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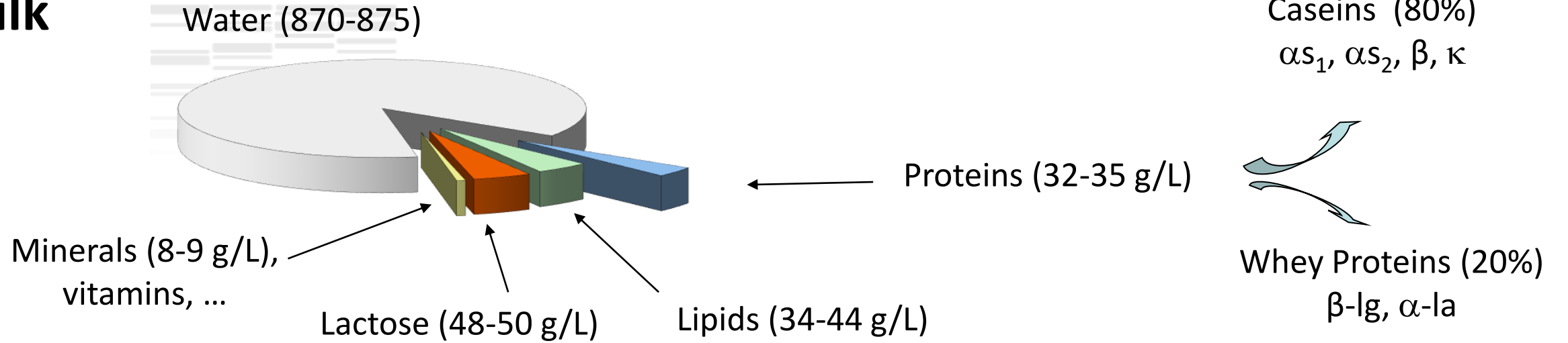
ROTORUA
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Casein micelle vs sodium caseinate: how does the difference in structure affect gastric emptying and protein metabolism in pigs?

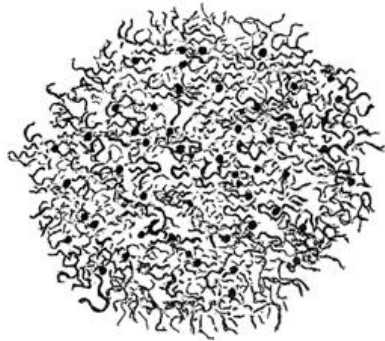
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1 STLO, INRA Agrocampus Ouest, Rennes, France - 2 Institut Numecan, INRA, INSERM, Univ Rennes, St-Gilles, France - 3 Ingredia Dairy Experts, Arras, France

Milk



$\varnothing \sim 200$ nm
(Holt, 1994)



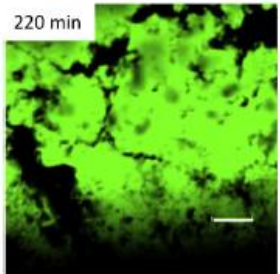
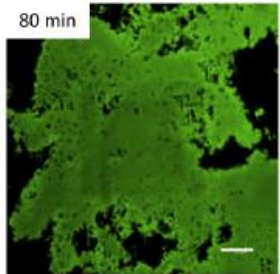
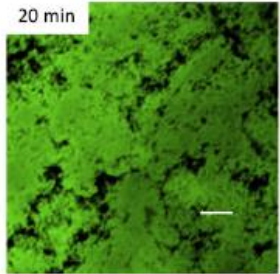
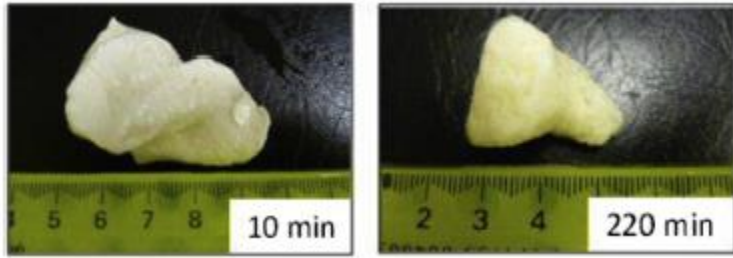
Casein organized into a supramolecular structure: the **casein micelle (CM)**



$\varnothing \sim 11$ nm
 ~ 15 casein molecules;
(Thomar *et al.* 2013)

Casein can also be extracted after acidification followed by neutralization: the **caseinate (CS)**

Milk coagulates in the stomach

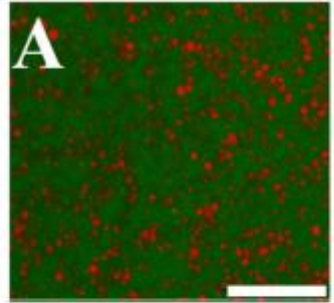

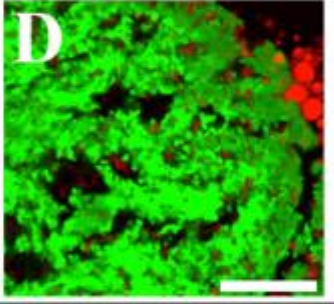

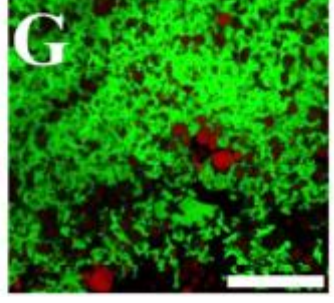



Unheated milk

In vitro demonstration using the HGS
Ye *et al.* 2016



Ye *et al.* 2019
In vivo evidence using a rat model

	Raw	
Initial		
36min		
182 min		

Mulet-Cabero *et al.* 2019
In vitro semi-dynamic model



Skim Milk Powder



Sodium Caseinate

Casein micelles and sodium caseinate form different coagulum
Wang *et al.* 2018

Objective

The objectives of the study were to:

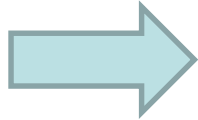
- 1 Determine whether gastric emptying of an isoproteic solution of CM and CS are different or not (exp. 1)
- 2 Characterize the structure of the resulting chyme and determine if CM and CS are differently metabolized (exp. 2)

Experiment 1 – Determination of Gastric Emptying

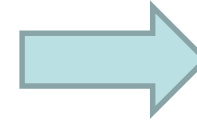
96 g of CM or CS
rehydrated in 800
ml of water

+12 g of glucose

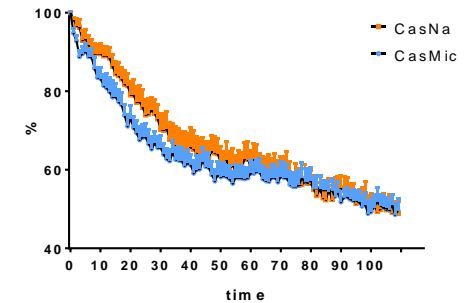
+ ^{99m}Tc -colloidal
(25Mbq)



9 pigs (20-25 kg)

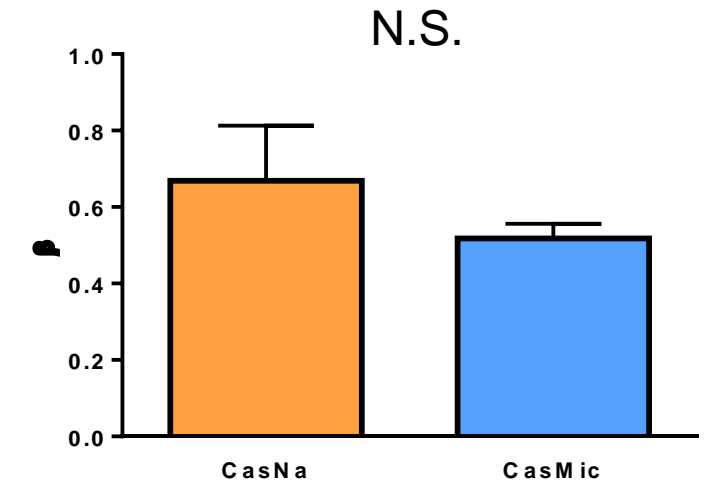
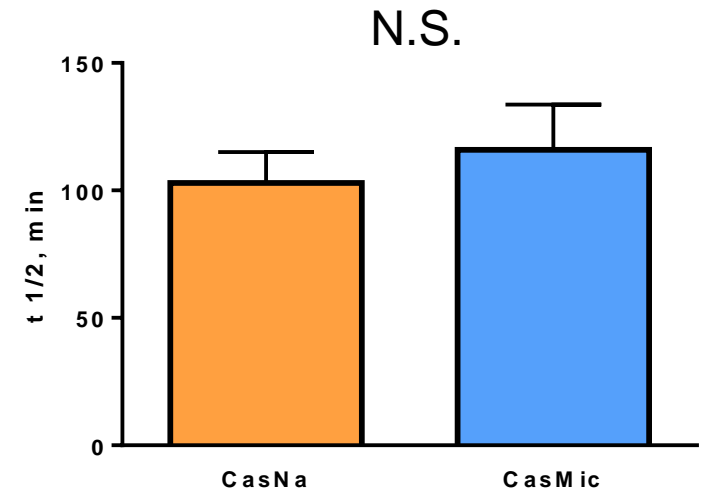
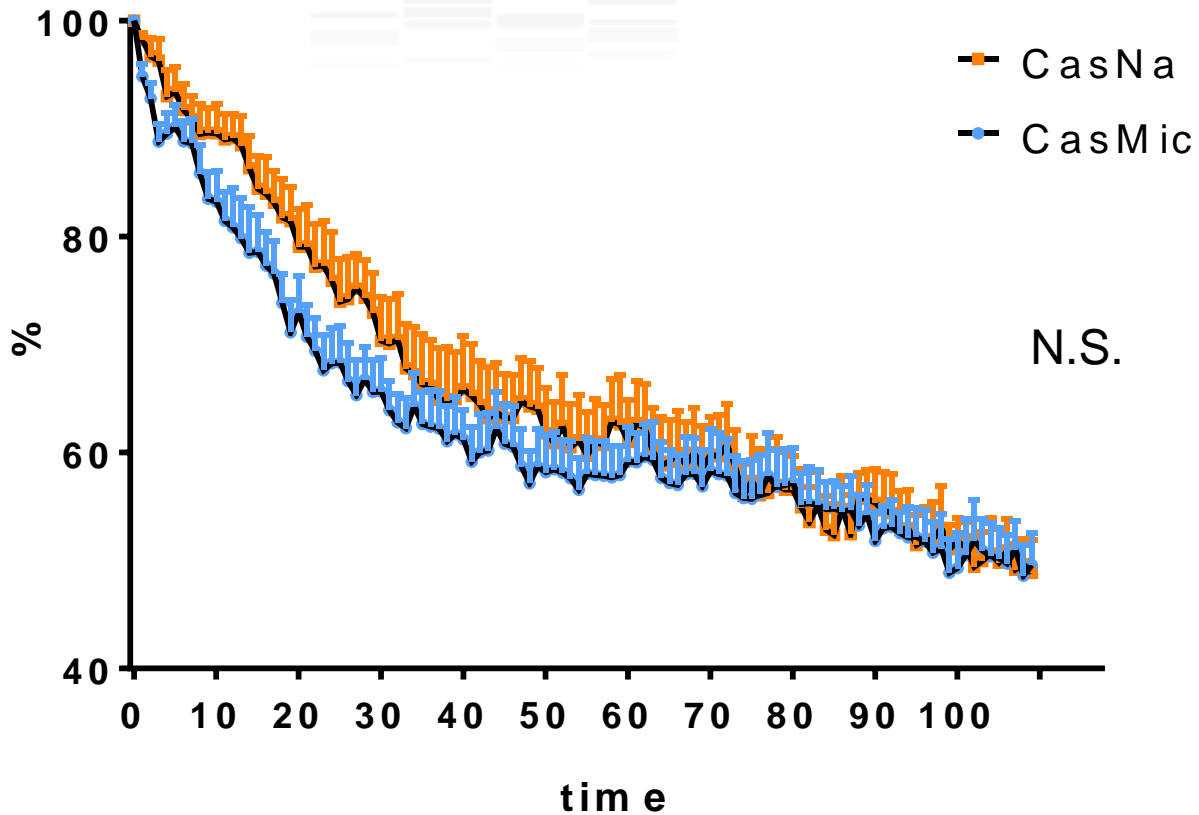


γ -scintigraphy over 120 min



Gastric emptying half-time ($t_{1/2}$)
and shape of the curve (β)

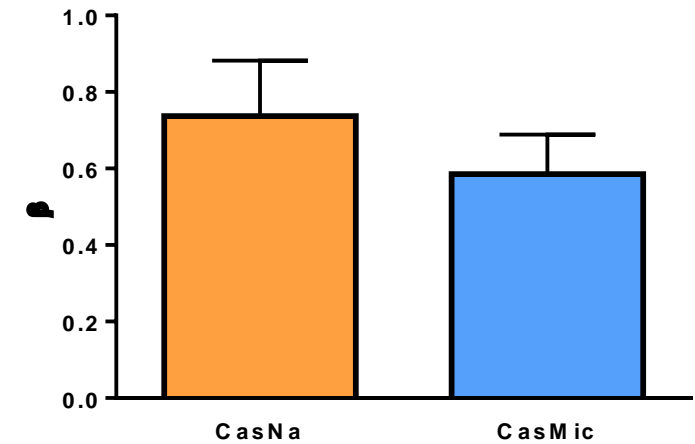
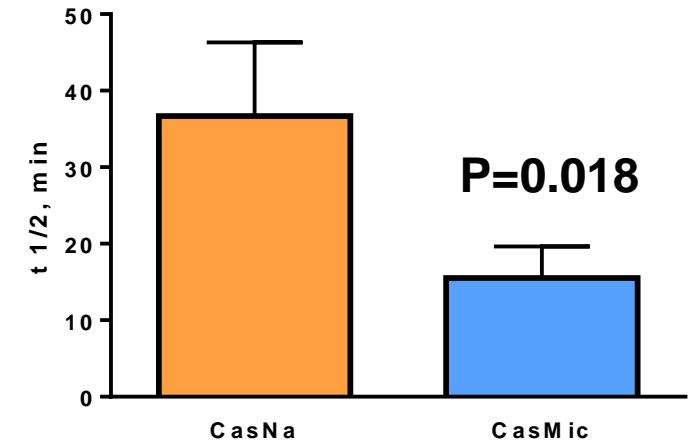
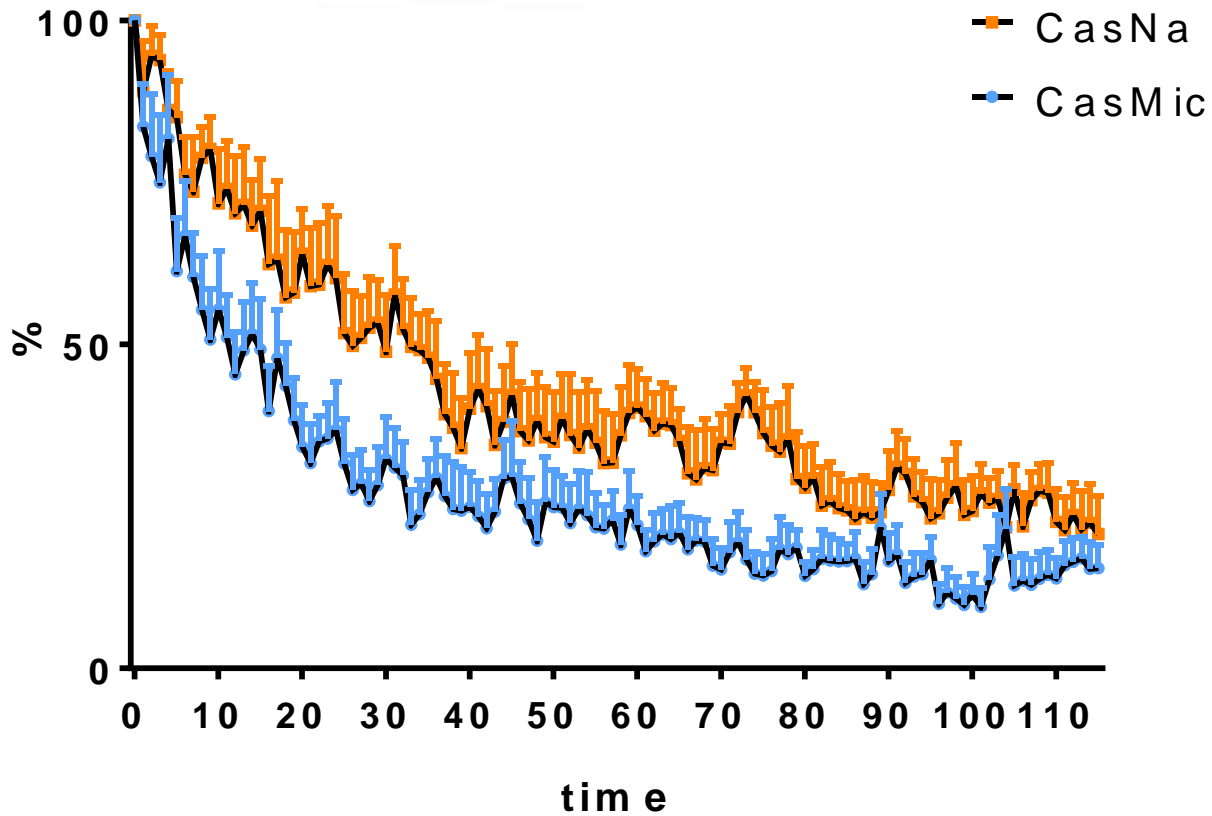
Gastric emptying



No significant differences in gastric emptying were observed by γ -scintigraphy when considering the whole stomach

Gastric Emptying – Proximal stomach

Casein structure P=0.029

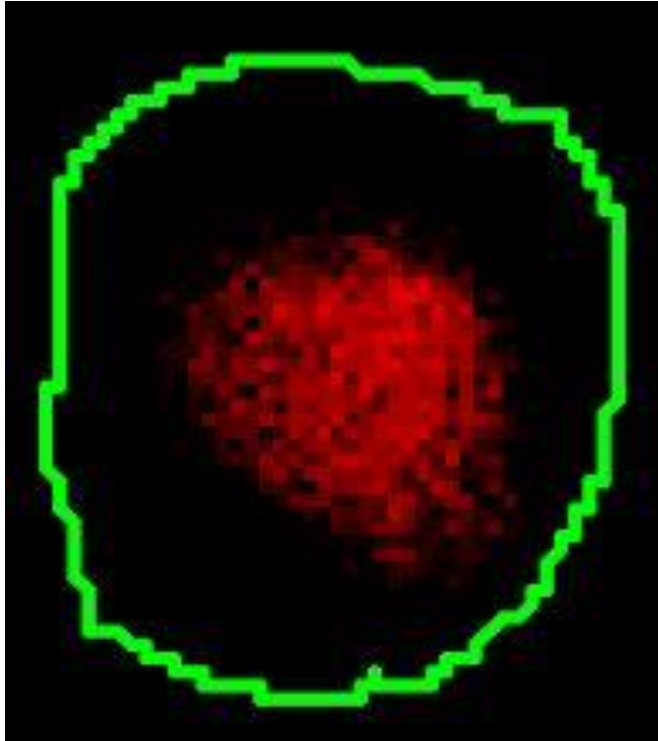


CS stays longer in the proximal stomach than CM

Differential behaviour of CS and CM in the stomach

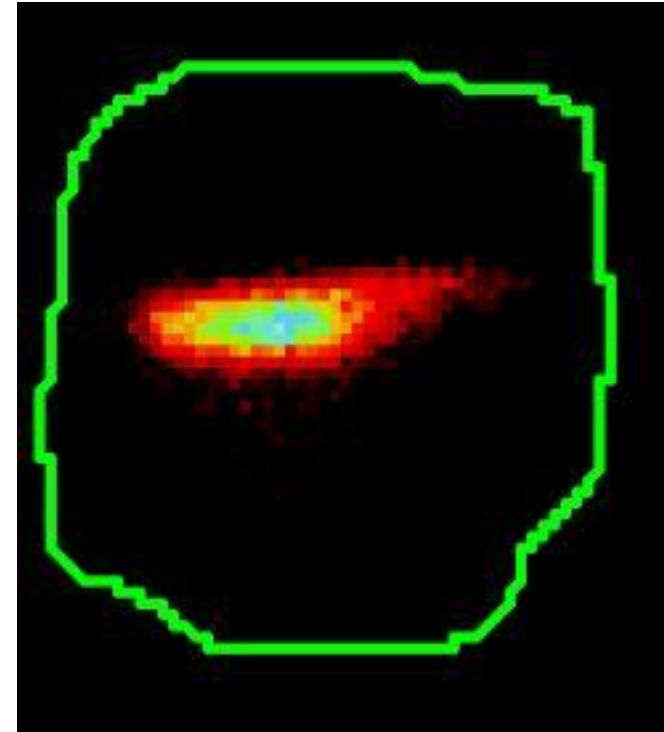
Exemple scintigraphic images at the beginning of gastric emptying (5-10 min after ingestion)

CM



Radioactivity fully fills the stomach

CS



Radioactivity is highly concentrated in the proximal part of the stomach

Objective

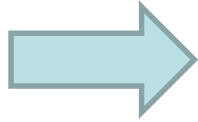
The objectives of the study were to:

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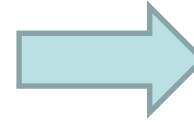
Experiment 2 – Chyme structure and protein metabolism

96 g of CM or CS
rehydrated in 800
ml of water

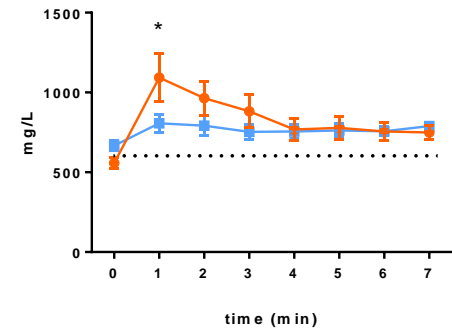
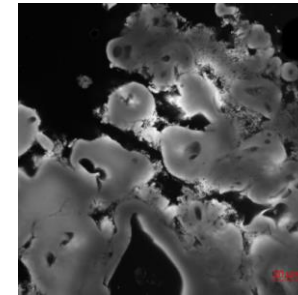
+12 g of glucose



6 catheterized pigs (20-25 kg)



Characterization of the chyme
structure (slaughtering after 10 min)



Free plasma amino acids over 7h



Collection of the stomach contents

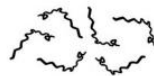


CM forms a large coagulum in the stomach whereas CS mainly remains in the liquid form

Liquid/solid repartition

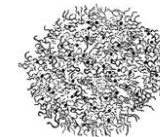
CS

Pig #	% of the meal in the stomach	% in the liquid phase	% in the solid phase
1	65	96	4
2	85	87	13
3	69	93	7
Mean	73	92	8
pH		6.3	5.1



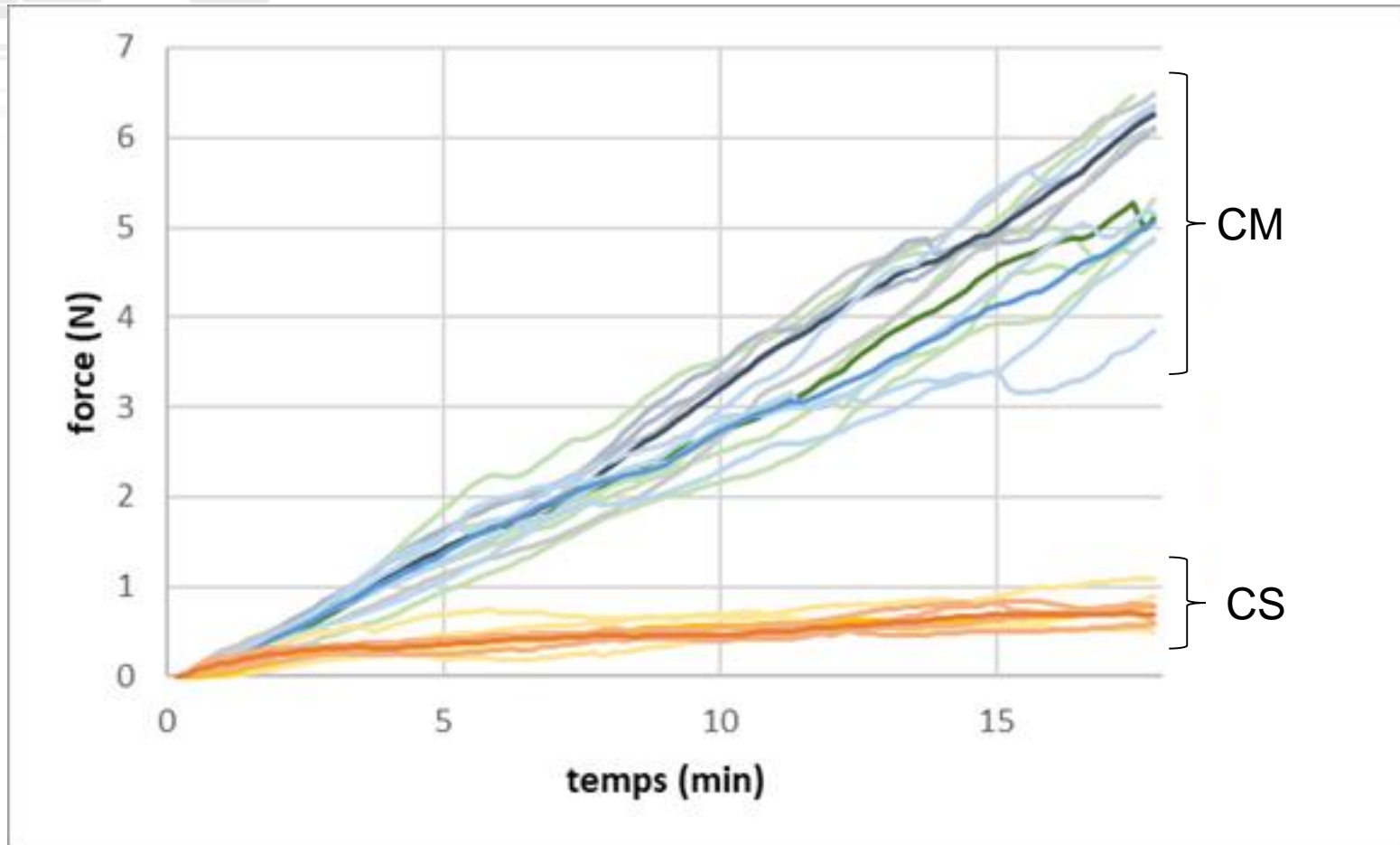
CM

Pig #	% of the meal in the stomach	% in the liquid phase	% in the solid phase
4	40	55	45
5	56	53	47
6	71	58	42
Mean	56	55	45
pH		6.4	6.1



Most of the meal is in a liquid form for CS whereas it is ~ equally distributed in the solid and liquid phases for CM

Rheological properties of the gastric chymes



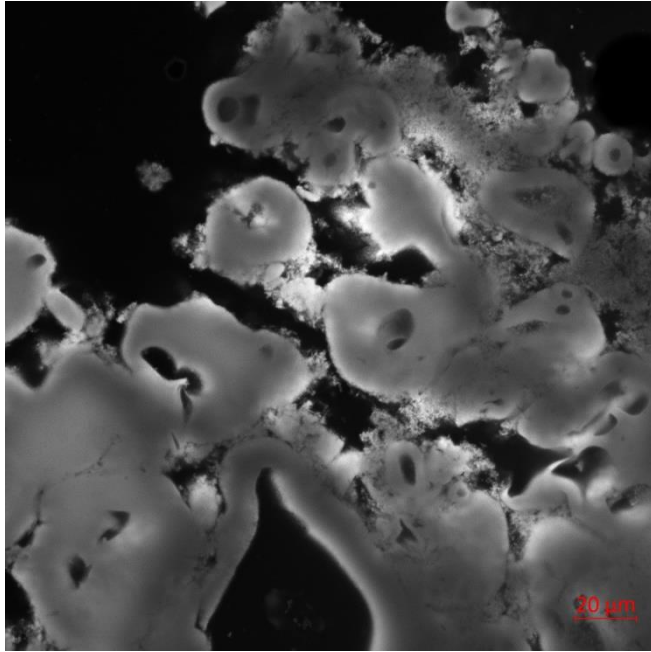
Heterogenous gels and high interindividual variability

CM gastric gels (blue) are much harder than the CS gels (orange)

CM

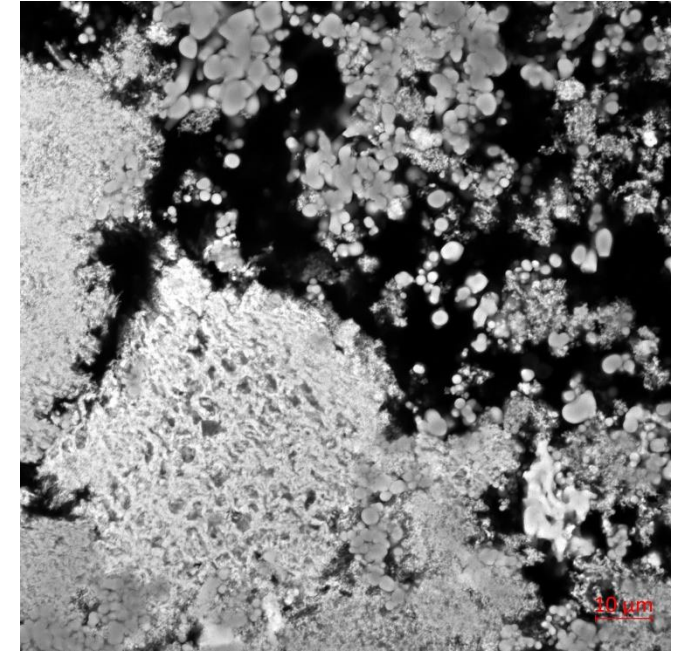
Microstructure of gastric gels

CS



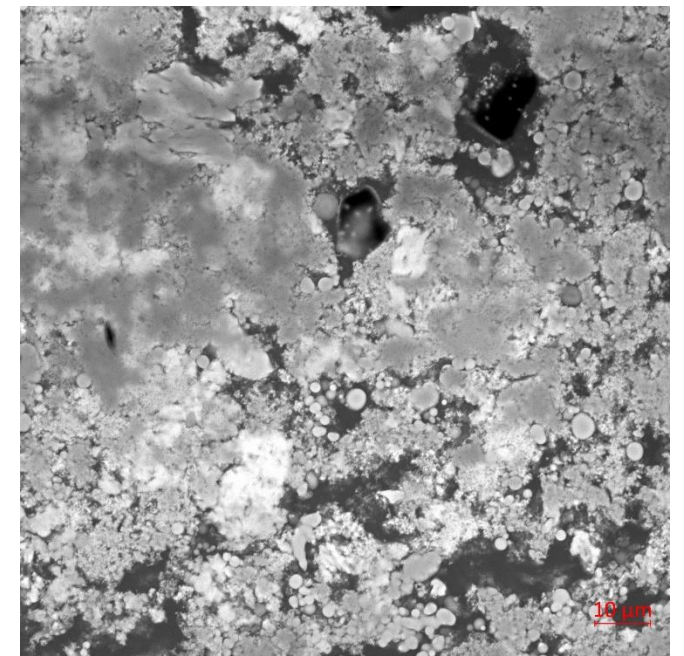
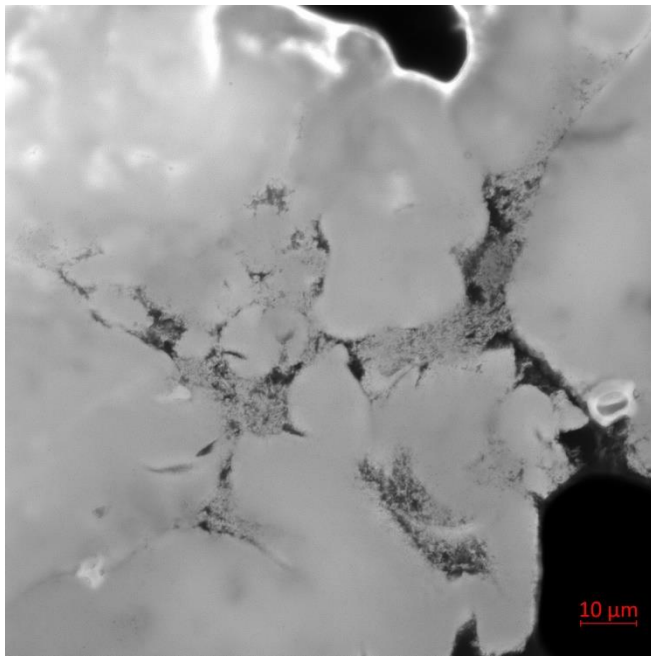
CM Gels (left) are compact and dense =

Strong coagulum

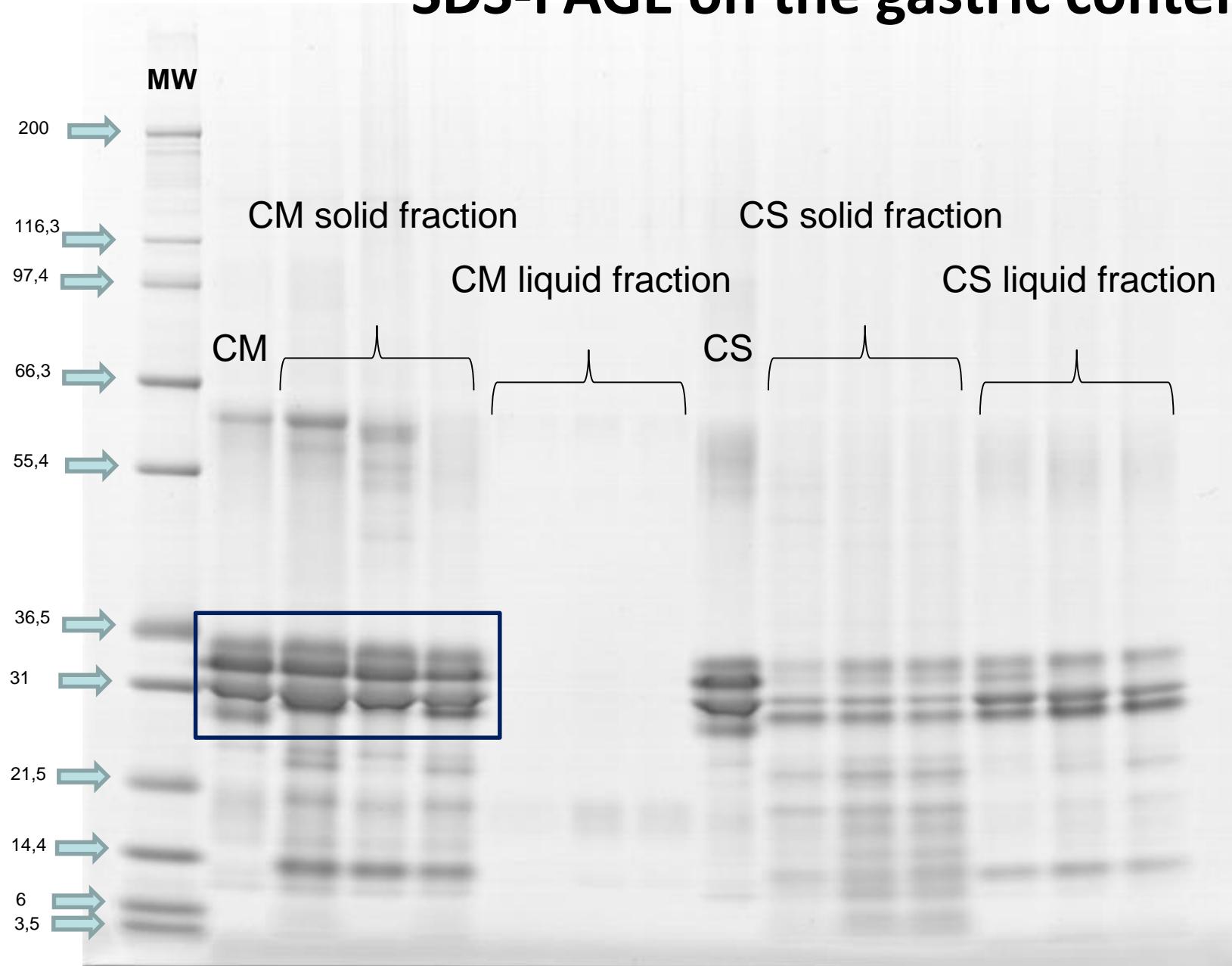


CS Gels (right) are an agglomerate of spherical particles that can easily dissociate. The gel have a very « loose » structure =

Protein precipitate



SDS-PAGE on the gastric contents

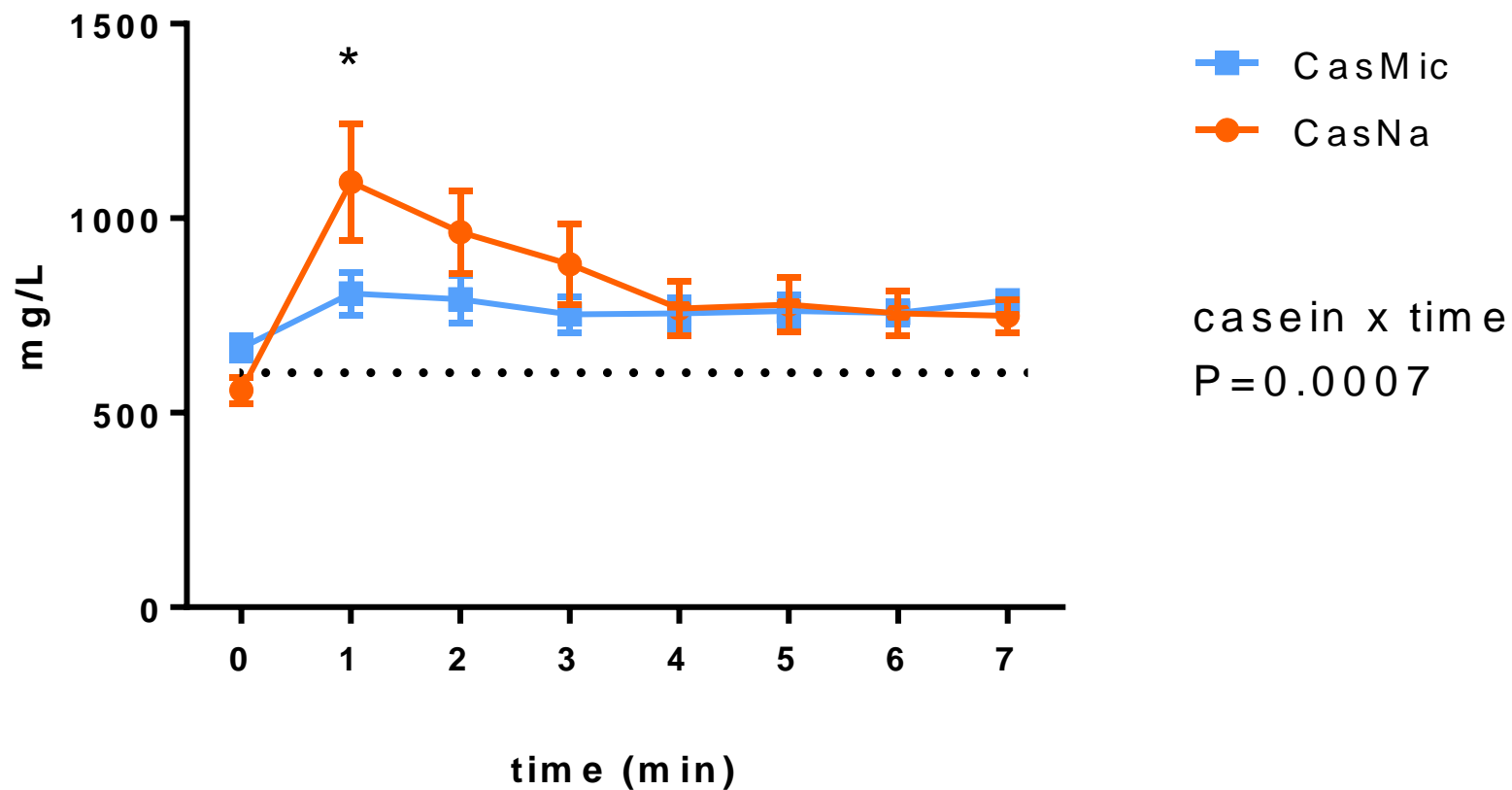


For CM, there are no visible proteins in the liquid fraction (concentration not high enough to be visible). The proteins are in the gel and do not seem to be hydrolyzed

For CS, proteins are present in both phases but mainly in the liquid fraction. They seem to be hydrolyzed in the solid fraction

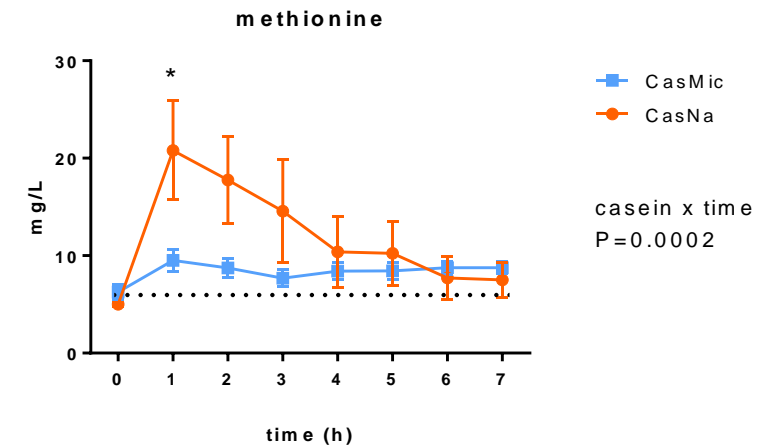
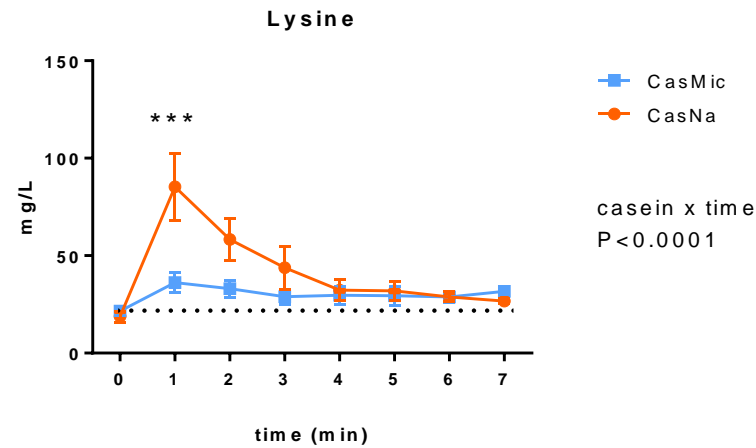
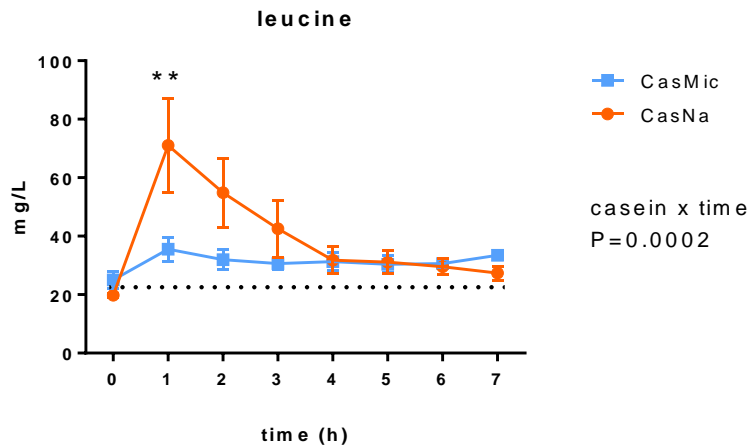
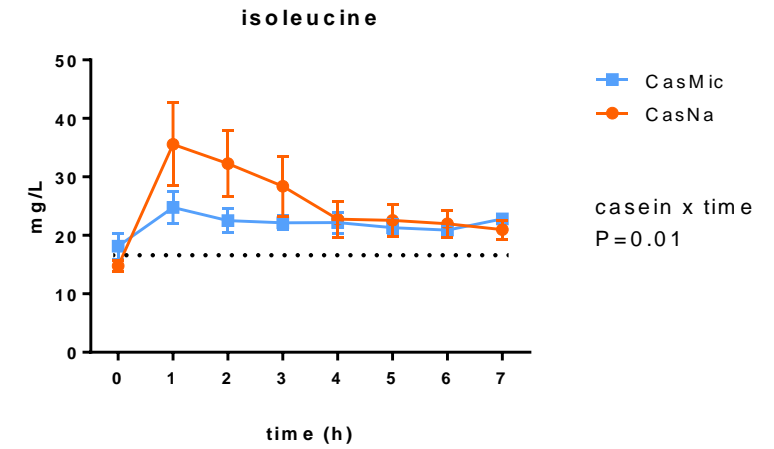
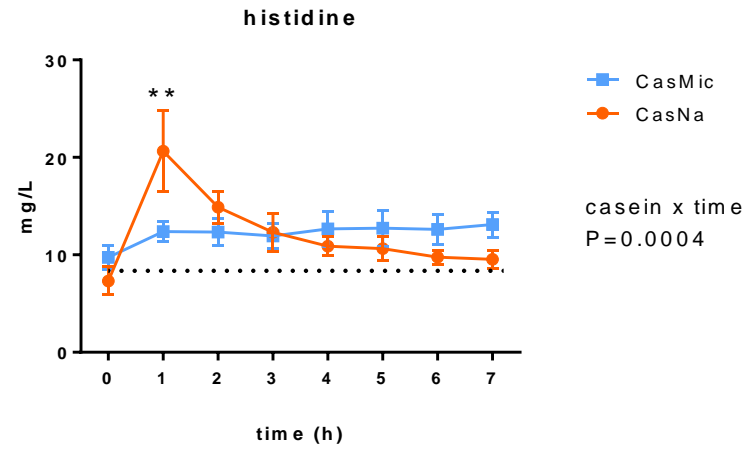
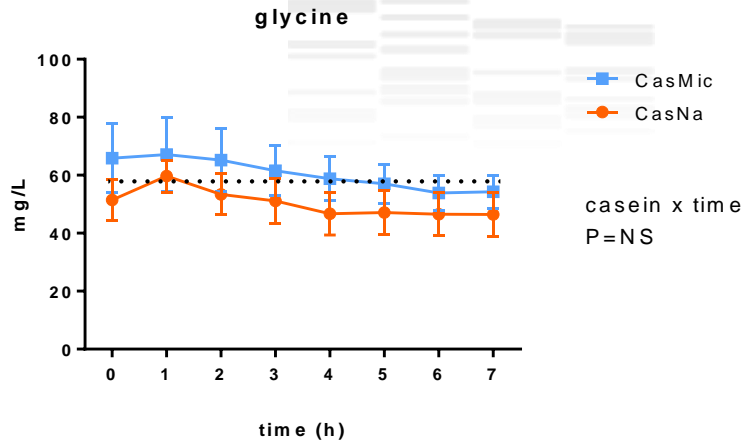


Plasma amino acids



AA peak after 1h for CM whereas the concentration remains stable for CS

Plasma concentration of 6 AA after CM or CS digestion



No significant differences were observed with non-dietary AA



Conclusion

- * CM form a strong coagulum in the stomach leading to a slow and constant release of plasma amino acids up to 7 h
- * CS form a loose precipitate in the proximal part of the stomach but most of the caseins remain solubilized in the liquid fraction
- * CS are rapidly metabolized in the small intestine leading to the appearance of a peak of plasma amino acids one hour after protein ingestion

CM = slow caseins, CS = fast caseins

Perspectives

- (1) Do some *in vivo* kinetics experiments
- (2) Use ^{15}N labelled-caseins to differentiate endo/exogenous proteins

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Improving health properties of food by sharing our knowledge on the digestive process

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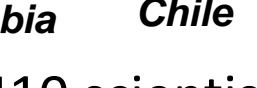
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