Storage of foods under mild pressure (hyperbaric storage) at variable (uncontrolled) room temperature – a possible new preservation concept and an alternative to refrigeration

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High pressure room temperature/cold pasteurization by microbial inactivation
Introduction

First observations:

40 years ago the Sub-marine Alvin sank to a depth of ~ 1,540 m (~15 MPa at ~4 °C)

✓ When rescued 10 months later, well-preserved foods (bouillon, sandwiches and apples) were recovered

✓ Possible improvement of refrigeration by additional microbial growth inhibition

✓ Still energy consumption throughout the storage period
Introduction

What about storage under pressure at ~ room temperature?

Advantages

✓ No energy consumption during storage

✓ Energy needed only for compression and decompression

✓ Reduced ecological footprint and better environmental sustainability
Questions

✓ Q1 - Can food storage under pressure (Hyperbaric Storage - HS) be used as a food preservation methodology by slowing down/inhibiting microbial growth similarly to refrigeration?

✓ Q2 - Can HS work at and above room temperature conditions and so under naturally variable (uncontrolled) room temperature conditions and basically energetically costless?
First observations:

Tilapia fillets at controlled 25 ºC

- 12 h at 101 MPa total plate counts similar to the initial (~ 4.7 Log CFU/g); at 203 MPa a reduction to 2.0 Log CFU/g
- Same results for psychrophilic bacteria 101 and 203 MPa
- K value - at 203 MPa showed a higher freshness than control (0.1 MPa)
- Posthyperbaric storage for 12 h at 25 ºC - enzymes were active and microorganisms could grow
  - inhibitory effect caused by pressure was not caused by microbial inactivation but by growth inhibition

Introduction

Recent observations:

Strawberry juice (acid food) at controlled 20ºC for 15 days

- At 0.1 MPa after - microbial loads increased by > 3 Logs (total aerobic mesophiles and yeasts/moulds), with unpleasant smell and gas production
- Under refrigeration (5 º) C - 2 Log units increase for total aerobic mesophiles
- Under pressure (25, 100 and 220 MPa ) - microbial loads below the detection limits

Experimental Strategy and Methods

Our experiments:

Constrains

✓ Very long experimental times to compare with refrigeration results
  ✓ Long use of pressure equipments needed for other experiments

✓ Strategy
  ✓ Highly perishable foods (non acid & high $a_w$) as proof-of-concept case-studies
  ✓ First experiments with watermelon and melon juices
  ✓ Followed by other foods at and above room temperature
  ✓ First experiments in an industrial high pressure equipment
Methodology

8, 16, 24 and 60 hours:
• 0.1 MPa at 5 °C
• 100 MPa at ≈ 20 °C

Microbiological Analyses:
• Total aerobic mesophiles
• Enterobacteriaceae
• Yeasts and moulds

Physicochemical Analyses:
• pH
• Titratable acidity
• Browning degree
• Cloudiness
• Total soluble solids
A. Microbiological Analyses

Values shown as 6 and 1 log units are meant to be higher than 6 and lower than 1 log units, respectively.
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A. Microbiological Analyses

✓ Storage at atmospheric pressure (0.1 MPa; 20 °C):  

✓ After 24h, microbial levels were already above quantification levels and unacceptable for consumption

✓ Hyperbaric storage (100 MPa; 20 °C):  

✓ After 8h, the initial microbial loads were reduced and remained thereafter unchanged up to 60h of storage
**A. Microbiological Analyses**

- **Storage at atmospheric pressure** (0.1 MPa; 30 °C):
  - Faster microbial growth after 8h, compared to 20 °C

- **Hyperbaric storage** (100 MPa; 30 °C):
  - Similar results compared to 20 °C
  - Can foods be preserved under pressure above room temperature?

Values shown as 6 and 1 log units are meant to be higher than 6 and lower than 1 log units, respectively.
A. Physicochemical Analyses

Hyperbaric storage:

- Attenuates the increase of **titratable acidity** (verified at 0.1 MPa);

- Higher **colour** changes (than 0.1 MPa):
  - Higher lightness;

- Lower **browning degree** (than 0.1 MPa).

The other parameters analyzed showed generally no statistical differences between the different samples.

**Methodology**

**Microbiological Analyses:**
- Total aerobic mesophiles
- *Enterobacteriaceae*
- Yeasts and moulds

**Physicochemical Analyses:**
- pH
- Titratable acidity
- Browning degree
- Cloudiness
- Total soluble solids

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**8, 16, 24 and 60 hours:**
- 0.1 MPa at 5 °C
- 100 MPa at ≈ 20 °C

**8 hours:**
- 0.1 MPa at 4 °C
- 0.1, **50, 75** and 150 MPa at **25 °C**
- 0.1, **25, 50, 75** and 150 MPa at **30 °C**
- 0.1 and 100 MPa at **37 °C**
Bars with * and # are indicative of values higher than 6 and lower than 1 Log10(CFU/mL), respectively.
B. Microbiological Analyses

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B. Microbiological Analyses

- Hyperbaric storage at 25 MPa showed no relevant microbial inhibition;

- After 8 hours of hyperbaric storage at 50/75 MPa, the microbial counts were similar to refrigeration.

- After 8 hours of hyperbaric storage at 100/150 MPa, the microbial counts were lower than refrigeration, due to microbial inactivation and microbial growth inhibition.

- Temperature at 20-37 °C seems to be irrelevant.
  - Food preservation under naturally variable (uncontrolled) room temperature and above.

Bars with * and # are indicative of values higher than 6 and lower than 1 Log10(CFU/mL), respectively.
B. Physicochemical Analyses

- pH
- Titratable acidity
- Browning degree
- Cloudiness
- Total soluble solids

Hyperbaric storage effects on physicochemical parameters were similar to those observed with refrigeration.

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Portfolio of three equipments:

- Laboratorial scale
- Pilot scale
- Industrial scale

Studies with different products

Minced meat

RTE meal (duck rice)

RTE meal (cod fish with potatoes and cream)

Sliced cooked ham

RTE Soup
Conclusions

Food preservation by microbial growth inhibition under pressure - hyperbaric storage (HS)

- Minimum of 50-75 MPa to have microbial growth inhibition
- At 100-150 MPa, additional inactivation effect, resulting in microbial loads lower than refrigeration
- At 20-37 °C no relevant effect of temperature

Pressure can be used as a variable to slowdown/inhibit microbial proliferation – a novel conceptual food preservation methodology?

Fernandes et al. (2014). Food preservation under pressure (hyperbaric storage) as a possible improvement/alternative to refrigeration: a review. Food Engineering Reviews. DOI 10.1007/s12393-014-9083-x
Further Research

As a novel recent possibility for food preservation, study:

✓ Other microrganims, e. g., pathogens
✓ Other quality parameters, e. g., enzymes
✓ Other food matrixes (with different pH and $a_w$)
✓ Quantitative effect and mathematical modeling of pressure/temperature on microbial growth inhibition and inactivation as influenced by food characteristics (pH, $a_w$, etc)
✓ Longer storage experiments for shelf life determination
✓ Sensorial analyses
✓ Economical data to compare with refrigeration, including sustainability issues and ecological footprint
40 years old University, ≈15 000 students
Aveiro – the Portuguese Venice
High Pressure Research Team

(Food and Biotechnological Applications)