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Impact of processing on the *in vitro* gastric digestion of sheep milk

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Digestion of milk

> **Bovine milk**

> **Non-bovine milk**

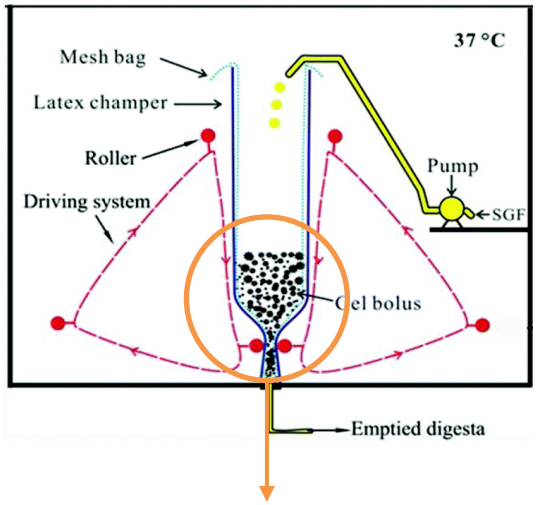
- Human
- Goat
- Deer
- Donkey
- Sheep
- Camel
- Mare

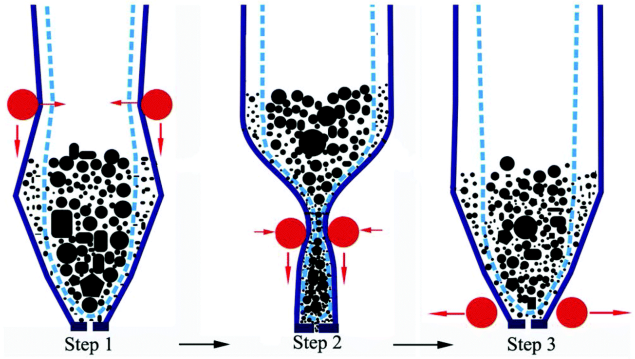
Parameter	Sheep	Cow
Total solid (g/100g)	18.6	12.1
Fat (g/100g)	5.9	3.3
Protein (g/100g)	5.6	3.4
Casein (g/100g)	4.1	2.5
α_{s2}-CN (%)	22.8	10.3
α_{s1}-CN (%)	6.7	39.7
β-CN (%)	61.6	32.7
κ-CN (%)	8.9	11.6
Whey proteins (g/100g)	1.3	0.9
β-Lg (%)	60.8	50.5
α-La (%)	25.6	19.6

Factors affecting digestion behavior

- Compositions
- Structures → Altered by Processing treatment

In vitro gastric digestion model: Human gastric simulator (HGS)



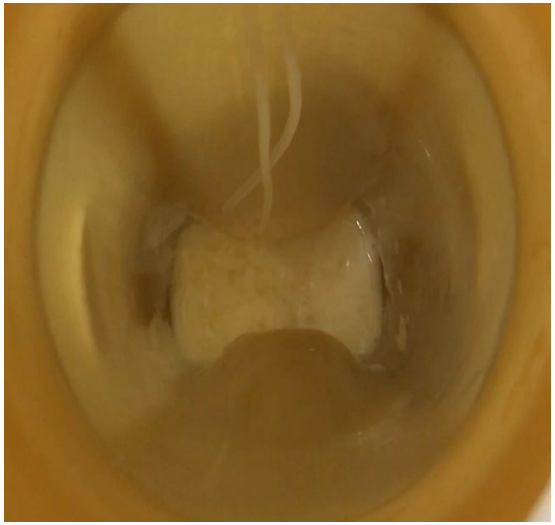


Kong & Singh, 2010

Main features:

- **Biochemical processes**
- **Temperature:** 37°C
- **Simulated gastric fluid (SGF):** 2000 U/ml pepsin, pH 1.5, 150 mM NaCl…
- **Secretion rate:** 3.0 ml/min
- **Peristaltic movement:** 3 cycles/min (contraction frequency)
- **Emptying rate:** 72 ml per 20 min

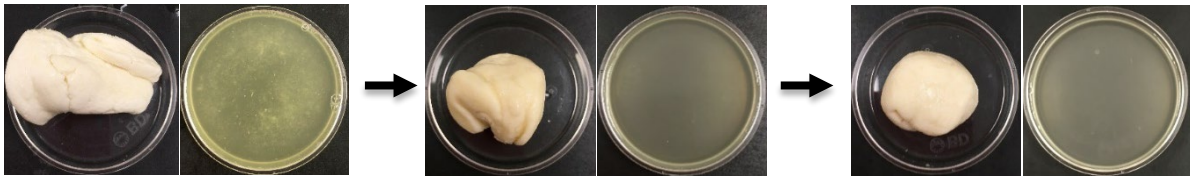
Gastric digestion of raw sheep milk in HGS



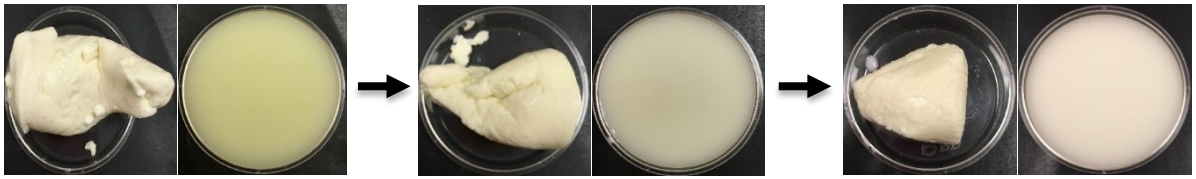
First 15 min of gastric phase

30 min 90 min 210 min

Raw sheep skim milk



Raw sheep whole milk



Left shows curd, right shows digesta

Roy, D., Ye, A., Moughan, P.J., and Singh, H. (2020). [Structural changes in milk during digestion]. Unpublished raw data.

Research protocol:

Preliminary experiments on gastric digestion of processed sheep milk

Sheep milk:

1. Raw
2. Pasteurization (75°C, 15s)
3. Homogenization-pasteurization (200/50 bar -75°C, 15s)
4. Homogenization-heat (200/50 bar - 95°C, 5 min)

HGS

Milk sample: 200 g

SGF: pH 1.5

Pepsin: 2000 U/ml

Gastric digestion time: 240 min

Digesta emptying:

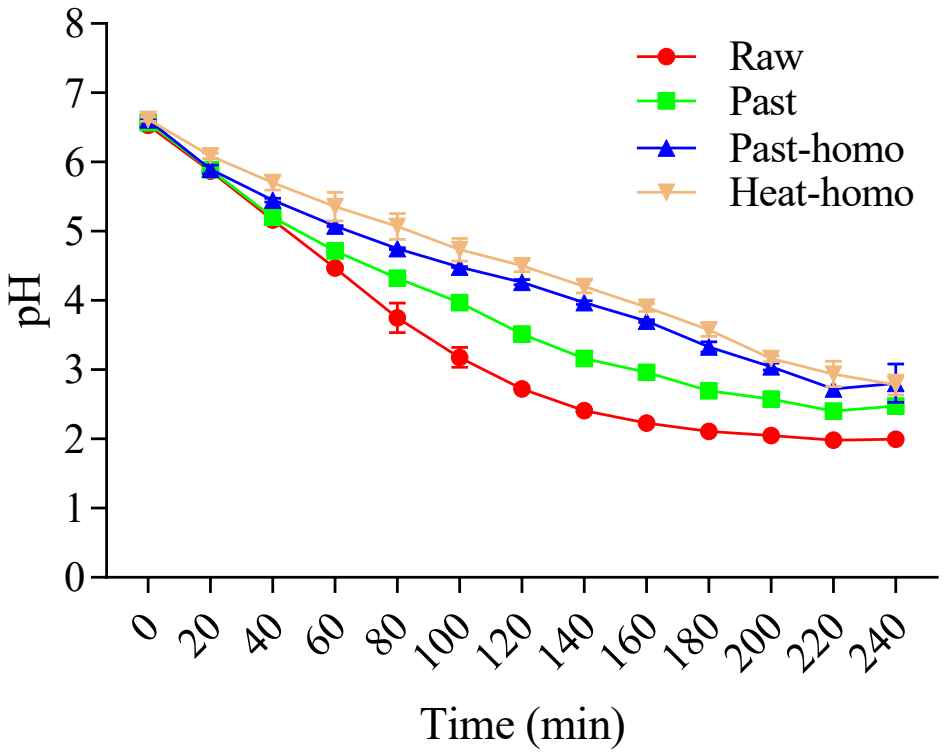
72 ml per 20 min through 1-mm sieve

Analysis:

- pH
- Curd appearance
- Curd content
- Rheological analysis
- Confocal microscopy

Gastric digestion of sheep milk:

pH of digesta at different digestion time



- pH in all samples decreased gradually as digestion time increased
- Thermal processed or homogenized milk could slower the decrease in pH

Figure. 1. pH changes during the gastric digestion of differently processed sheep milk: ●, raw milk; ■, pasteurized (Past) milk; ▲, pasteurized and homogenized (Past-homo) milk; ▼, heated and homogenized (Heat-homo) milk

Gastric digestion of sheep milk:

Curds' structure of different milk samples during gastric digestions

Looser, more fragmented, less integrated

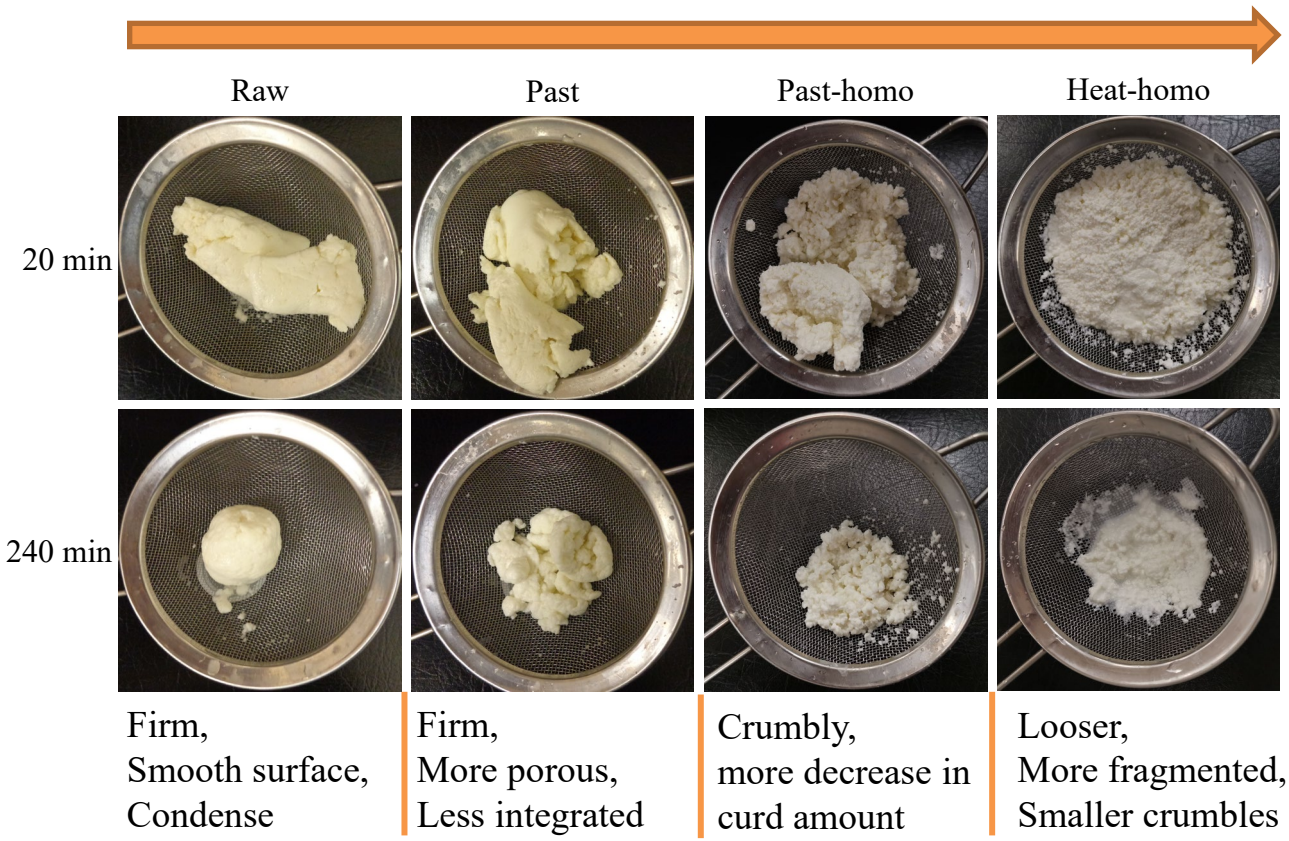
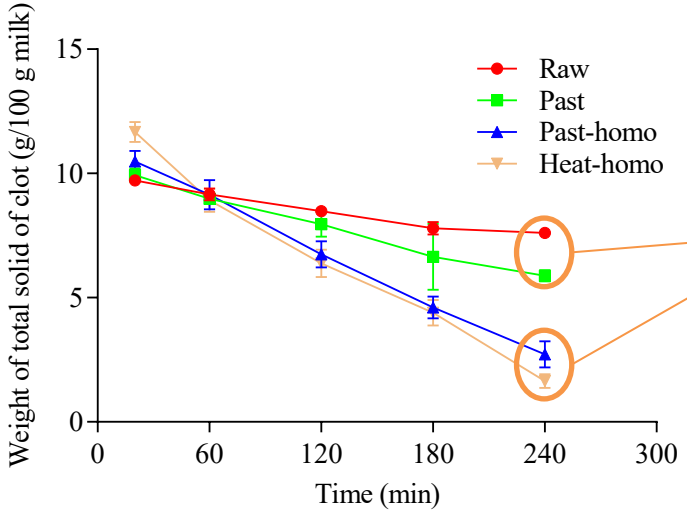


Figure 2. Images of curds formed during the gastric digestion

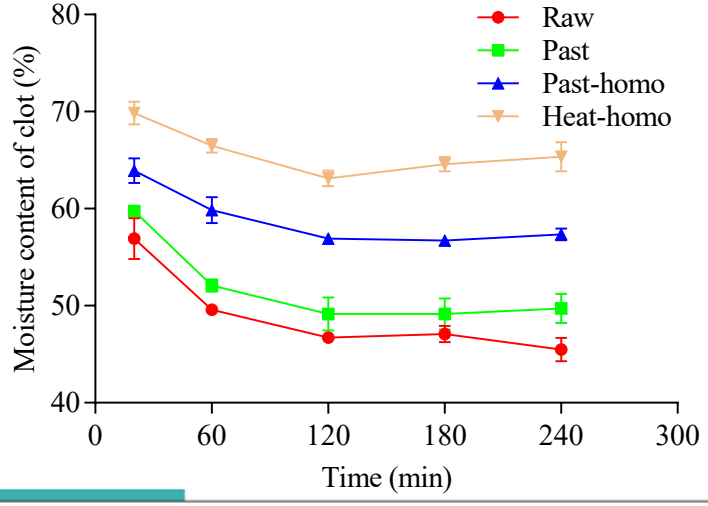
Gastric digestion of sheep milk:

Total solid and moisture content of curds



- The total solid content of curds in homogenized milk decreased more rapidly than unhomogenized milk

Figure 3. Changes in weight of total solid of curd during the gastric digestion of differently processed sheep milk

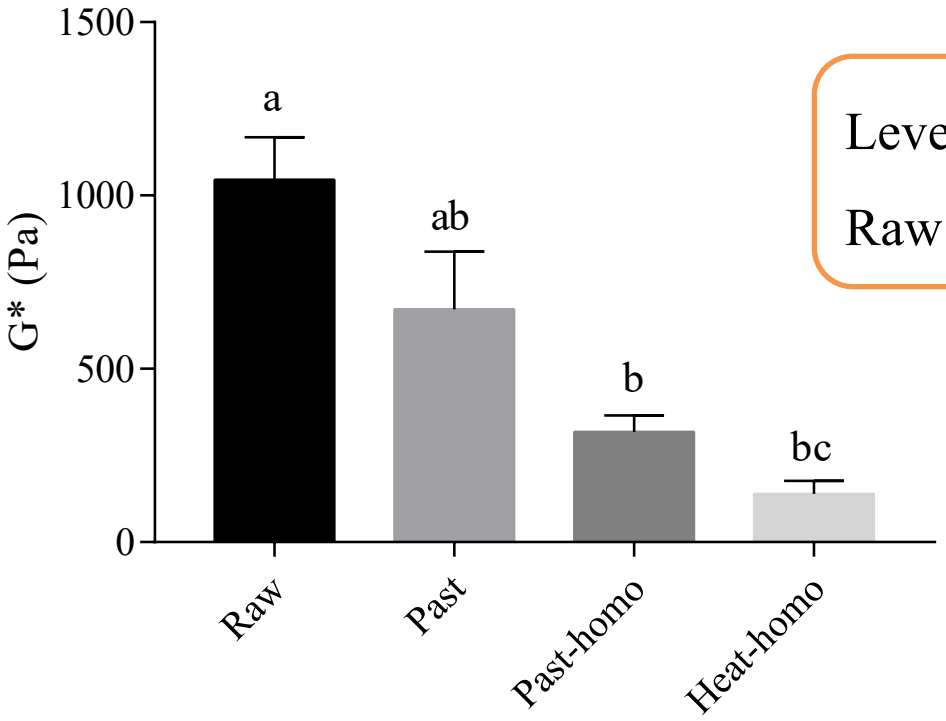


Hydration of the curd throughout the period of gastric digestion:
Raw < Past < Past-homo < Heat-homo

Figure 4. Changes in moisture content of curd during the gastric digestion of differently processed sheep milk

Gastric digestion of sheep milk:

Rheological properties of milk curds (complex modulus, G*)



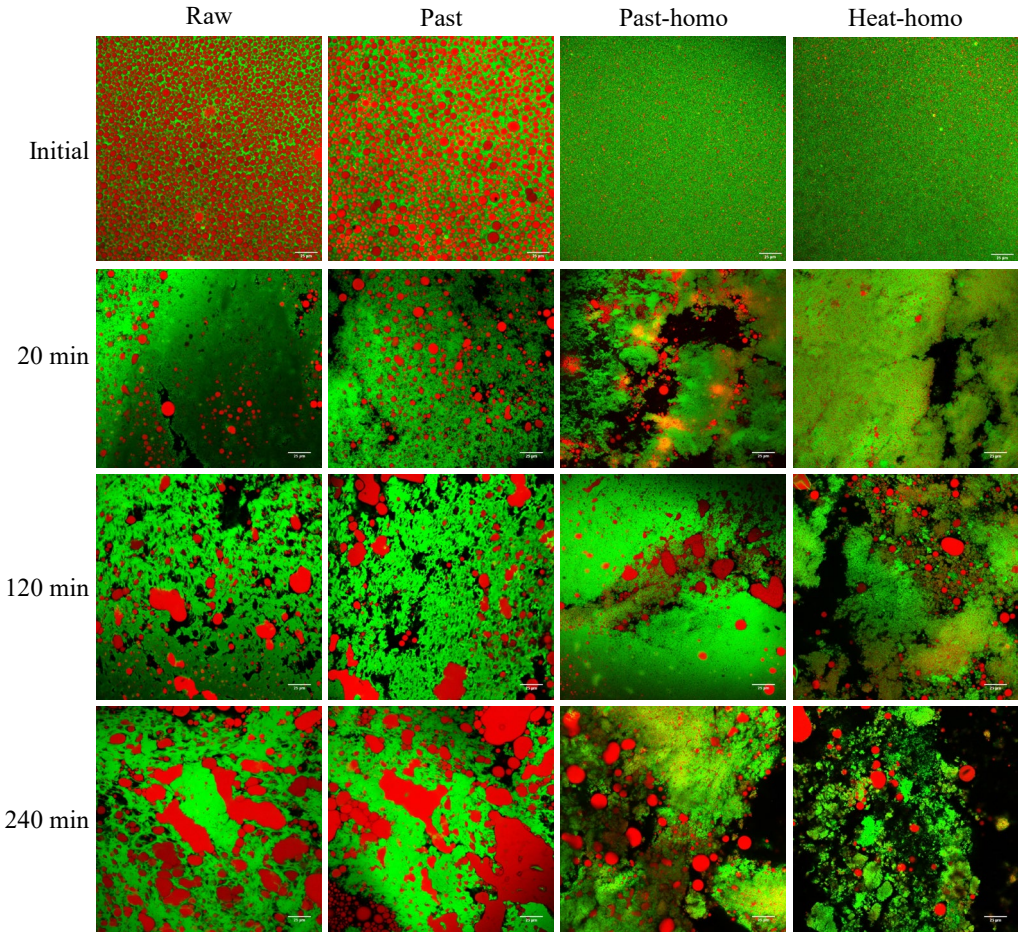
Level of resistance to curd deformation:

Raw > Past > Past-homo > Heat-homo

Figure 5. Complex modulus, G*, at 10 min of shear of the milk curd collected at the end of digestion time (240 min)

Gastric digestion of sheep milk:

Confocal microscopy images of curd structure



- Fat globules evenly distributed in protein aqueous phase

- Closely-knit network of protein matrix in all samples
- Fat globules distributed in the matrix

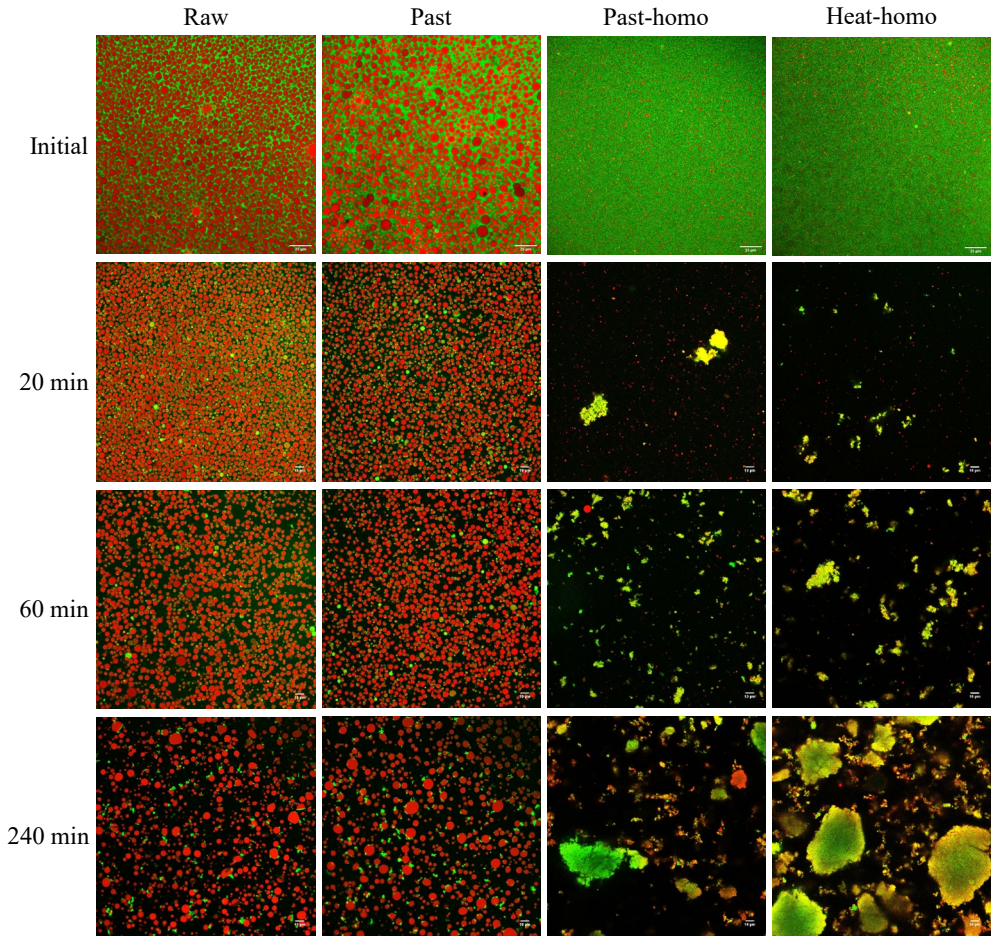
- Signs of fat globule coalesence

- Further coalescence of fat globules
- Curd's structure in homogenized samples is looser with more pores

Figure 6. Confocal microscopy images (**red shows fat, green shows protein ;** scale bar: 25 μm)

Gastric digestion of sheep milk:

Confocal microscopy images of digesta



- Fat globules evenly distributed in protein aqueous phase
- More fat globules remained in the digesta of unhomogenized milk
- Most proteins disappeared in all digesta samples
- More protein particles presented in homogenized milk samples

Figure 7. Confocal microscopy images (**red shows fat, green shows protein;** scale bar: 10 μm)

Conclusions

- Sheep milk could form structural curds as found in cow milk during gastric digestion
- Processing affects pH changes during gastric digestion
- Processing could influence the structures, composition, and rheological properties of curd
- Processing could result in different composition and structure of gastric digesta and hence affect the delivery of nutrients to the small intestine

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