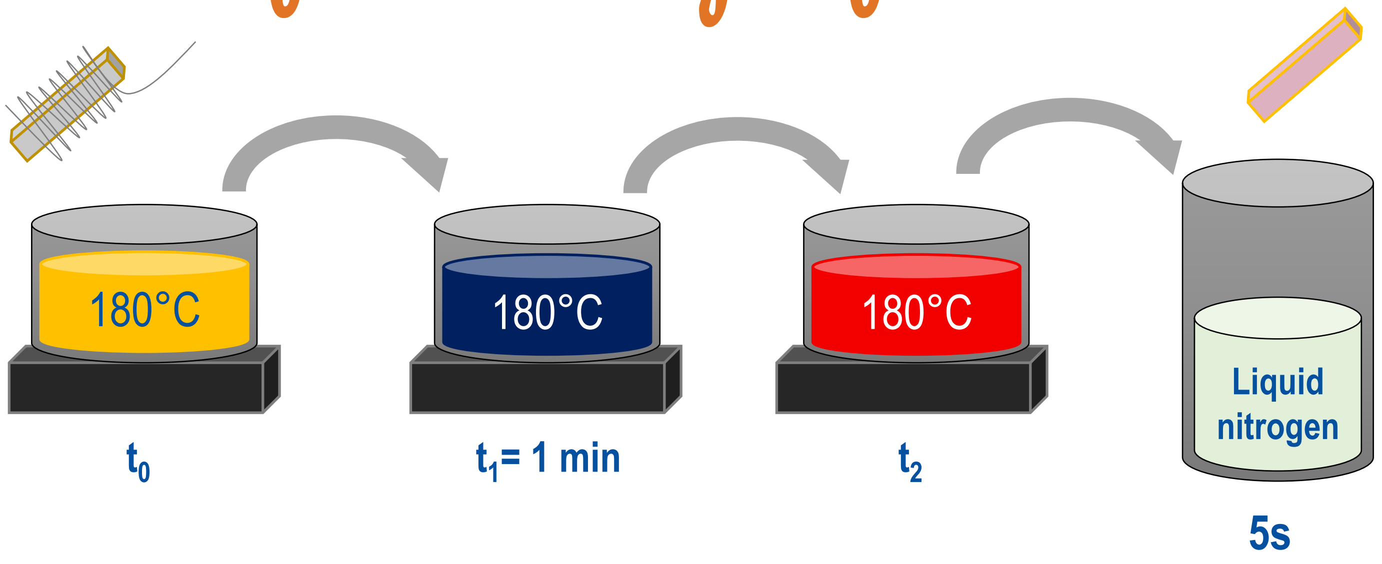
from par-fried frozen





Achir et al. Food Res Int (2010), 43(1), 307-314
Vauvre, J.-M. et al., Eur. J. Lipid Sci. Technol. (2014), 116, 741-755

Difference between fresh and parfried French-Fries



$$t_0 + t_1 + t_2 = 5\ min$$

t_1=1 min	t_2=4 min

t_0=1 min	t_1=1 min	t_2=3 min

t_0=3 min	t_1=1 min	t_2=1 min

INRA SCIENCE & IMPACT

Patsioura, A. *et al.*, Mechanisms of Oil Uptake in French Fries, In "Advances in Potato Chemistry and Technology, 2nd Edition" (Chapter 17), *J. Singh and Lovedeep Kaur (Eds.), Academic Press,* ***2018***

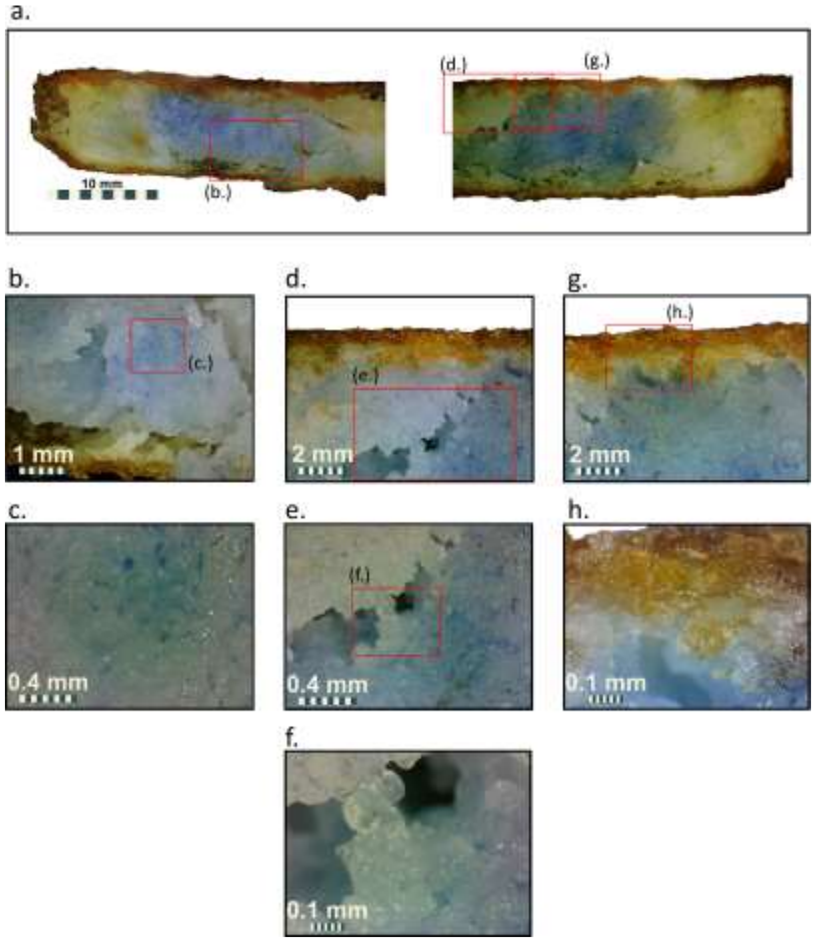
Difference between fresh and parfried French-Fries

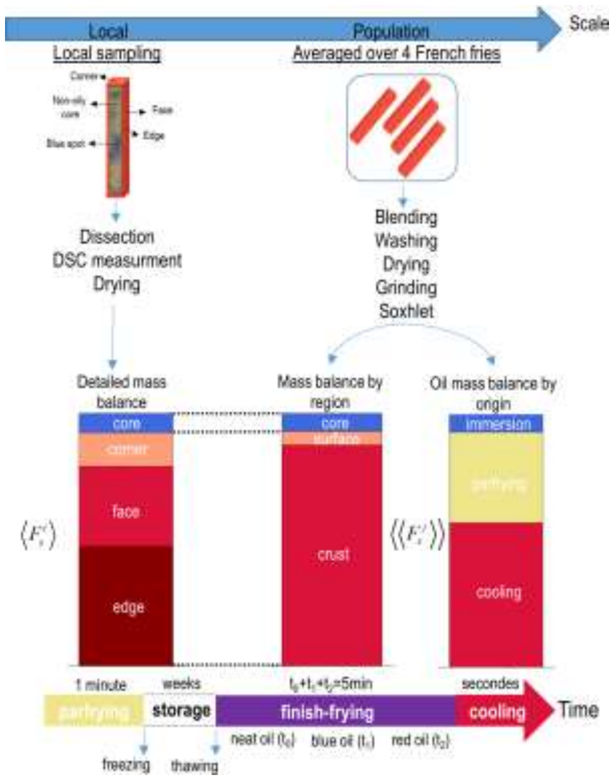
INRA SCIENCE & IMPACT

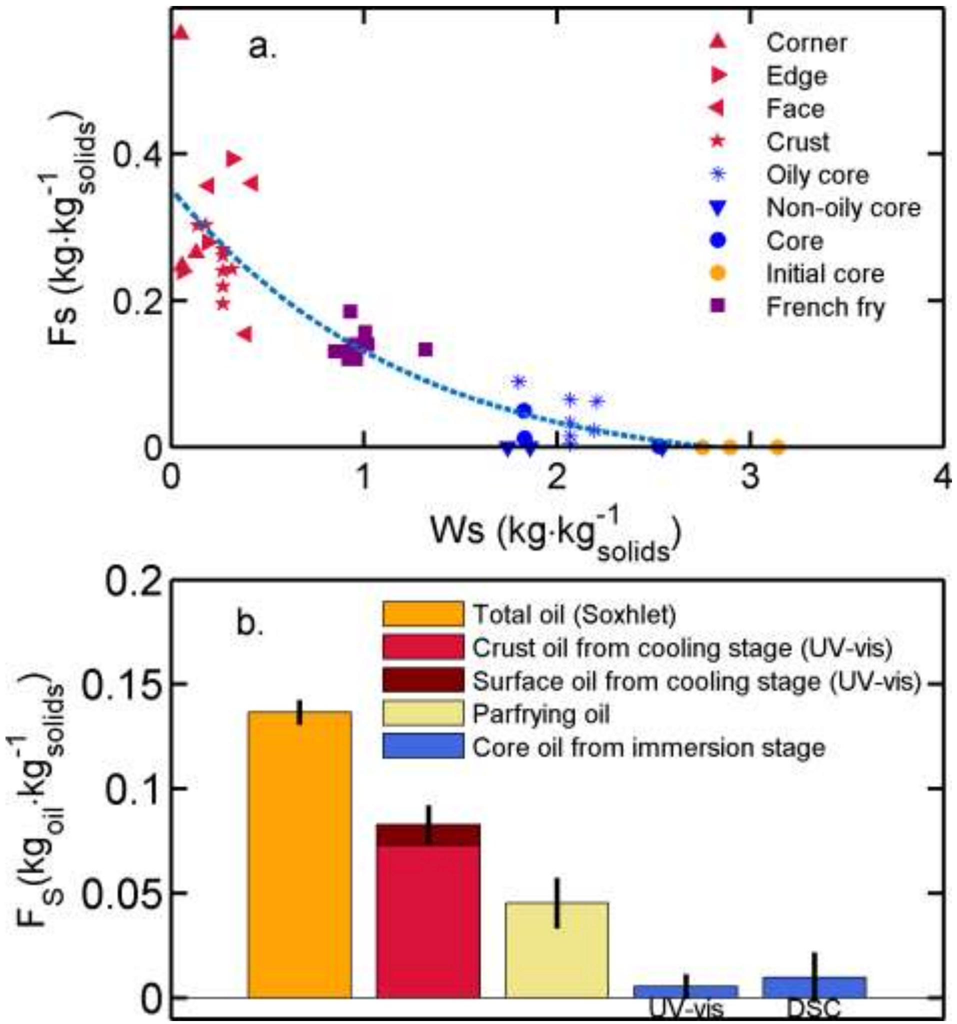
Patsioura, A. *et al*., Mechanisms of Oil Uptake in French Fries, In “Advances in Potato Chemistry and Technology, 2nd Edition” (Chapter 17), *J. Singh and Lovedeep Kaur (Eds.), Academic Press,* ***2018***

Difference between fresh and parfried French-Fries

(dissection and local measurement)



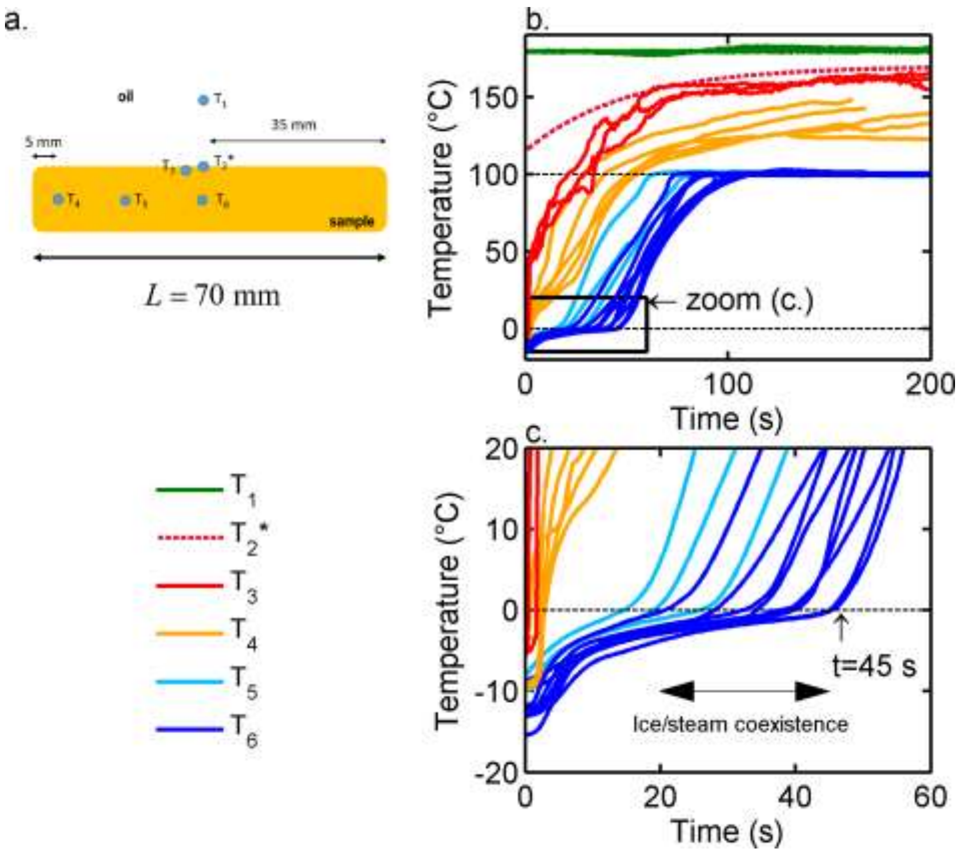


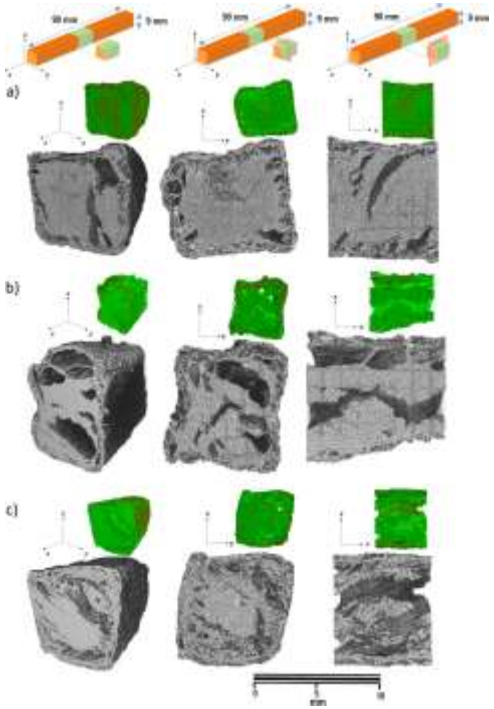


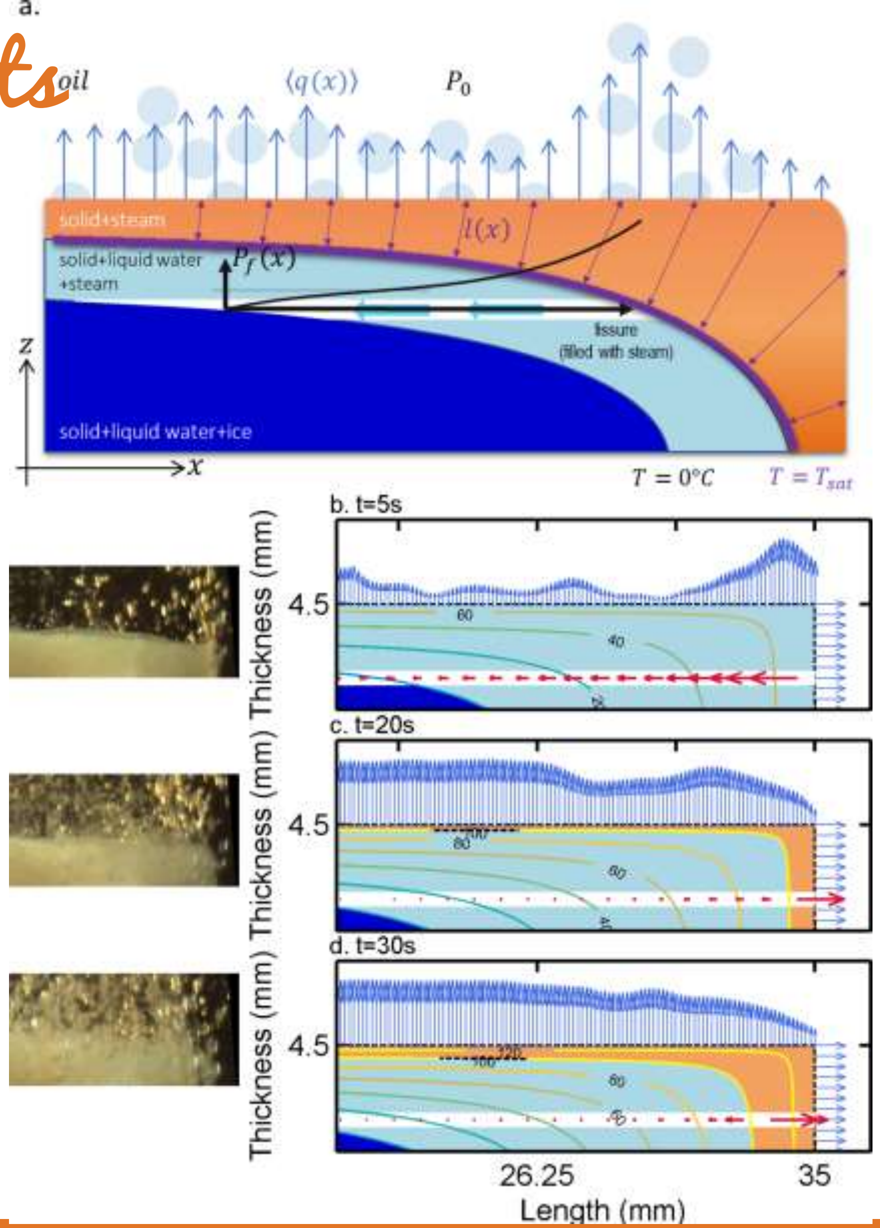
INRA SCIENCE & IMPACT

Touffet M, Trystram G, Vitrac O. Revisiting the mechanisms of oil uptake during deep-frying. Food and Bioproducts Processing. 2019;submitted

Why oil can penetrate in parfried frozn products during the first minute of immersion

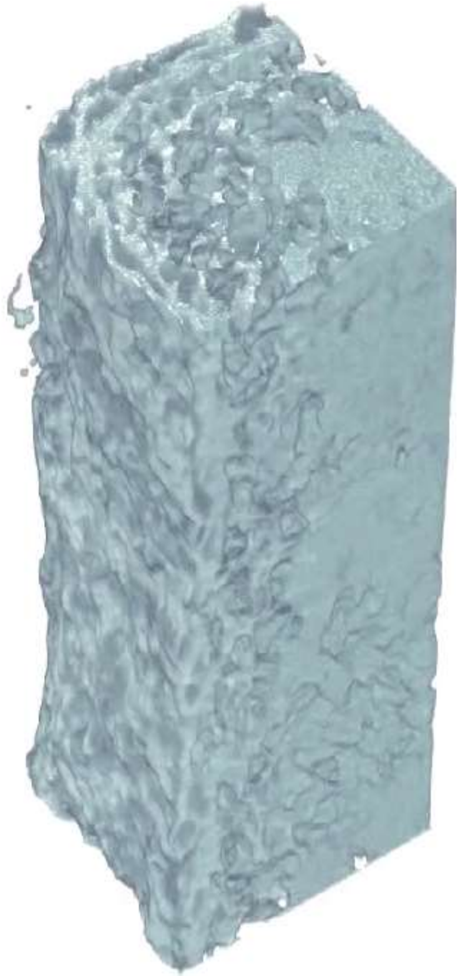




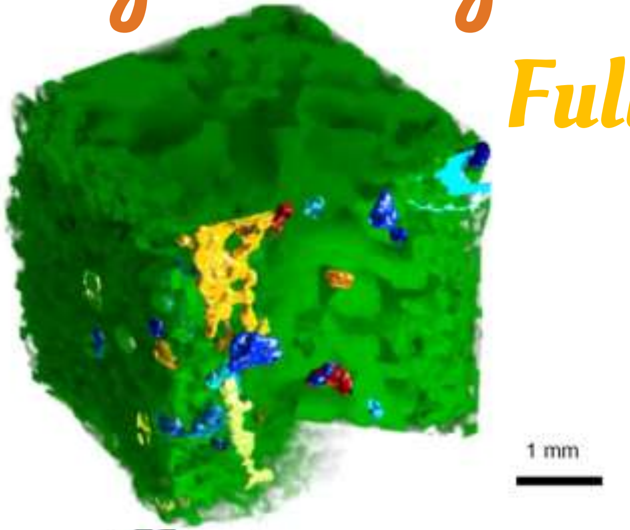


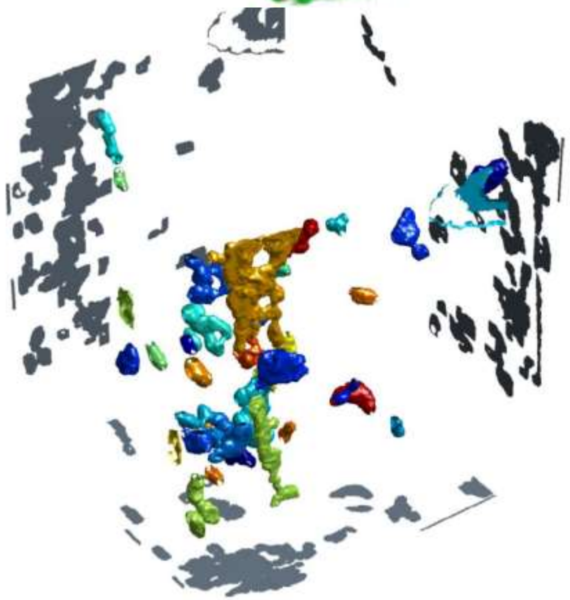
Touffet M, Trystram G, Vitrac O. Revisiting the mechanisms of oil uptake during deep-frying. Food and Bioproducts Processing. 2019;submitted

Oil percolation during cooling

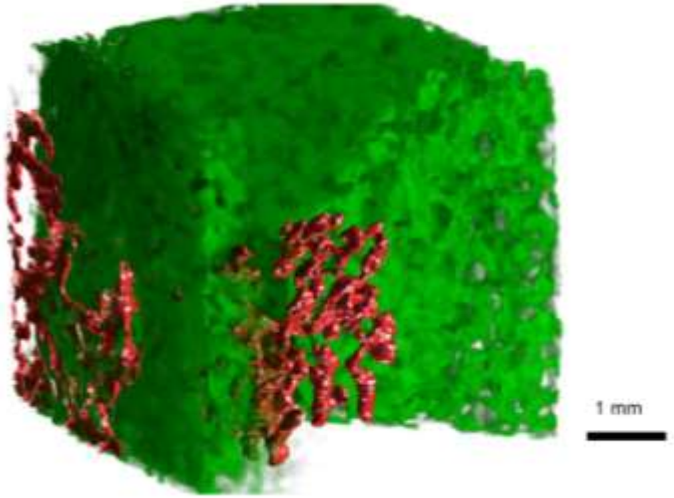


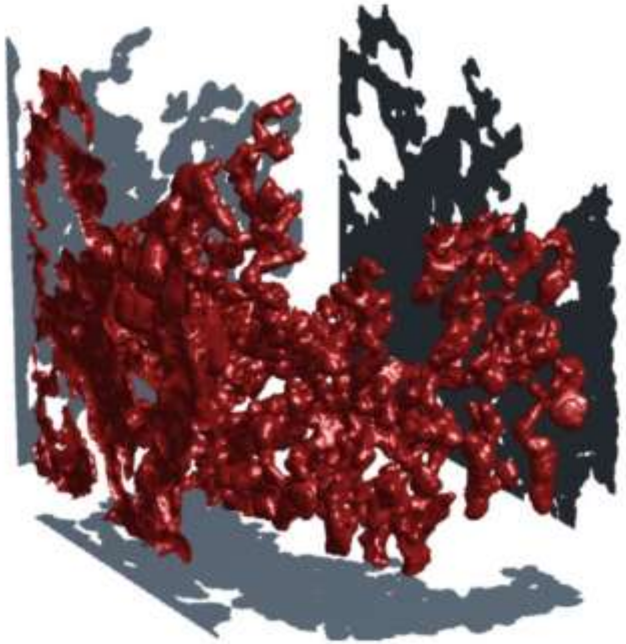
Par-fried

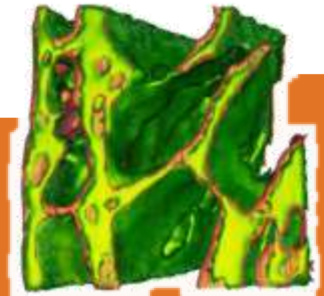




Full-fried

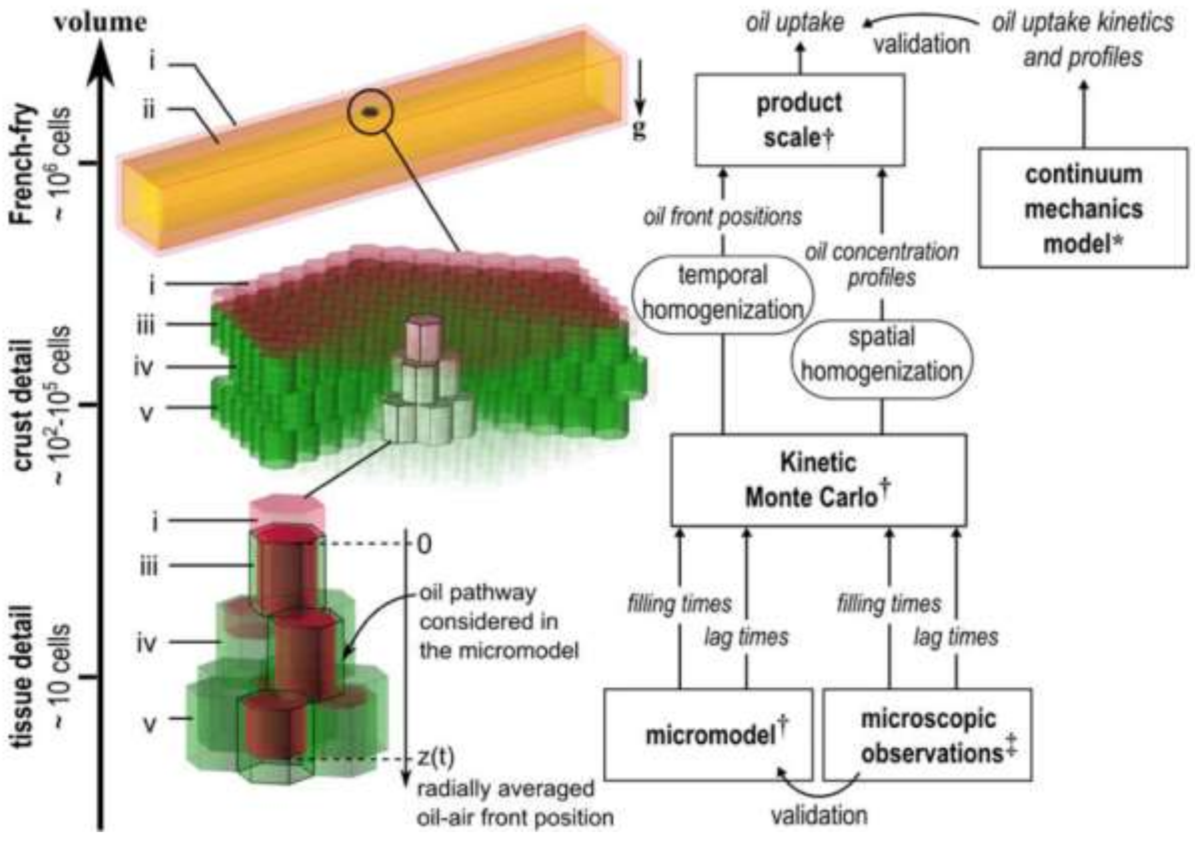


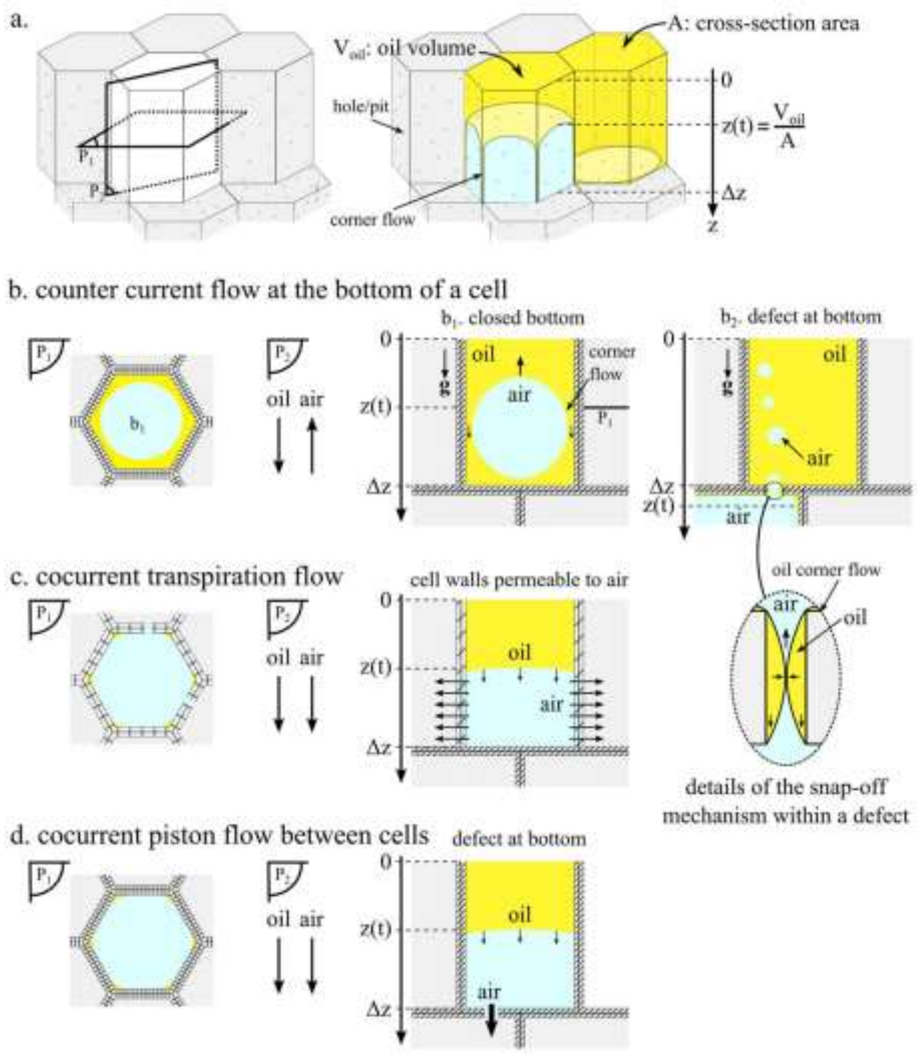




On average, ca. 10 entries points per French-fry centimeter length

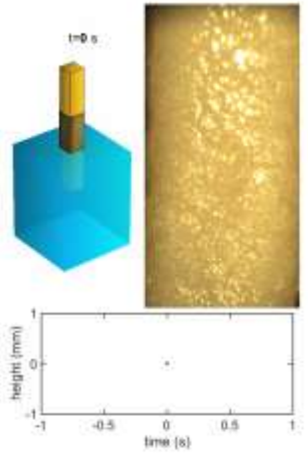
Microscopic oil uptake model



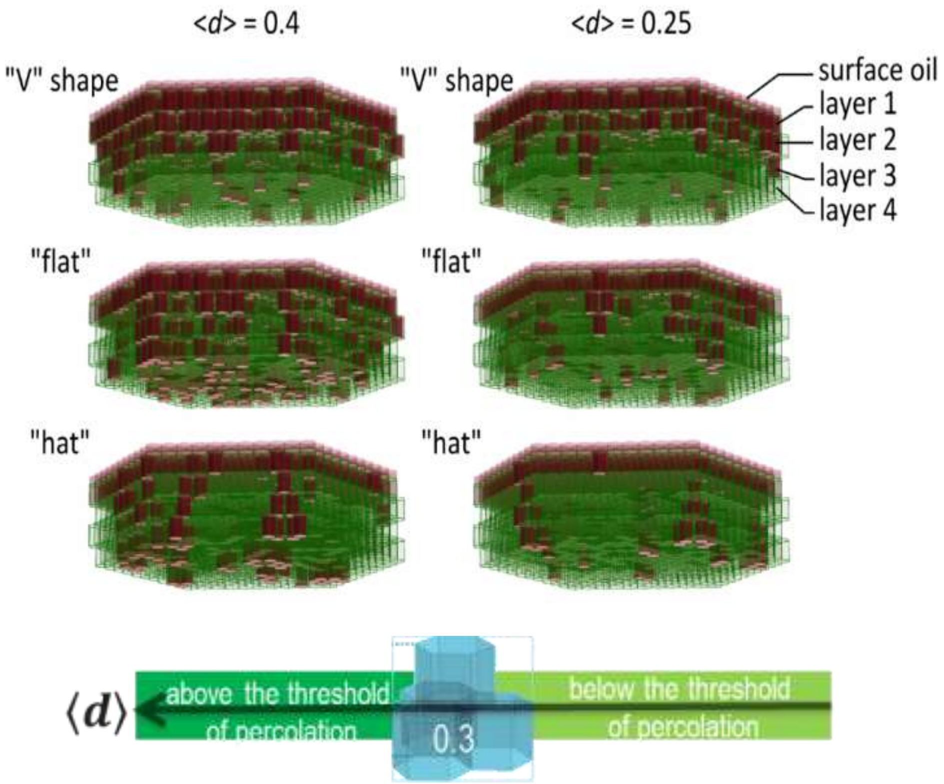


Vauvre et al. AIChE J. (2015) 61(7), 2329-2353

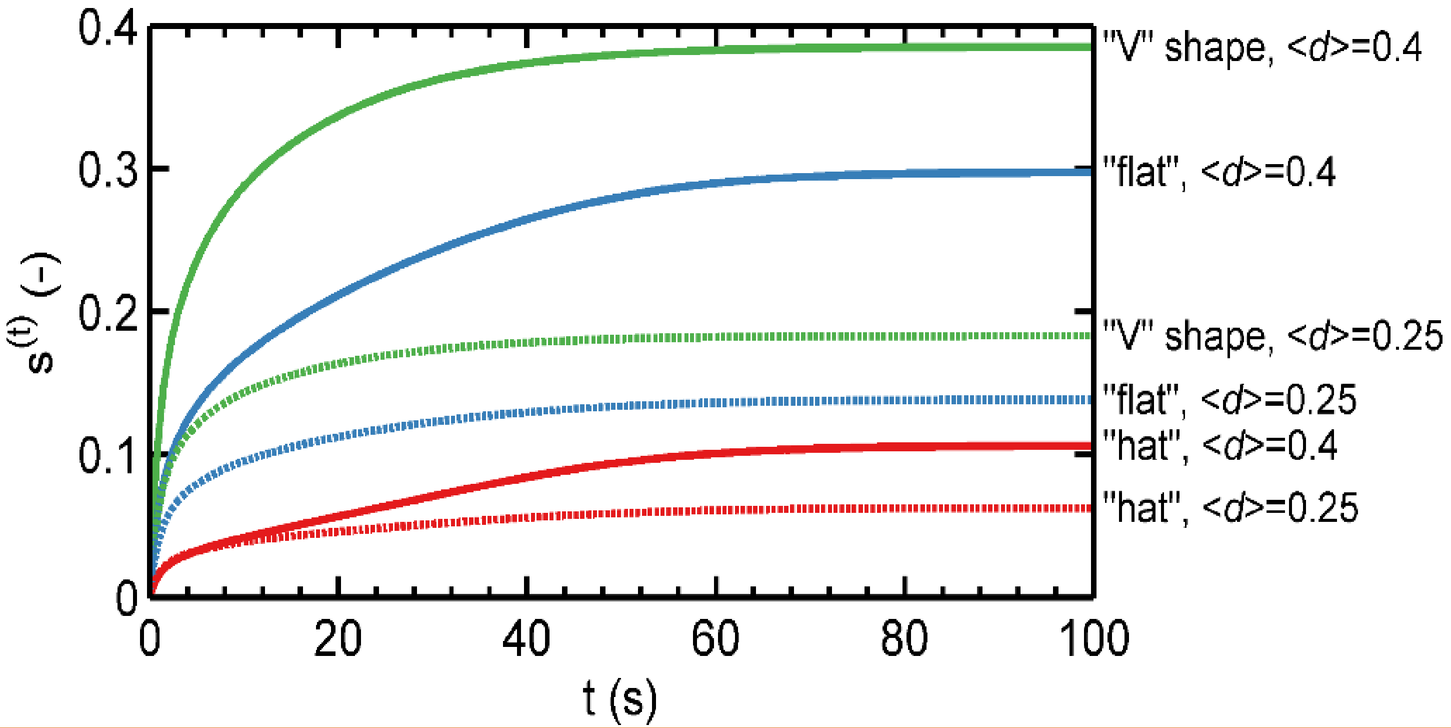
Effect of cellular damage



❖ Damage profiles

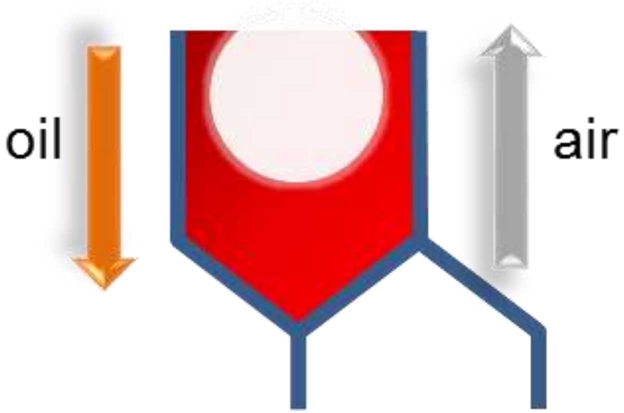


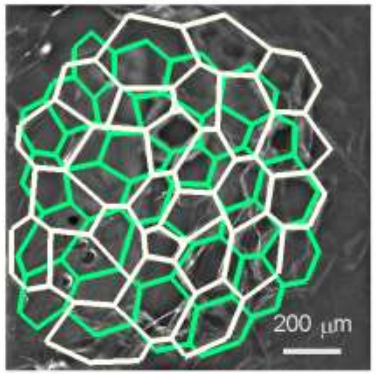
❖ Oil uptake kinetics: saturation $s(t)$

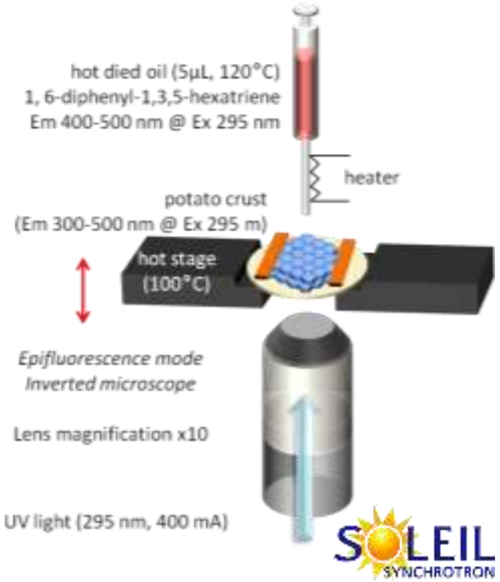


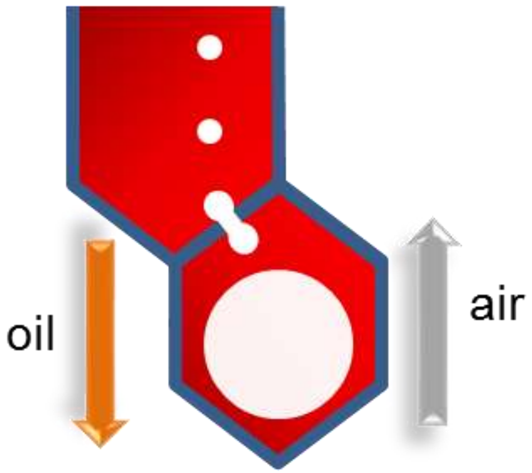
Vauvre et al. AIChE J. (2015) 61(7), 2329-2353

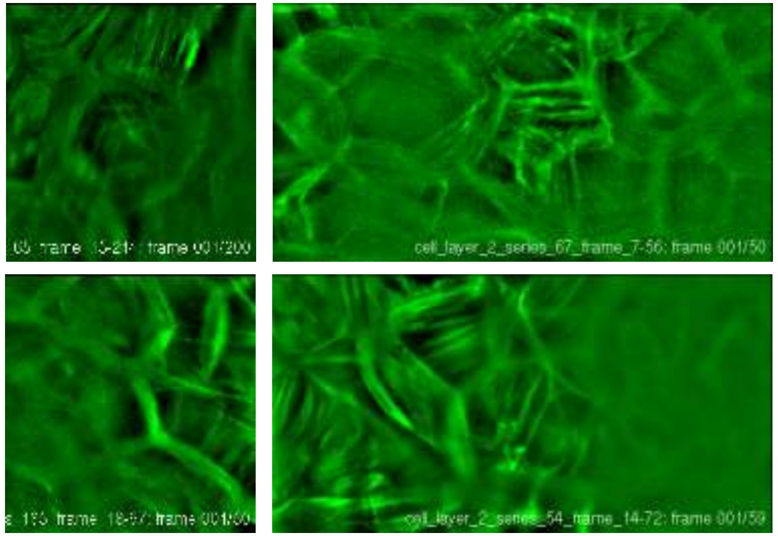
Air can stop oil uptake

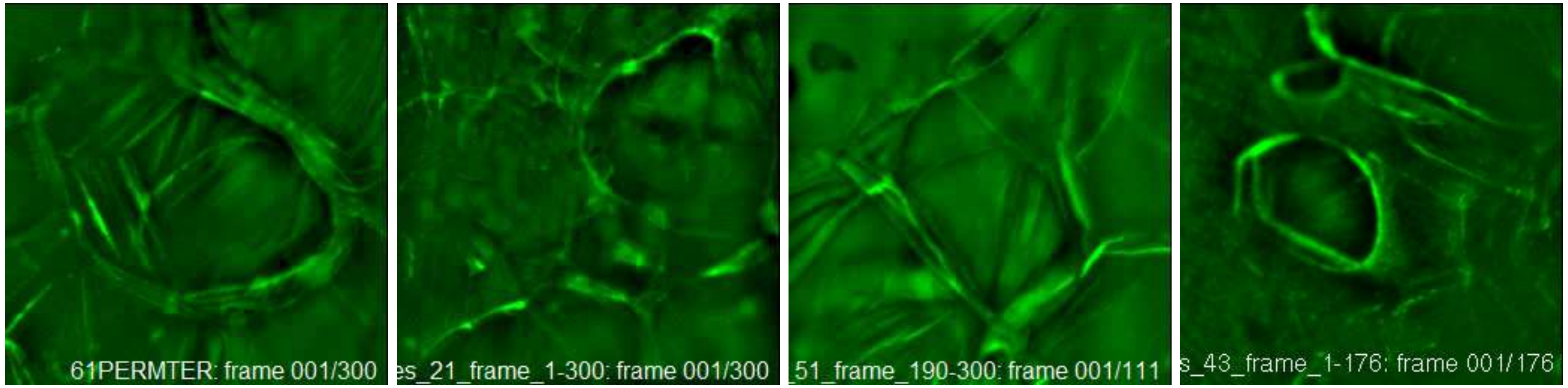








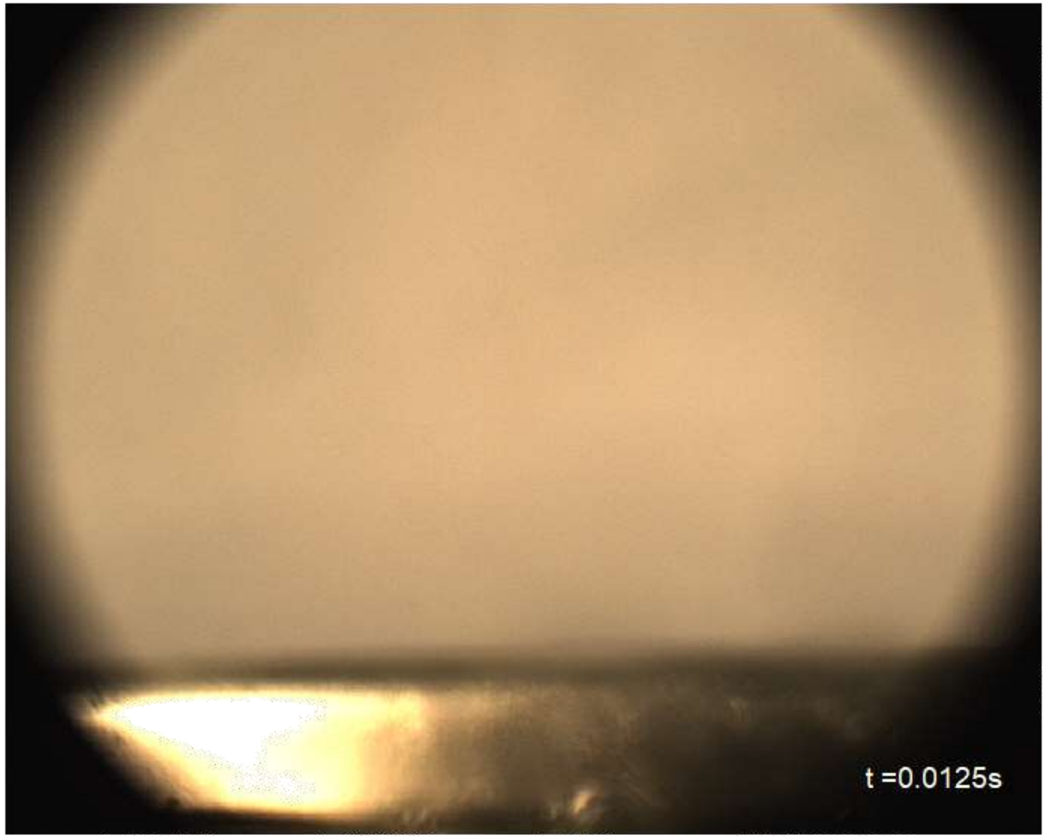


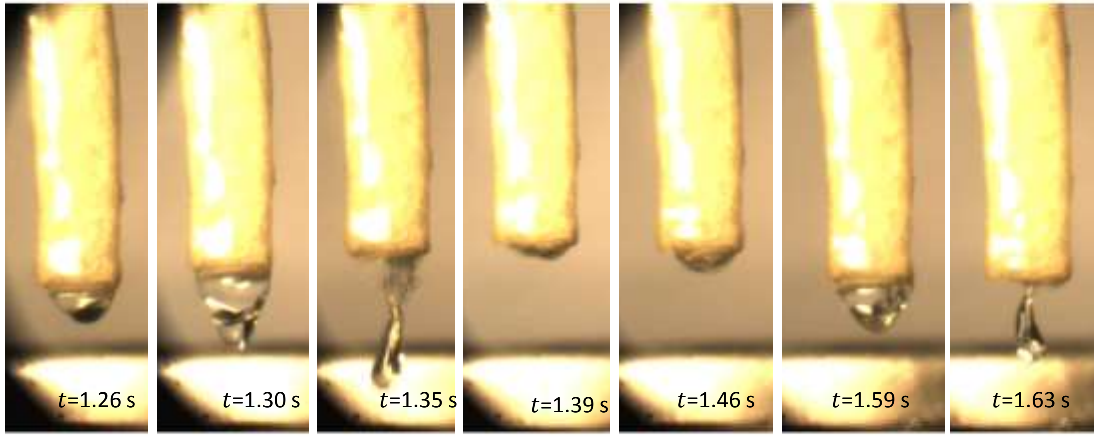


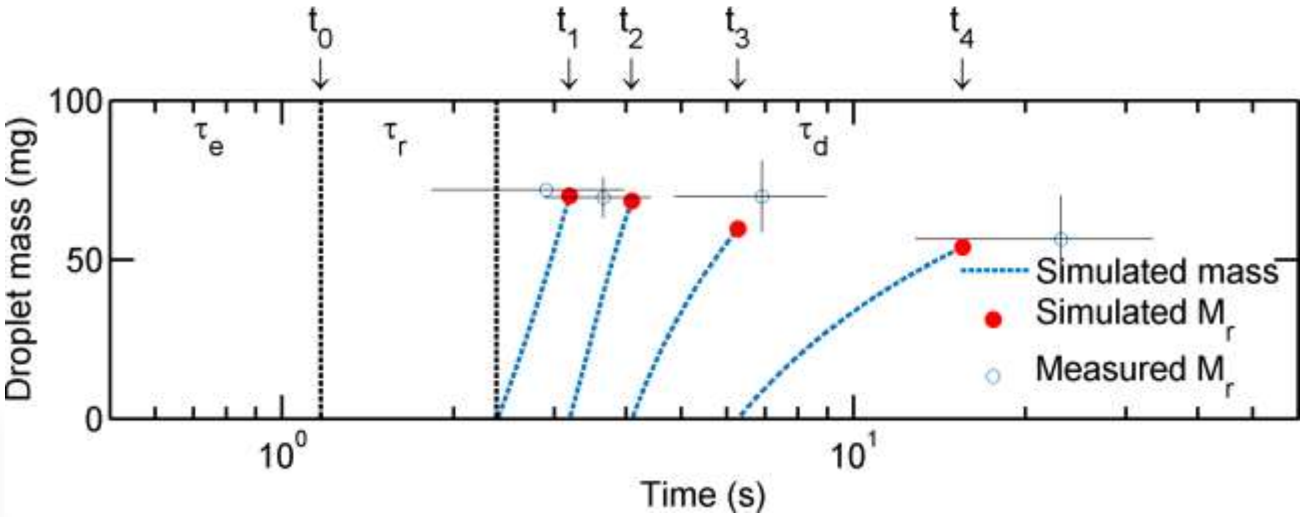
INRA
SCIENCE & IMPACT

Patisoura et al. AIChE J. (2015) 61(4), 1427-1446

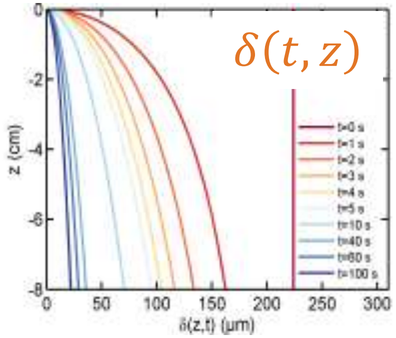
Oil dripping process (cooling)

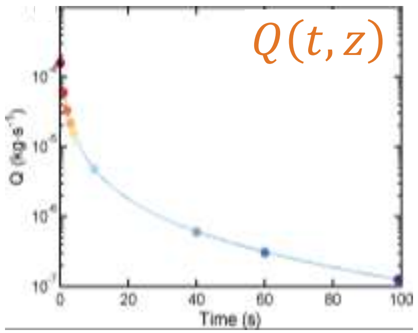


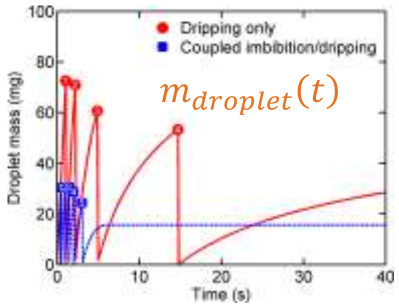


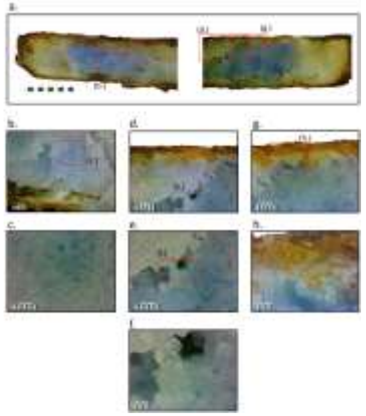


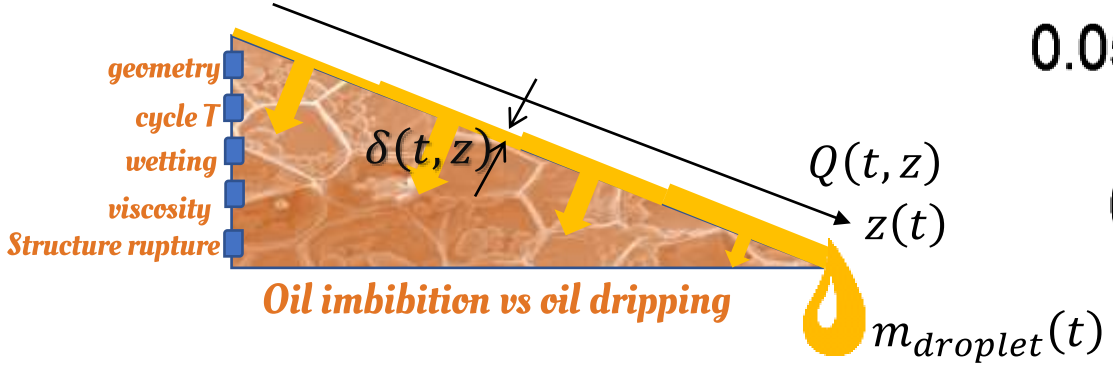
A. Patsioura, *et al*, *Food and Bioproducts Processing* ***2017, 101, 84-99.***
M. Touffet *et al.*, *Journal of Food Engineering* ***2018, 224, 1-16.***

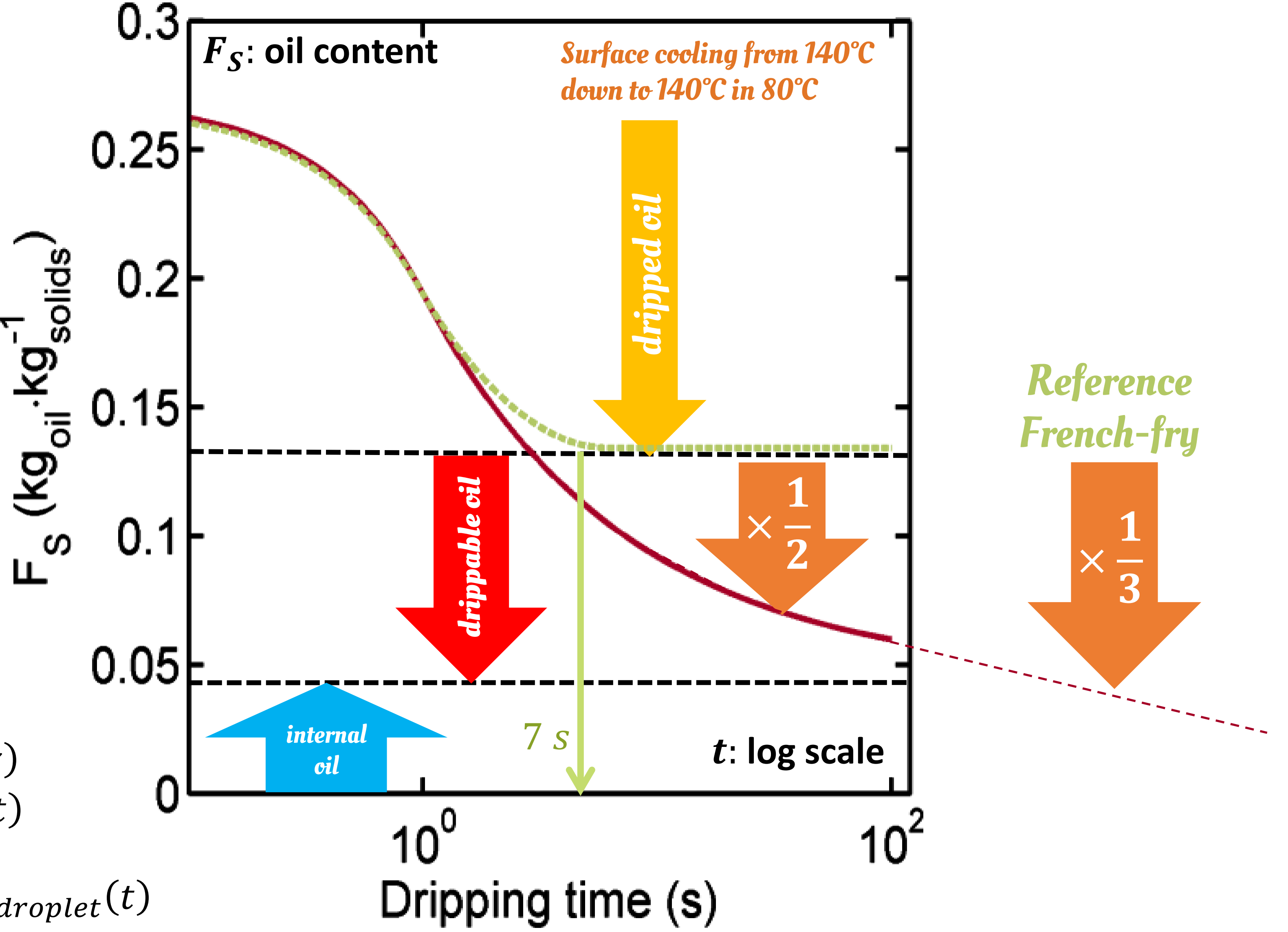












Theoretical oil reduction achievable

La prise d'huile est maîtrisable, partiellement réversible

⊕ *Facteurs limitants la prise d'huile*

- Surpression interne (*intermédiaire*)
- Présence d'air (*difficile*)
- Allonger le temps d'égouttage au delà de 7 s (*intermédiaire*)
- Force centrifuge ou autres (*simple*)
- Nouveaux paniers (*simple*)

⊖ *Facteurs favorisant la prise d'huile*

- Pomme de terre immergée congélée
- Produit frais découpé
- Retrait trop rapide du bain d'huile
- Refroidissement trop rapide
- Huile à point de fusion élevé (saturée)
- Egouttage en lit