Cornell CALS
College of Agriculture and Life Sciences
Food Science

Achieving Sustainable Food Processing using Novel Technologies

CARMEN I. MORARU
PhD, University "Dunarea de Jos" Galati
Dr. Honoris Causa, USAMV Bucharest

Professor & Chair
Department of Food Science
Cornell University

Cornell CALS
College of Agriculture and Life Sciences
Food Science

1. A brief presentation of the Department of Food Science at Cornell University

---

2. Achieving Sustainable Food Processing using Novel Technologies

Cornell CALS College of Agriculture and Life Sciences

Food Science

1. A brief presentation of the Department of Food Science at Cornell University

2. Achieving Sustainable Food Processing using Novel Technologies

Cornell CALS College of Agriculture and Life Sciences
Food Science

Department of Food Science, Cornell University

IFT feeding the minds that feed the world

Approved Undergraduate program

$11.9M
Research & Extension Expenditures FY'22

Industry Engagement
Extension Program
CIFS-IPP
Food Venture Center
Advisory Council

128
Undergraduate Students
97 FDSC, 31 VIEN

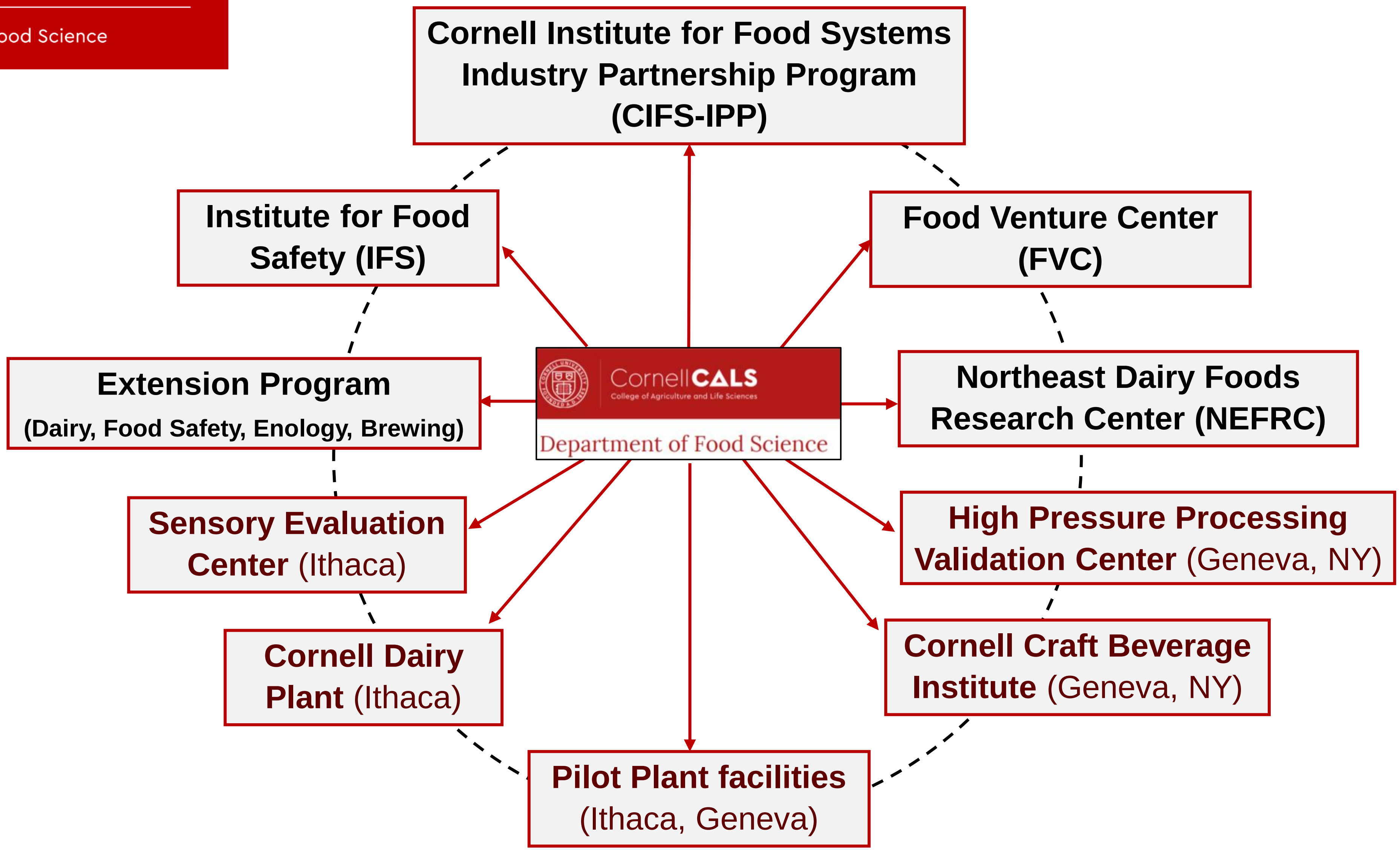
127
Graduate students
27MFS, 12MS, 88PhD

105
Students in the CAU-Cornell dual degree program, Beijing, China

26
Professorial and Teaching Faculty
~ 100
Research and Extension Staff

Chair: Prof. Carmen I. Moraru
cim24@cornell.edu
Assoc. Chair: Prof. Gavin Sacks
gls9@cornell.edu

Departmental programs & facilities



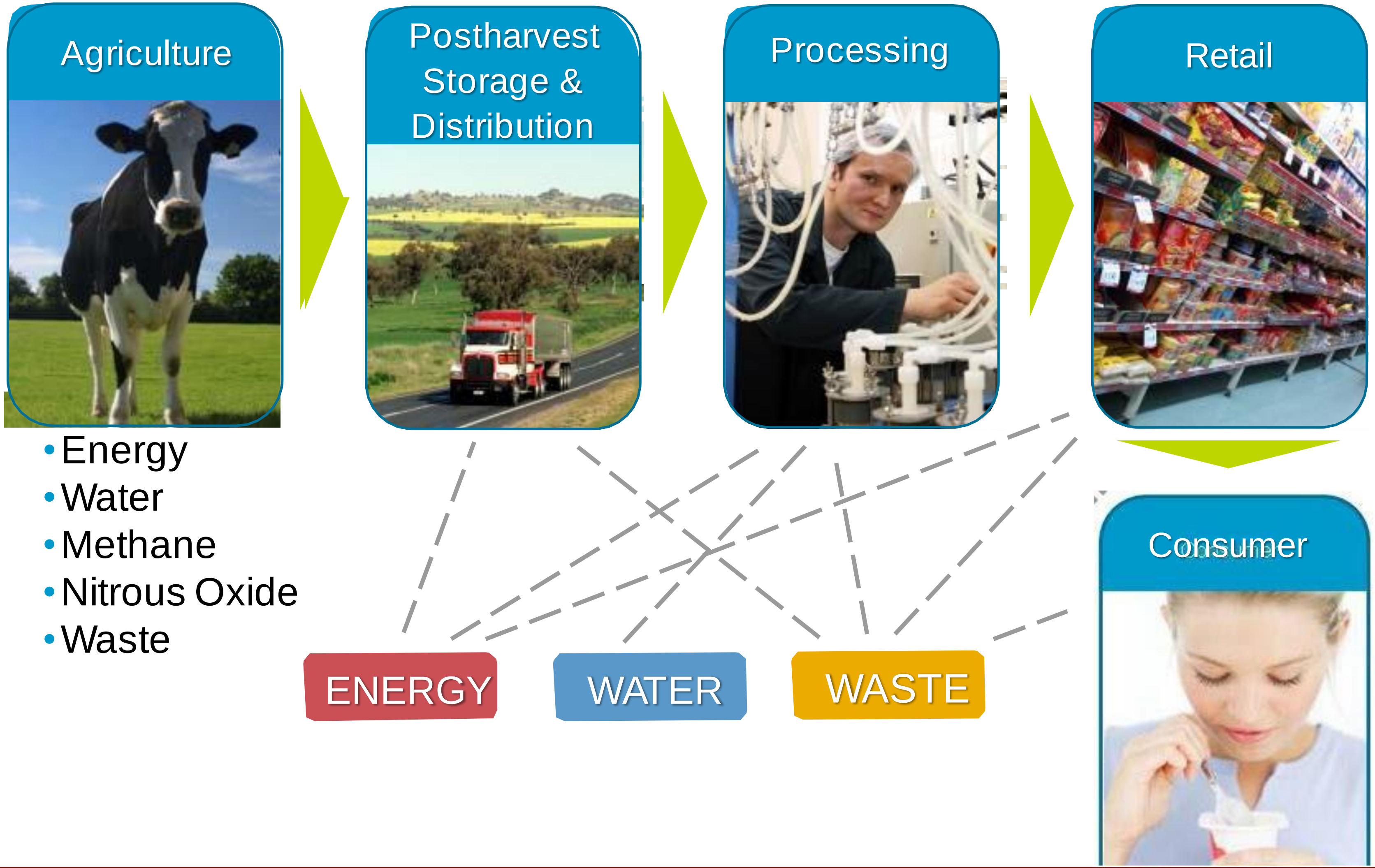
Cornell CALS
College of Agriculture and Life Sciences
Food Science

1. A brief presentation of the Department of Food Science at Cornell University

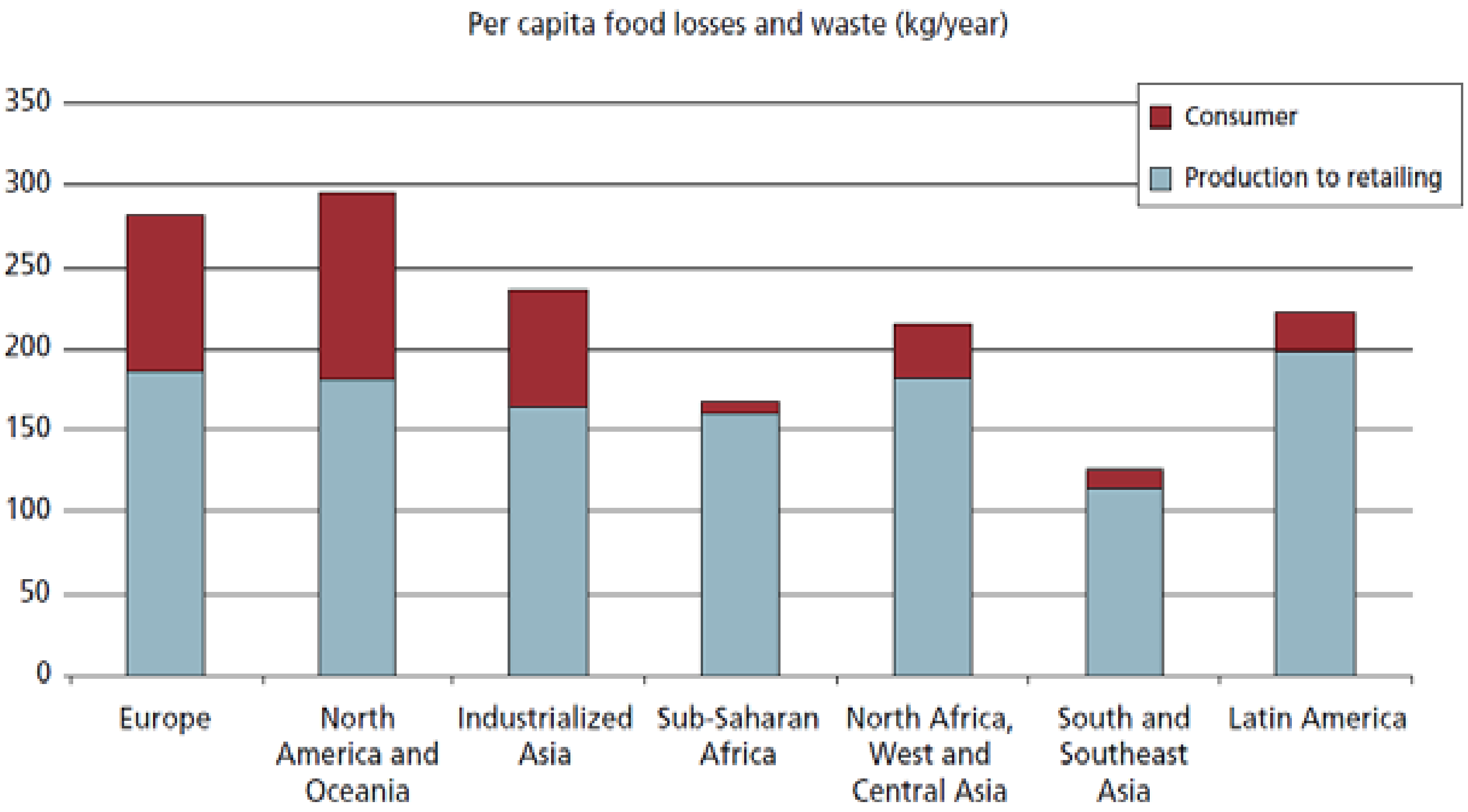
---

2. Achieving Sustainable Food Processing using Novel Technologies

Environmental impact of food manufacturing

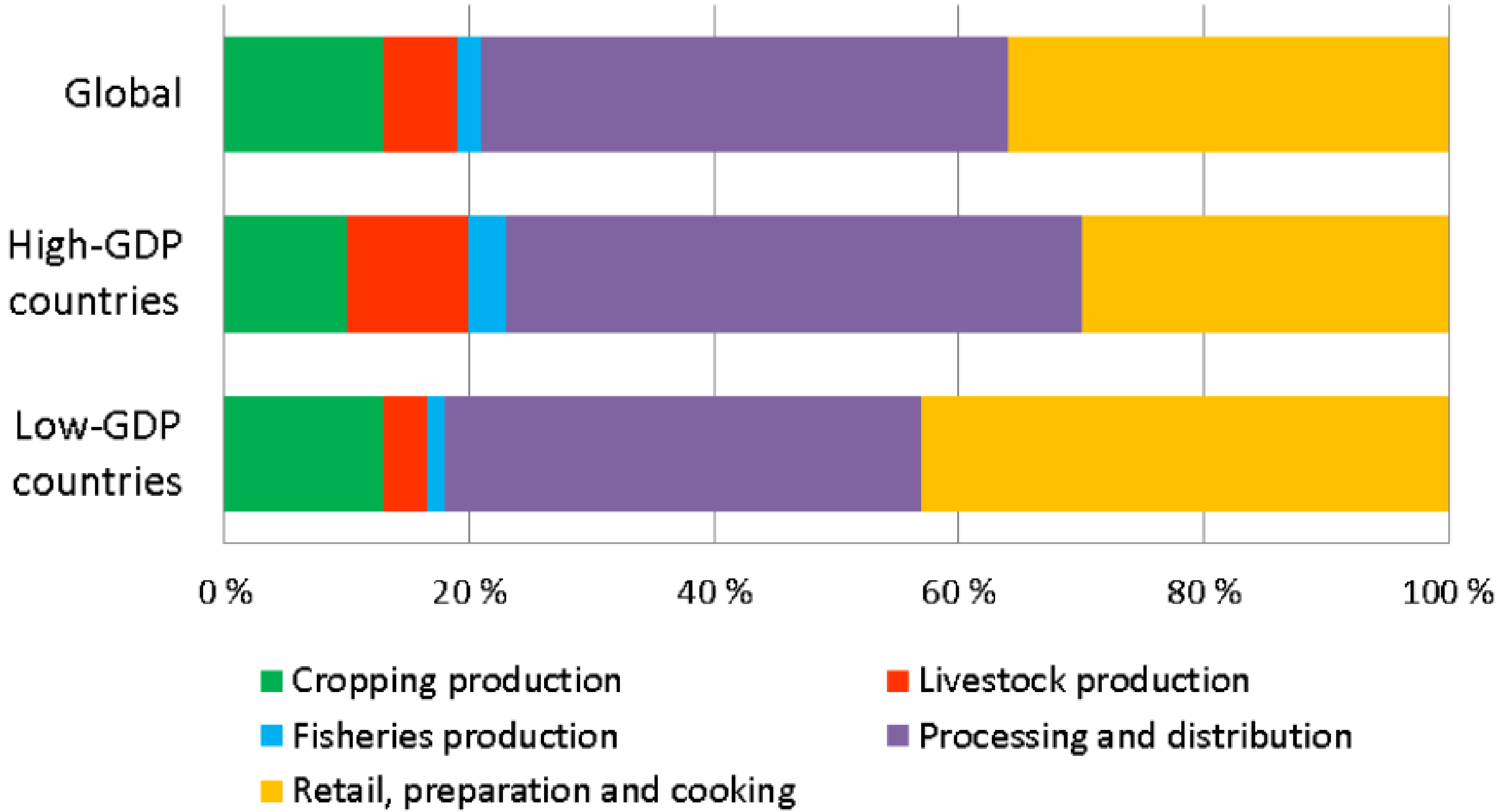


Food loss and food waste



- About 1/3 of the food produced in the world for human consumption is lost or wasted every year (~ 1.3 billion tons)
- Food losses and waste amount to ~ US$ 680 billion in industrialized countries and US$ 310 billion in developing countries.

Also important: energy use



A significant amount of energy in the food manufacturing sector is used for:

- Thermal processing
- Cold chain

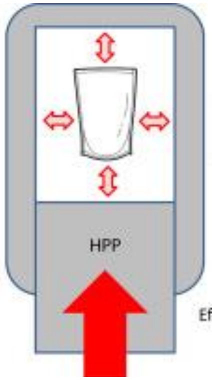
Final energy consumption in the food sector and its shares for various production steps. Global (top) high-GDP (middle) and low-GDP (bottom) countries Source: (FAO, 2013).

Opportunities for nonthermal technologies

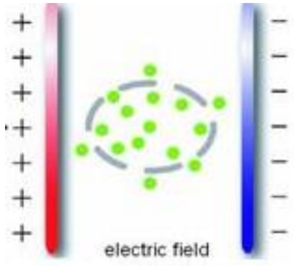
- **Alternative preservation methods that do not rely on thermal energy**
  - High pressure processing (HPP)
  - Liquid state pulsed electric fields (PEF)
  - Membrane filtration
  - UV / Light / Plasma treatments
- **Improve the efficiency of conventional processes**
  - Solid state PEF and ultrasonics
  - Improve extraction efficiency (reduce the need for harsh solvents)
  - Improve drying efficiency

Most common nonthermal technologies

High Pressure Processing (HPP)

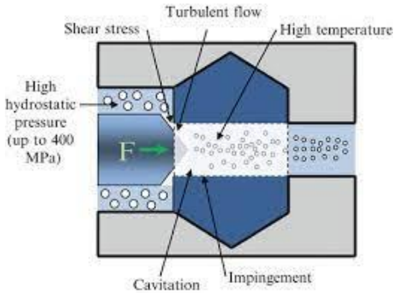


Pulsed Electric Field (PEF)

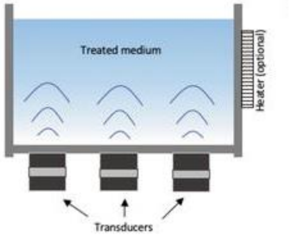


Light treatments (UV, Pulsed light, LED)

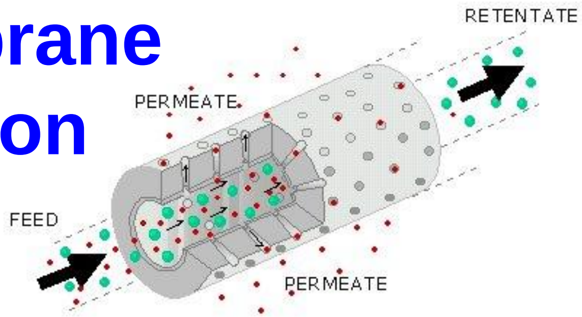
High Pressure Homogenization (HPH)



Ultrasound



Membrane filtration



Irradiation

Waste reduction through extended shelf life

Example 1: **HPP of deli meats**

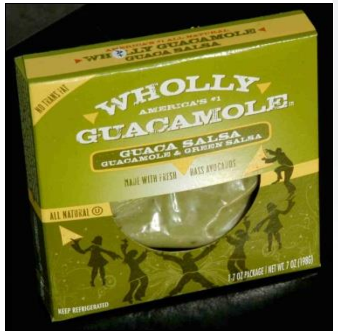
- Extends shelf life of ham from ~4 to 8 weeks
- Enables reduction of additives (clean label)

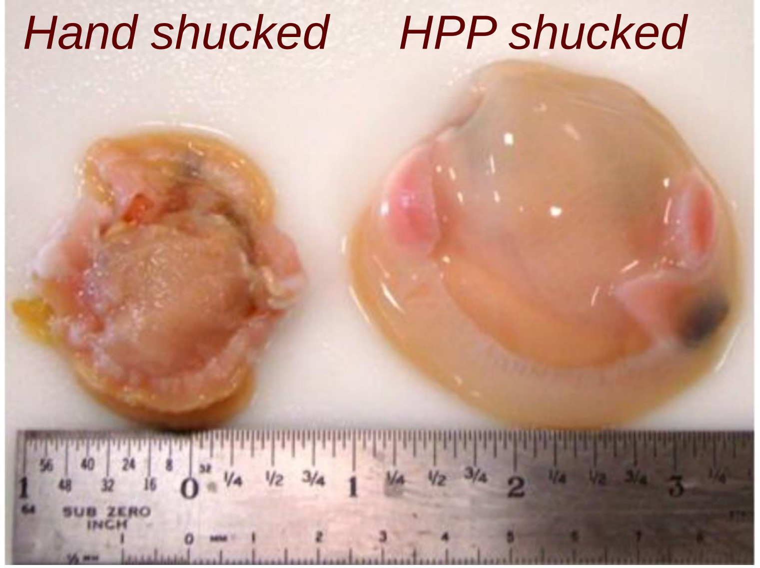
→

- **Reduction of waste losses**
- **Cleaner / greener manufacturing**

Example 2: **HPP of shellfish**

- Better meat extraction (and better quality)





Waste reduction using in-package HPP structuring

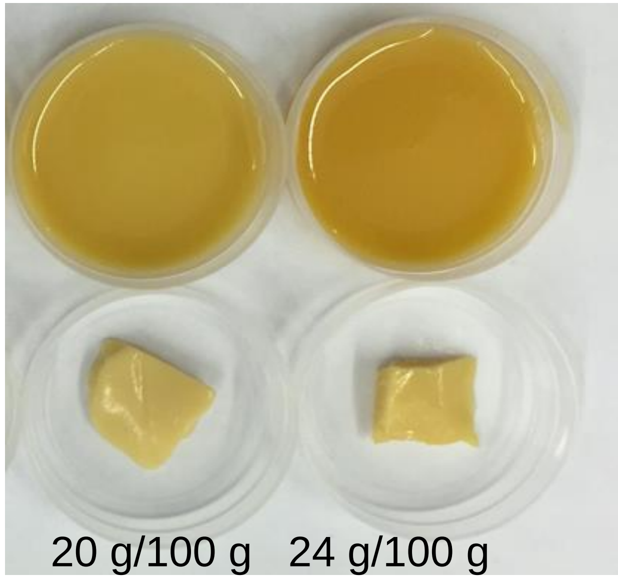
HPP induced gelation of proteins can be used for new product development:

- - Desirable texture and taste
- - High nutritional value
- - Prevents losses (in package treatment)
- - Built in safety

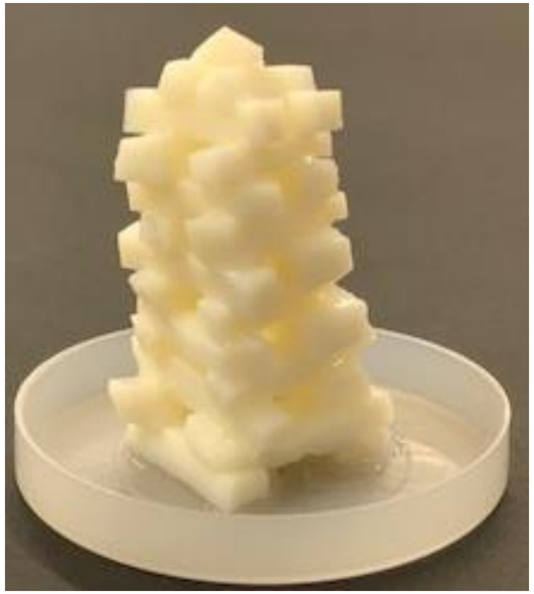
Plant proteins

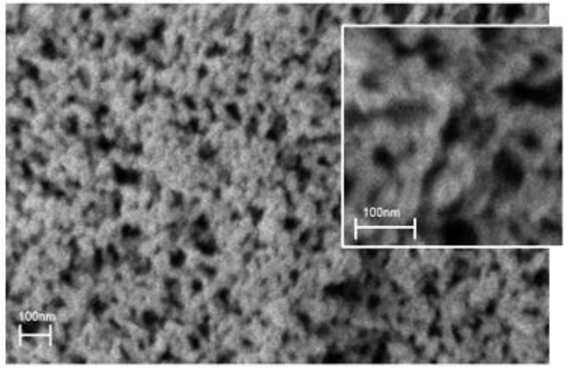
Untreated pea protein concentrate (PPC)

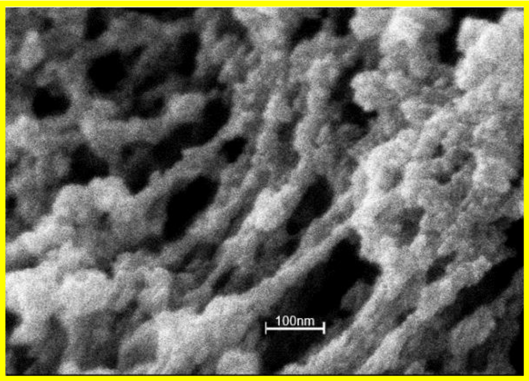
HPP-treated PPC (600 MPa, 3 min)



HPP treated milk proteins



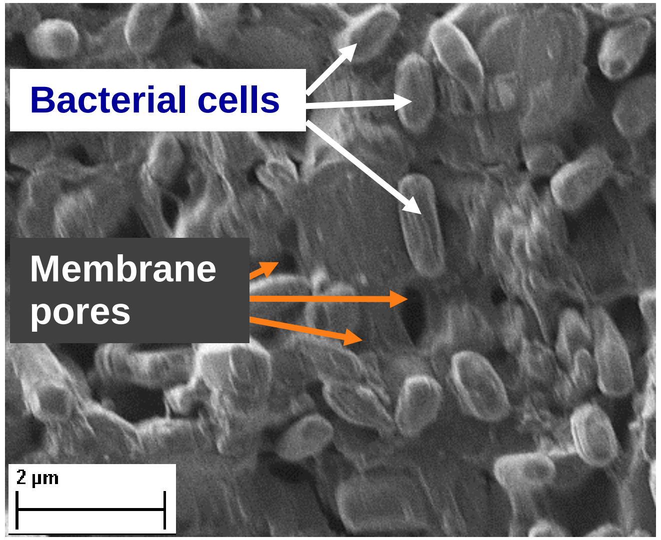




(Sim and Moraru, 2019)

(Cadesky et al, 2017; Wang et al., 2020)

Membrane filtration:
Increasing shelf life through microbial reduction

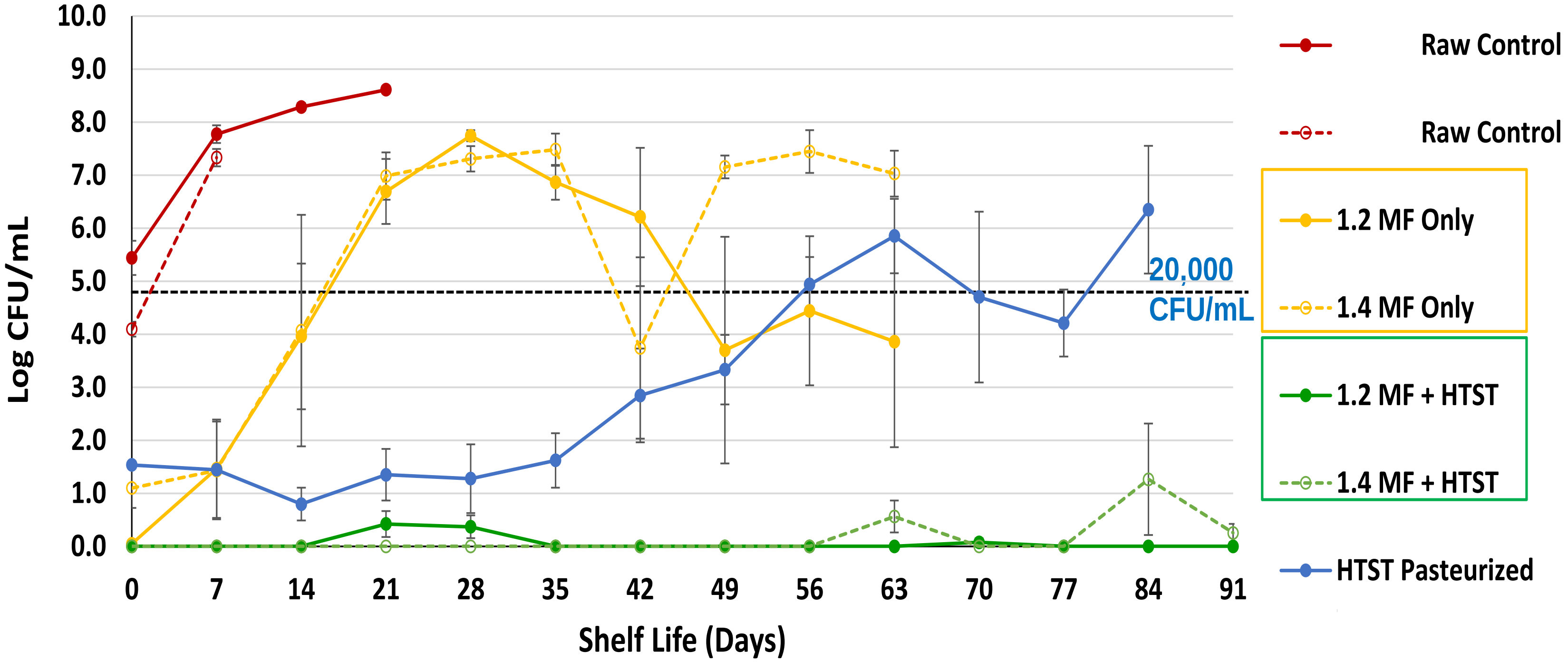


Microfiltration

3 - 4 log reduction of total bacteria

No heat induced flavor

Increased shelf life

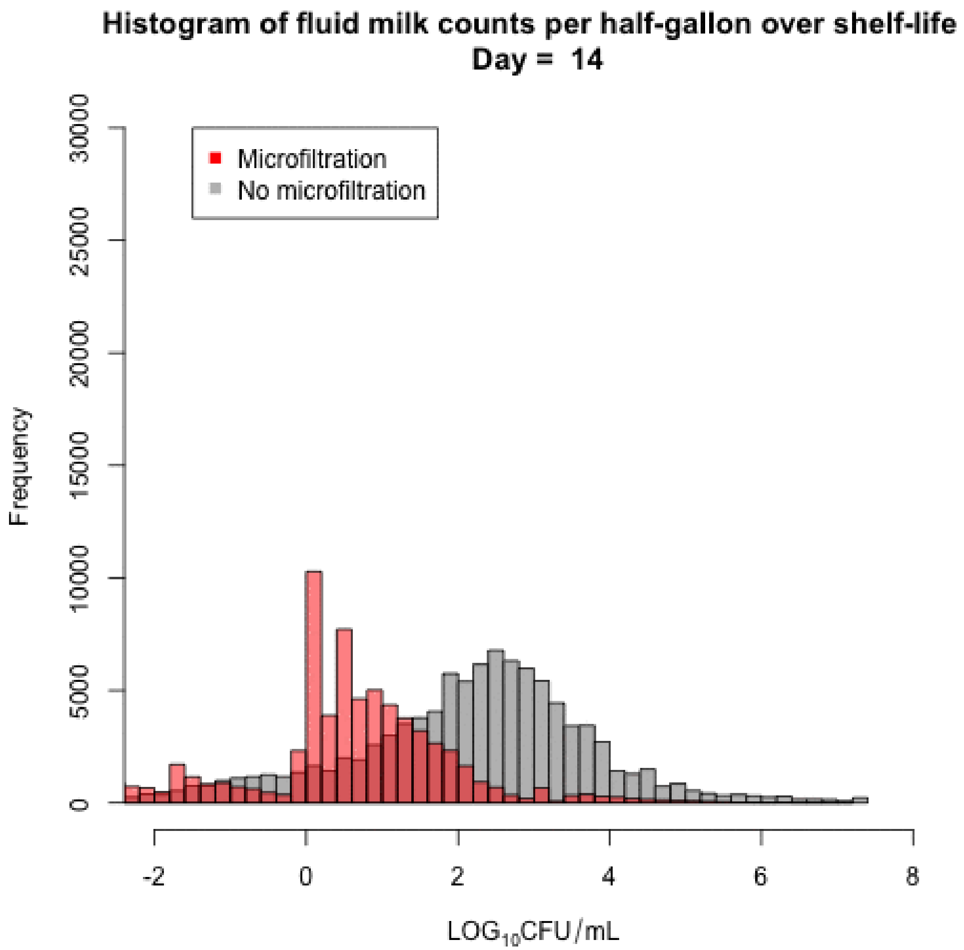


- A combination of MF and HTST treatment led to virtually <u>no bacterial growth</u> in skim milk over 91 days of refrigeration

(Griep and Moraru, 2018)

Impact of nonthermal processing on milk shelf life

Microfiltration

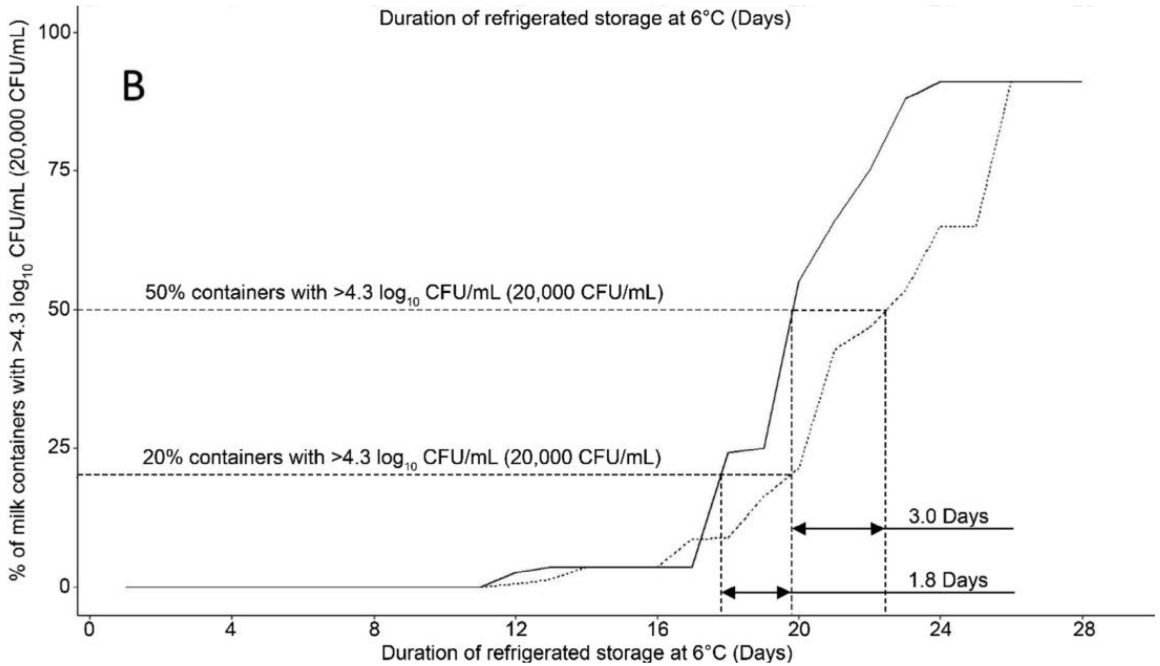


Bactofugation

J. Dairy Sci. 105:9439–9449
https://doi.org/10.3168/jds.2022-22174

Monte Carlo simulation model predicts bactofugation can extend shelf-life of pasteurized fluid milk, even when raw milk with low spore counts is used as the incoming ingredient

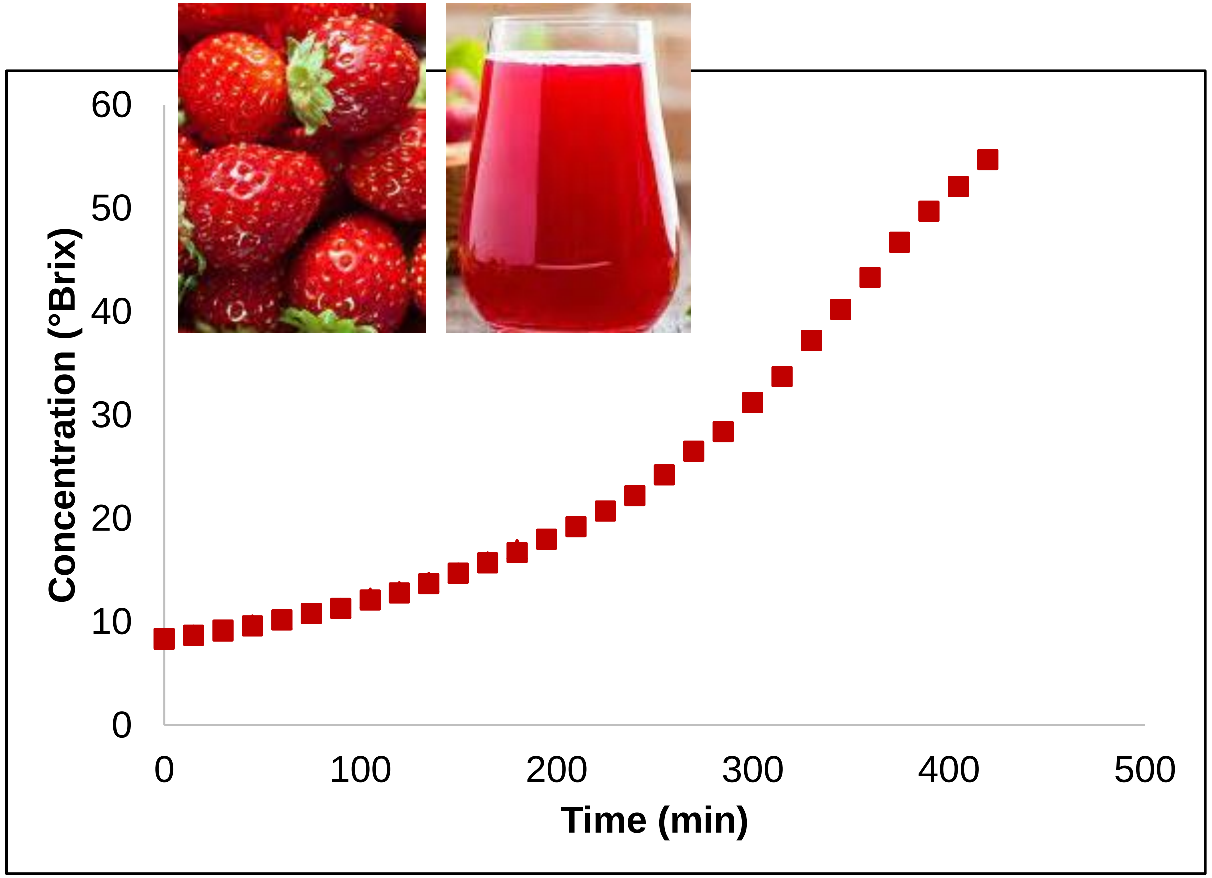
E. R. Griep-Moyer, A. Trmčić,* C. Qian, and C. I. Moraru*
Department of Food Science, Cornell University, Ithaca, NY 14853



Membrane filtration for energy efficiency

Nonthermal concentration by Forward Osmosis

Strawberry juice



Cranberry juice & FO juice concentrate
8°Brix → 51°Brix

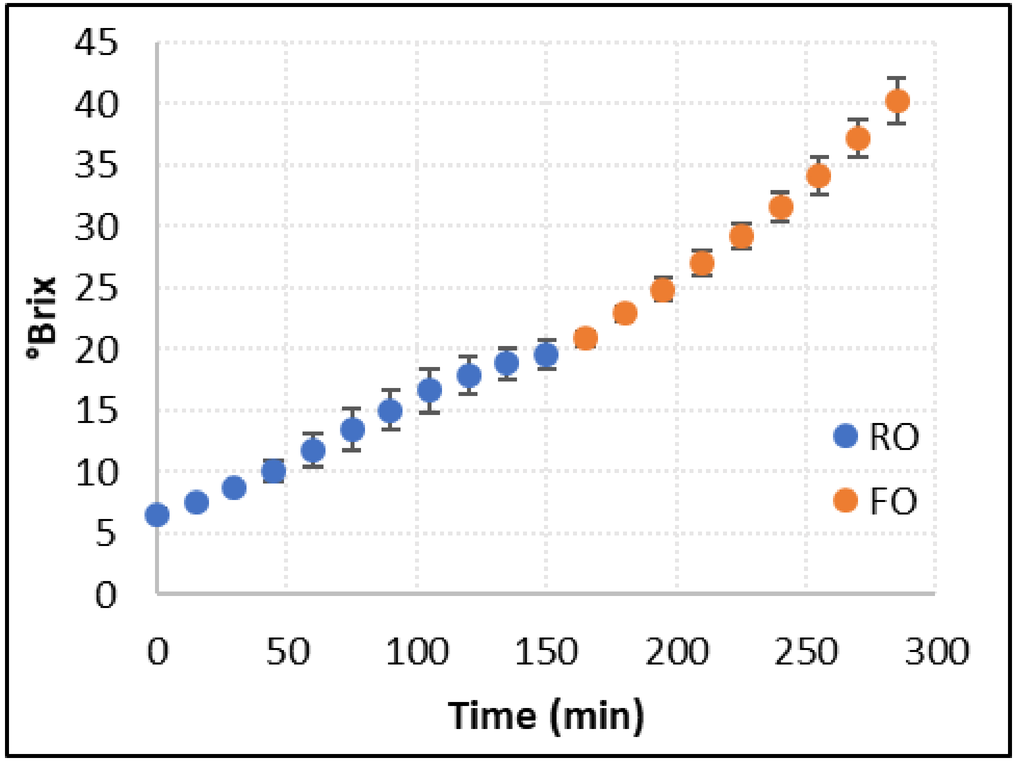
- High quality concentrates
- High concentration factor achieved

(Beldie and Moraru, 2023)

Punzalan & Padilla-Zakour (2021)

Maximizing benefits by combining RO & FO

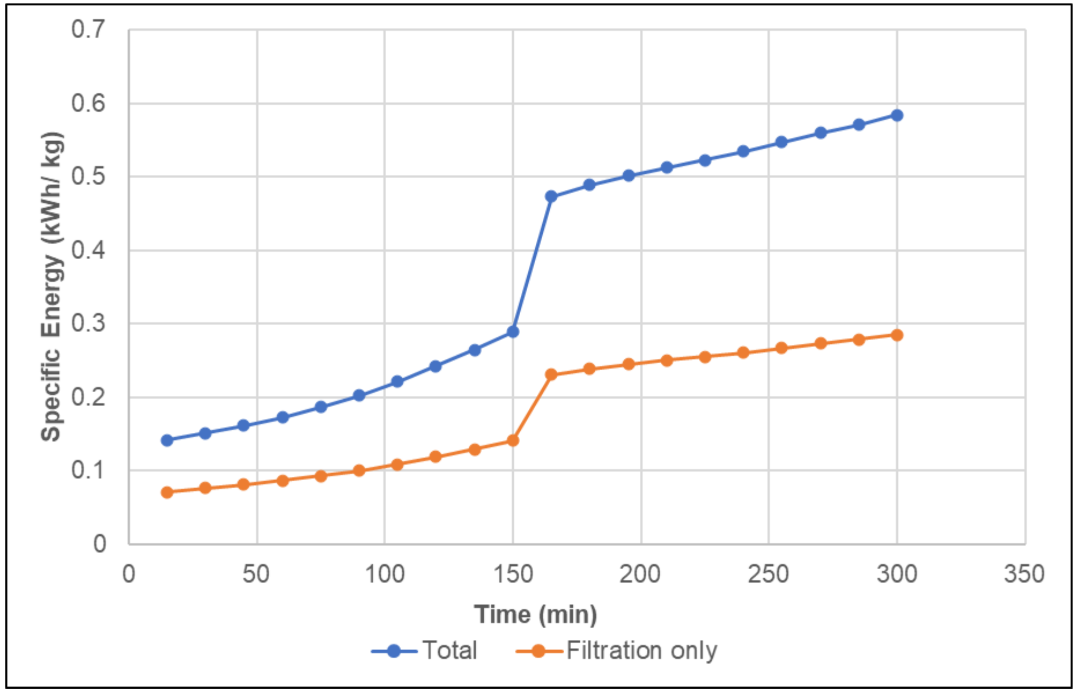
- Takes advantage of the high fluxes of RO at low concentration and excellent performance of FO at high concentration



How energy efficient is the process?

Total energy demand:

- 0.099 kWh/ kg water removed for FO concentration
- 3.553 kWh/ kg water removed for thermal concentration



(Menchik and Moraru, 2019)

Is this process economically feasible?

- Cost estimation for scaling up from pilot to commercial scale:

	RO	FO	RO-FO
Feed (raw material) (L/ hr)	15000	5000	15000
Concentrate (L/ hr)	5000	2500	2500
Water removed (L/ hr)	10000	2500	12500
Cost per L of concentrate ($/ L)	**0.050**	**0.086**	**0.186**
Cost per L of water removed ($/ L)	0.025	0.086	0.037

Impact on sustainability goes beyond energy

Ozone Depletion Potential

Global Warming Potential

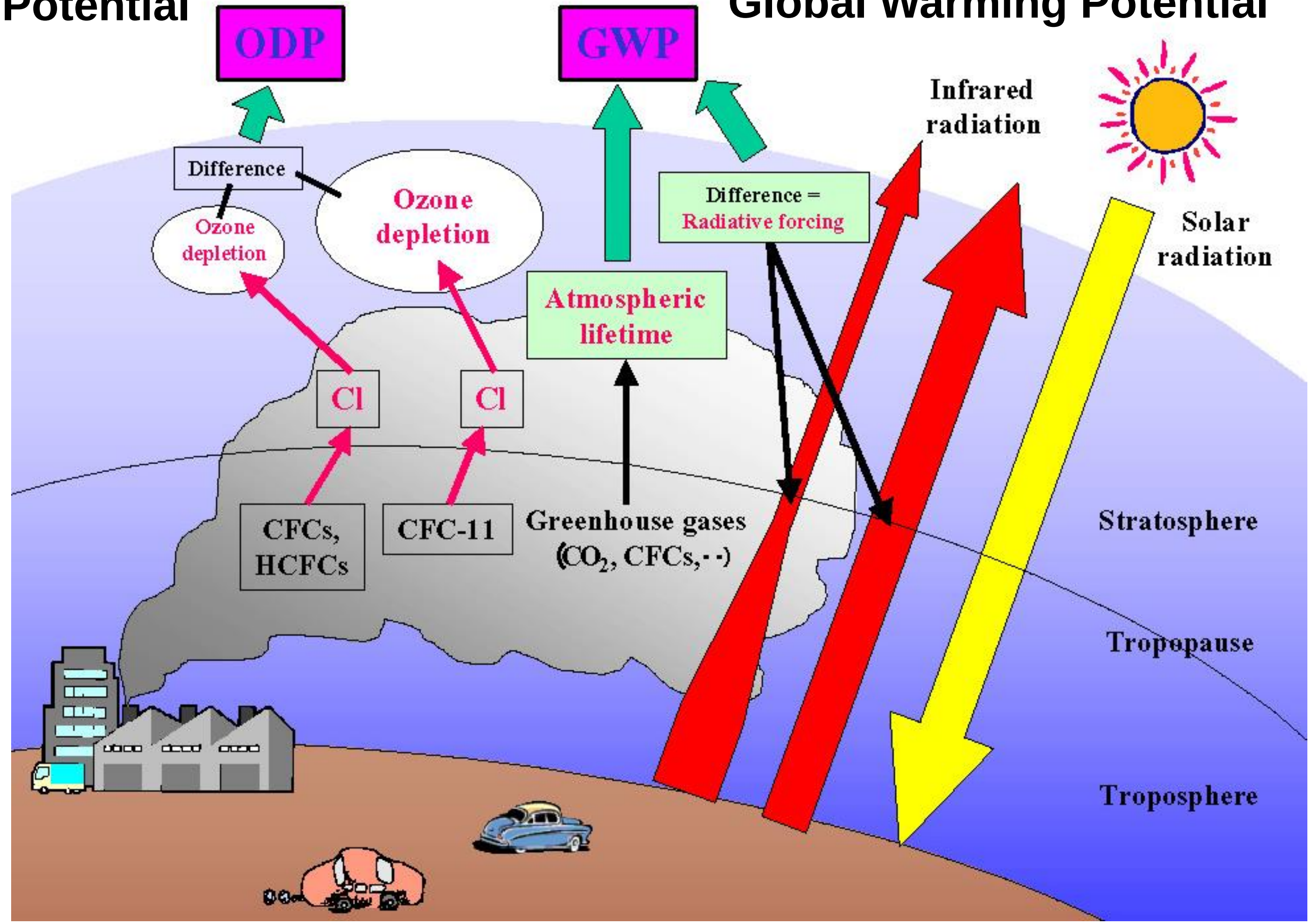


Photo: https://ccsr.aori.u-tokyo.ac.jp/~imasu/Japanese/English/4.htm

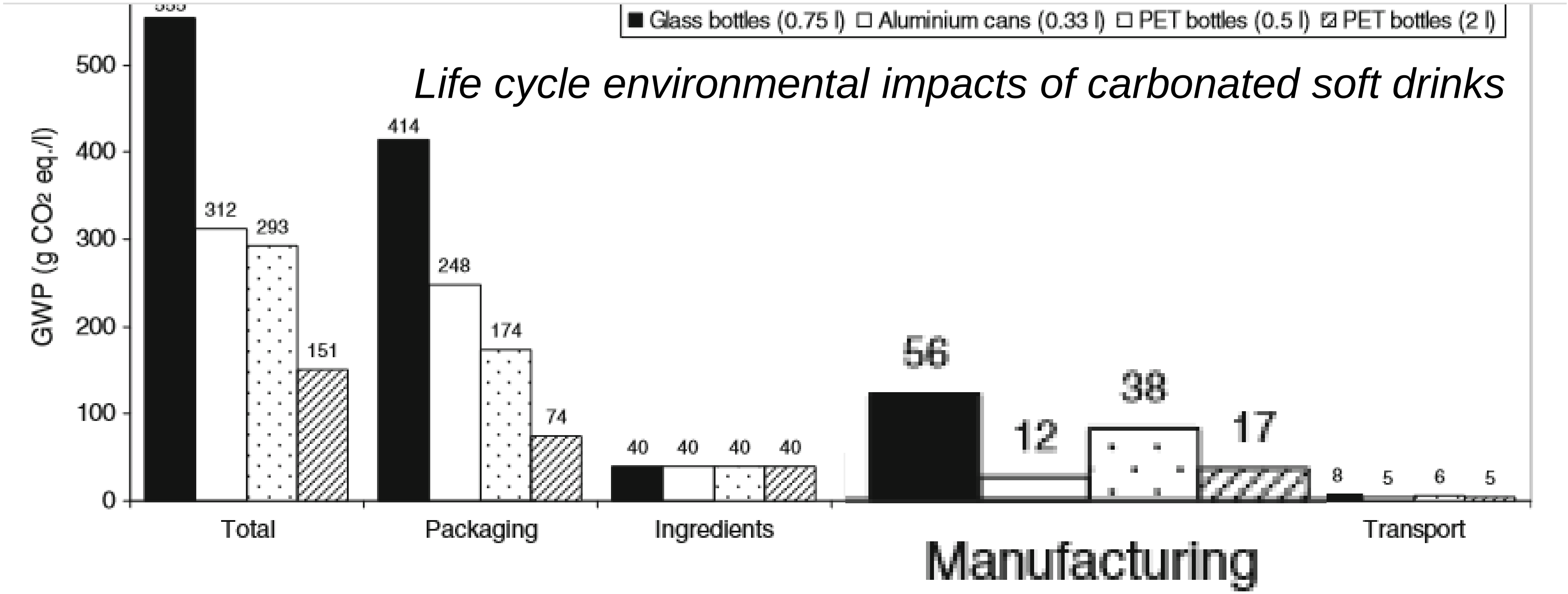
Main contributors to Global Warming Potential of the RO-FO process

	RO module	**FO module**	**RO-FO process**
GWP contribution of the process	85.7%	14.3%	100%
GWP contribution of energy	*4.58%*	*0.77%*	*5.35%*
GWP contribution of materials	*7.00%*	*1.17%*	*8.17%*
GWP contribution of chemicals	*73.87%*	*12.33%*	*86.2%*

Global Warming Potential of the RO-FO process

GWP (kg CO_2 eq) per L	RO module contribution	FO module contribution	RO-FO process (concentrate)	RO-FO process (water removed)
Kg CO_2 eq/ L concentrate	0.21	0.03	0.24	-
Kg CO2 eq/ L water removed	0.04	0.01	-	0.05

How does this compare to other processes?



Source: Amienyo, Gujba Stichnothe & Azapagic (2013)

Thoughts on the role of nonthermal processing for food systems sustainability

- Nonthermal technologies can improve the sustainability of the food system due to:
  - Lower energy consumption compared to traditional processing
  - Better retention of nutrients
- Commercial applications increasing significantly → costs are coming down
- Comprehensive LCA analysis required before commercial adoption!

Cornell CALS College of Agriculture and Life Sciences

Food Science

THANK YOU!

CARMEN I. MORARU, Professor & Chair

Department of Food Science, Cornell University

CIM24@CORNELL.EDU