Pressure, shear, thermal and interaction effects on quality of raw milk treated by Continuous High Pressure Processing system

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INTRODUCTION

- Continuous High Pressure Processing (HPP) system involves pressurization of liquid foods upto high pressure of 400 MPa and subsequent depressurization by passage through a tiny clearance
- The intense pressure, shear, and heat generated during process facilitate emulsification, particle size, enzyme and microbial reduction in liquid foods, like milk
- Previous studies did not consider the contributions of individual process parameters (pressure, temperature, shear) and their interactions
  - Such knowledge will be useful for food processors and equipment developers to understand the role of the process parameters and their interactions on food product safety and quality

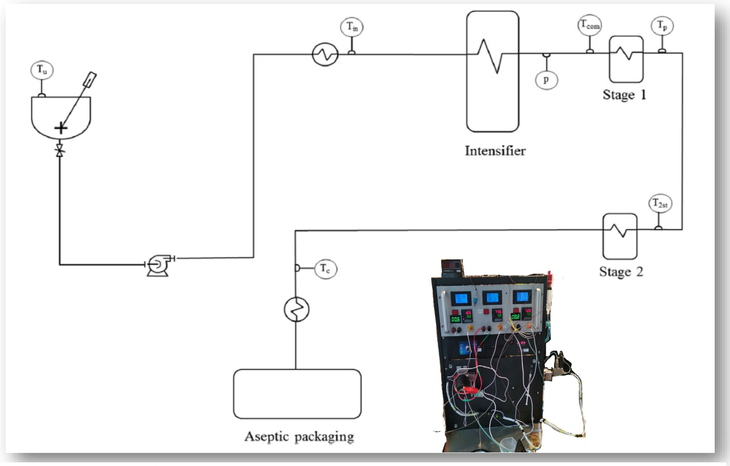


Fig. 1: Continuous High Pressure Processing System

OBJECTIVE

To study the effect of pressure, shear, temperature and their interaction during continuous high pressure process on quality attributes of raw milk

MATERIALS AND METHODS

Experimental design

1) Continuous HPP

- **Pressure:** 400 MPa
- **Process temperature:** i) 70°C – Thermal effect; ii) 40°C – No thermal effect
- **Shear:**
  - Shear flow rates – 70°C: Low (0.41±0.10g/s) & High (1.05±0.06g/s)
  - Shear flow rates – 40°C: Low (0.16±0.11g/s) & High (1.41±0.63g/s)

2) Batch HPP — Pressure only! No Shear!

- 400 MPa – 42.02±0.7°C- 1 s
- 400 MPa – 42.89±0.4°C- 3 min

3) Control - Fresh Raw milk

Source: https://www.madebycow.com.au/nutrition

Source: https://www.cdc.gov/features/rawmilk/index.html

Fig. 2: Need for minimally processed liquid beverages

Analyses

RESULTS

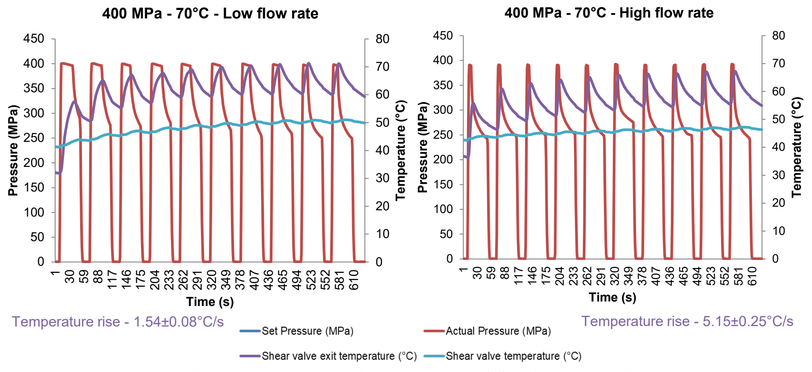
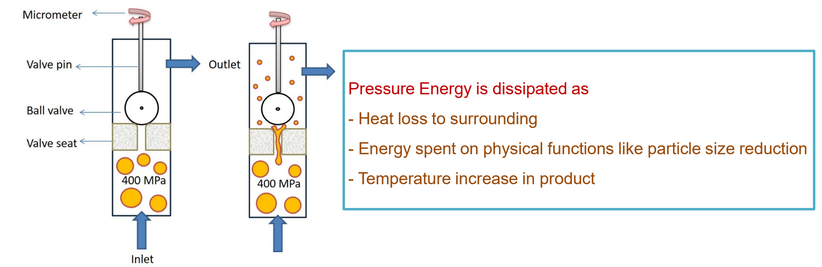


Fig. 3: Pressure-Temperature history of Continuous HPP samples

Table 1: Temperature history during Continuous HPP

	Pressure (MPa)	Initial milk T (°C)	T rise by pressure (°C) @ ~3°C/100 MPa	T rise by shear (~°C) @ ~26°C/100 MPa	Final theoretical T (°C)	Actual T (°C)	Temperature lost (°C)	Loss (%)
Continuous HPP at 70°C								
Low flow rate	400	25	12	104.8	141.8	69.52	72.28	50.97
High flow rate	400	25	12	104.8	141.8	65.48	76.32	53.82
Continuous HPP at 40°C								
Low flow rate	400	15	12	105	132	30.49	101.51	76.90
High flow rate	400	15	12	105	132	38.24	93.76	71.03



Pressure Energy is dissipated as
- Heat loss to surrounding
- Energy spent on physical functions like particle size reduction
- Temperature increase in product

Fig. 4: Shear valve operation

Shear followed by pressure reduced fat-protein particle size

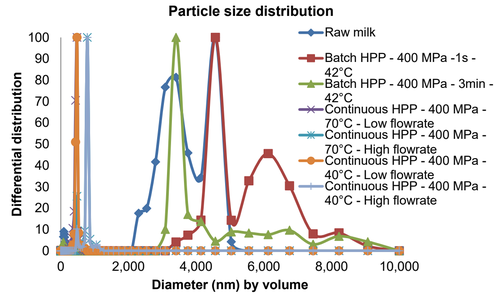
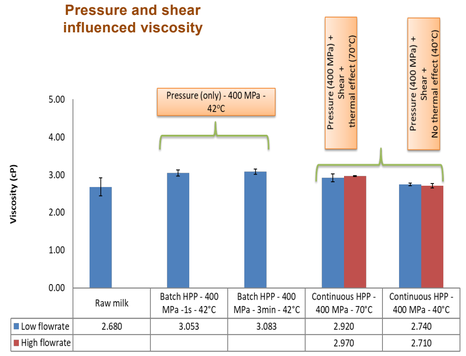


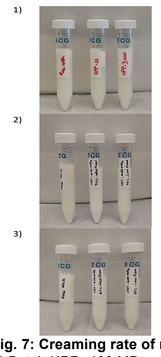
Fig. 5: Particle size distribution of milk samples

Pressure and shear influenced viscosity



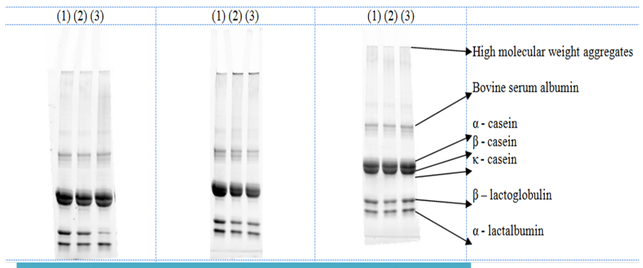
	Raw milk	Batch HPP - 400 MPa -1s - 42°C	Batch HPP - 400 MPa - 3min - 42°C	Continuous HPP - 400 MPa - 70°C	Continuous HPP - 400 MPa - 40°C
Low flowrate	2.680	3.053	3.083	2.920	2.740
High flowrate				2.970	2.710

Fig. 6: Viscosity of milk samples



No creaming in continuous HPP samples

Fig. 7: Creaming rate of raw milk vs
1) Batch HPP -400 MPa - 42°C - 1s & 3 min
2) Continuous HPP – 400 MPa - 70°C – Low & High flow rate
3) Continuous HPP – 400 MPa - 40°C – Low & High flow rate



A	B	C
1) Raw milk	1) Raw milk	1) Raw milk
2) Batch HPP - 400 MPa – 40°C – 1 s	2) Continuous HPP – 400 MPa – 70°C – Low flow rate	2) Continuous HPP – 400 MPa – 40°C – Low flow rate
3) Batch HPP – 400 MPa – 40°C - 3min	3) Continuous HPP – 400 MPa – 70°C – High flow rate	3) Continuous HPP – 400 MPa – 40°C – High flow rate

Temperature and Pressure influenced protein fractions

Fig. 8: SDS−PAGE analysis of milk samples

CONCLUSIONS

- Batch pressure only treatment did not have significant effect ($p>0.05$) on particle size, but had significant effect ($p<0.05$) on viscosity and creaming rate of samples
- Continuous HPP involving pressure associated shearing action significantly ($p<0.05$) reduced particle size
- Within the range of the experimental conditions, process temperature during continuous HPP did not have any significant effect ($p>0.05$) on particle size
- The temperature of continuous HPP had varying effect on the proteins, with 40°C treatment retaining better protein quality
- Shear flow rates did not exhibit significant effect ($p>0.05$) on quality attributes, despite different rates of temperature rise
- The findings revealed the differential effect of pressure, shear, temperature and their interactions during continuous HPP treatment on raw milk quality

REFERENCE

Hayes, M. G., Fox, P. F., & Kelly, A. L. (2005). Potential applications of high pressure homogenisation in processing of liquid milk. *Journal of Dairy Research, 72*(1), 25-33.
Martínez-Monteagudo, S. I., Kamat, S., Patel, N., Konuklar, G., Rangavajla, N., & Balasubramaniam, V. M. (2017). Improvements in emulsion stability of dairy beverages treated by high pressure homogenization: A pilot-scale feasibility study. Journal of Food Engineering, 193, 42-52.

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