

# Ultraprocessed Plant-based Foods:

Creating healthy and sustainable alternatives to animal-based foods



**\$8 billion sales in 2022**

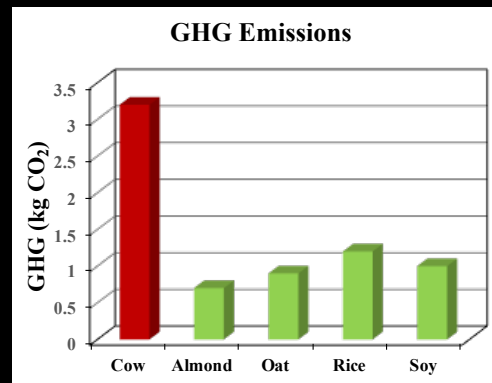
*(Good Food Institute, USA)*

# Plant-based Food: Drivers

## Ethical



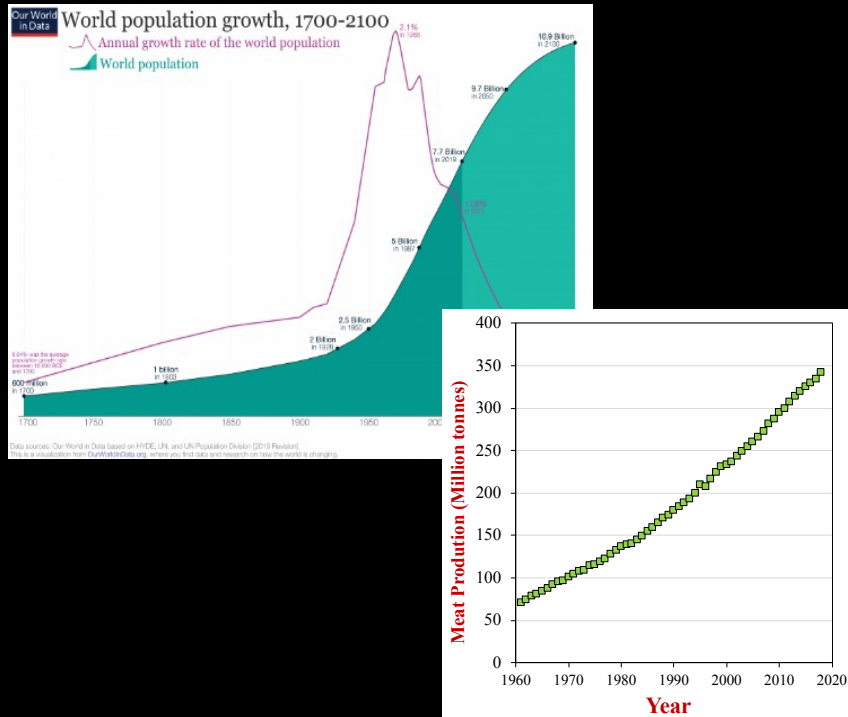
## Environmental



## Health



# ENVIRONMENTAL IMPACT



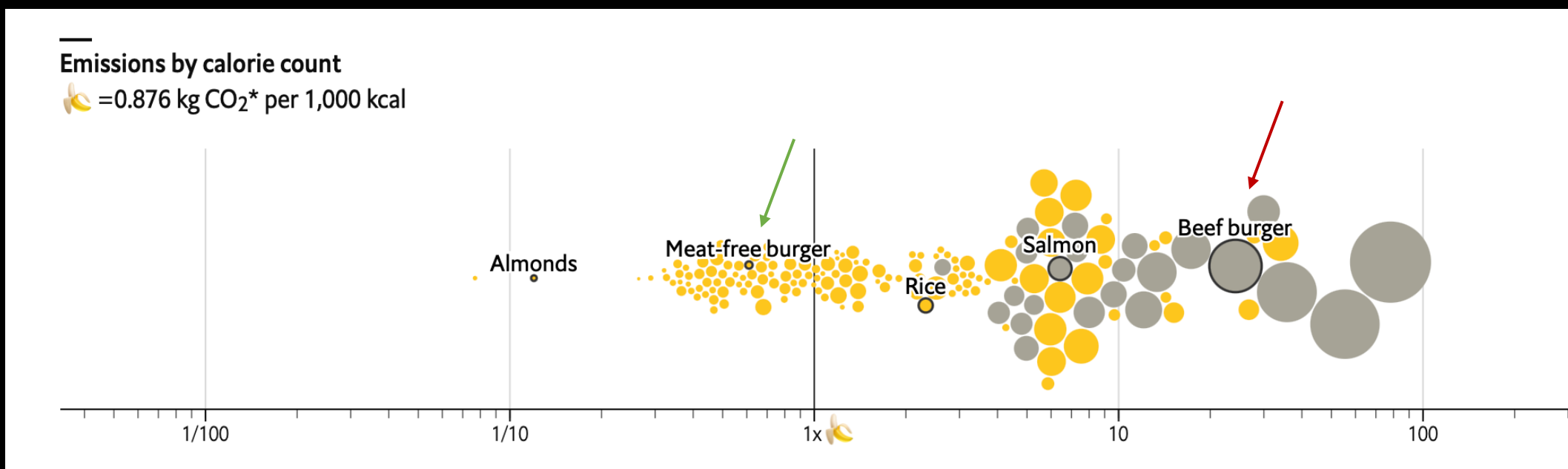
## Challenges

- Growing population
- Land use, water use, pollution
- Greenhouse gas production
- Biodiversity loss
- Zoonotic disease
- Antimicrobial resistance

## EAT-Lancet Commission Recommendation

- Defined a healthy and sustainable diet based on planetary boundaries and nutrition knowledge
- Eat less animal foods!

# Greenhouse Gas Emissions of Plant- and Animal-based Foods





# Health



**Traditional Plant-based diet**



**Traditional Animal-based diet**

# Health

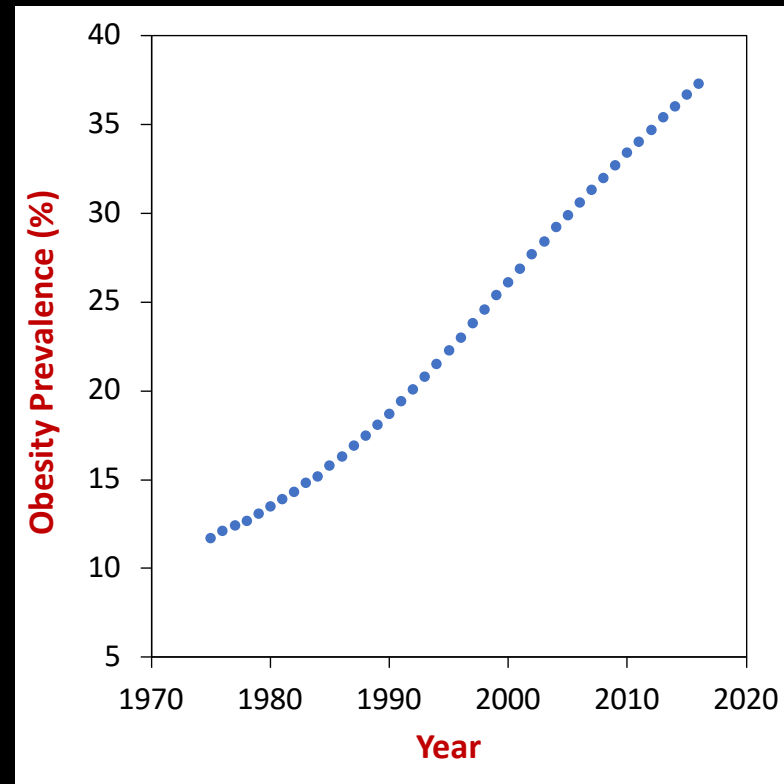


**Next-Gen Plant-based Foods**

**Traditional Animal-based diet**

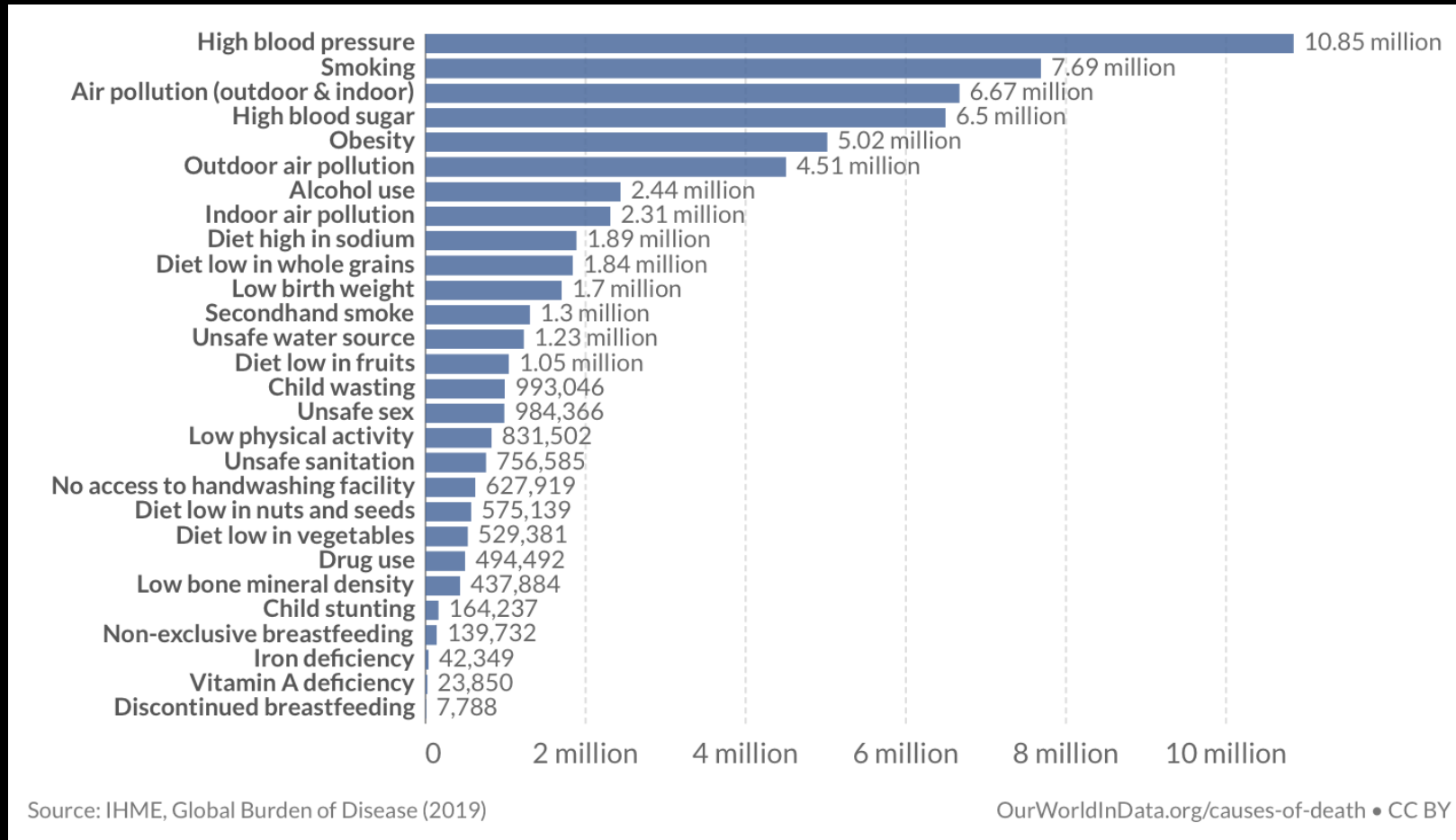


Americans Are Addicted to  
'Ultra-Processed' Foods,  
and It's Killing Us  
(Newsweek)





# Diet-Related Risk Factors for Early Death







Number of Deaths by Risk Factor (USA)

# Classifying Ultraprocessed Foods



Carlos Monteiro 2009 (Brazil)

NOVA Food classification			
Unprocessed or minimally processed foods	Processed culinary ingredients	Processed foods	Ultra-processed foods
<p>Foods which did not undergo processing or underwent minimal processing technics, such as fractioning, grinding, pasteurization and others.</p> 	<p>These are obtained from minimally processed foods and used to season, cook and create culinary dishes.</p> 	<p>These are unprocessed or minimally processed foods or culinary dishes which have been added processed culinary ingredients. They are necessarily industrialized.</p> 	<p>These are food products derived from foods or parts of foods, being added cosmetic food additives not used in culinary.</p> 
Legumes, vegetables, fruits, starchy roots and tubers, grains, nuts, beef, eggs, chicken, milk	Salt, sugar, vegetable oils, butter and other fats.	Bottled vegetables or meat in salt solution, fruits in syrup or candied, bread, cheeses, purees or pastes.	Breast milk substitutes, infant formulas, cookies, ice cream, shakes, ready-to-eat meals, soft drinks and other sugary drinks, hamburgers, nuggets.



Food and Agriculture  
Organization of the  
United Nations

## Ultra-processed foods, diet quality, and health using the NOVA classification system

Prepared by

Carlos Augusto Monteiro  
Geoffrey Cannon  
Mark Lawrence  
Maria Laura da Costa Louzada  
*and*  
Priscila Pereira Machado

Food and Agriculture Organization of the United Nations

Rome, 2019





# Are Next-generation Plant-based Foods Ultraprocessed?

The Guardian



**Ultraprocessed Foods:**  
“Foods that have undergone  
extensive processing, and  
often contain many different  
ingredients”

**YES**

# PLANT-BASED MEAT

## Nutrition Facts

Serving size 4 oz (113g)

Amount per serving

**Calories 250**

% Daily Value\*

Total Fat 14g 18%

Saturated Fat 8g 40%

Trans Fat 0g

Cholesterol 0mg 0%

Sodium 370mg 16%

Total Carbohydrate 8g 3%

Dietary Fiber 3g 11%

Total Sugars <1g

Includes <1g Added Sugars 1%

**Protein 19g 31%**

Vitamin D 0mcg 0%

Calcium 170mg 15%

Iron 4.2mg 25%

Potassium 610mg 15%

Thiamin 28.2mg 2350%

Riboflavin 0.4mg 30%

Niacin 5.3mg 35%

Vitamin B<sub>6</sub> 0.4 mg 25%

Folate 115mcg DFE 30%

Vitamin B<sub>12</sub> 3 mcg 130%

Phosphorous 180mg 15%

**Zinc 6.0mg 50%**

\* The % Daily Value tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Ingredients: Water, Soy Protein Concentrate, Coconut Oil, Sunflower Oil, Natural Flavors, 2% or less of: Potato Protein, Methylcellulose, Yeast Extract, Cultured Dextrose, Food Starch Modified, Soy Leghemoglobin, Salt, Soy Protein Isolate, Mixed Tocopherols (Vitamin E), Zinc Gluconate, Thiamine Hydrochloride (Vitamin B<sub>1</sub>), Sodium Ascorbate (Vitamin C), Niacin, Pyridoxine Hydrochloride (Vitamin B<sub>6</sub>), Riboflavin (Vitamin B<sub>2</sub>), Vitamin B<sub>12</sub>.

Contains: Soy

## Nutrition Facts

Serving size 4 oz (112g)

Amount per serving

**Calories 220**

% Daily Value\*

Total Fat 14g 18%

Saturated Fat 6g 30%

Trans Fat 0g

Cholesterol 60mg 20%

Sodium 65mg 3%

Total Carbohydrate 0g 0%

Dietary Fiber 0g 0%

Total Sugars 0g

Includes 0g Added Sugars 0%

**Protein 23g**

Vitamin D 0mcg 0%

Calcium 10mg 0%

Iron 2.5mg 15%

Potassium 330mg 8%

\* The % Daily Value tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Ingredients: 100% Beef

1 Ingredient

## Nutritional differences

- More fiber, calcium, potassium
- More calories, saturated fat, sodium



23 Ingredients

# HEALTH BENEFITS?

## NUTRITIONAL IMPLICATIONS

PB bacon has no protein!

Nutrition Facts	
10 servings per container	
<b>Serving size</b>	<b>1 Strip (15g)</b>
<b>Amount Per Serving</b>	
<b>Calories</b>	<b>40</b>
% Daily Value*	
<b>Total Fat</b> 2.5g	<b>3%</b>
Saturated Fat 2g	<b>10%</b>
Trans Fat 0g	
<b>Cholesterol</b> 0mg	<b>0%</b>
<b>Sodium</b> 110mg	<b>5%</b>
<b>Total Carbohydrate</b> 4g	<b>1%</b>
Dietary Fiber 0g	<b>0%</b>
Total Sugars 0g	
Includes 0g Added Sugars	<b>0%</b>
<b>Protein</b> 0g	<b>0%</b>
Not a significant source of vitamin D, calcium, iron, and potassium	
*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.	

Nutrition Facts	
Serving Size 1 Skillet Cooked Slice (15g)	
Servings Per Container Varied	
<b>Amount Per Serving</b>	
<b>Calories</b> 80	Calories from Fat 60
% Daily Value*	
<b>Total Fat</b> 7g	<b>11%</b>
Saturated Fat 2.5g	<b>13%</b>
Trans Fat 0g	
<b>Cholesterol</b> 20mg	<b>7%</b>
<b>Sodium</b> 220mg	<b>9%</b>
<b>Total Carbohydrate</b> 0g	<b>0%</b>
Dietary Fiber 0g	<b>0%</b>
Sugars 0g	
<b>Protein</b> 3g	
Vitamin A 0%	Vitamin C 0%
Calcium 0%	Iron 2%
*Percent Daily Values are based on a 2,000 calorie diet.	
CURED WITH: WATER, SALT, SUGAR, SODIUM PHOSPHATE, SODIUM ERYTHORBATE, SODIUM NITRITE.	

## Nutritional differences

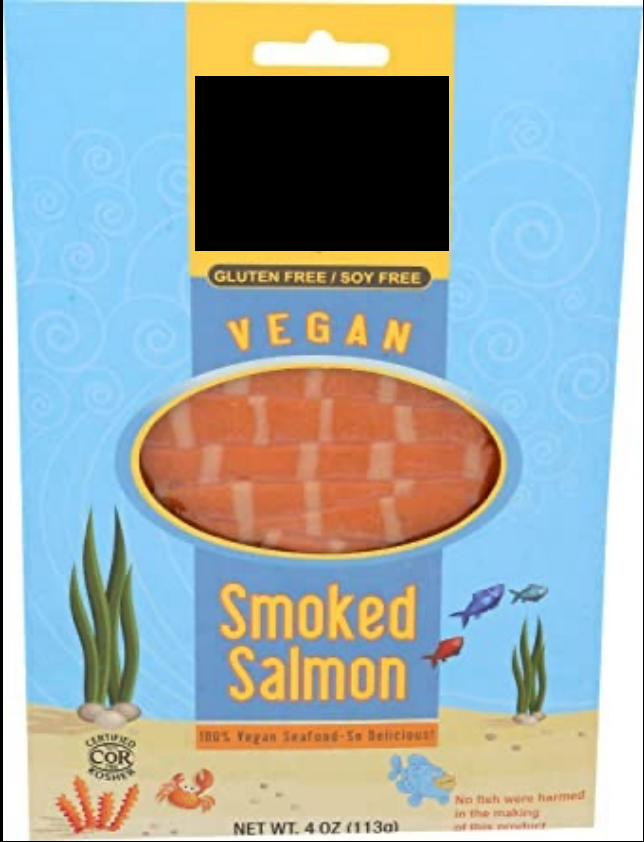
- More fiber, calcium, potassium
- More calories, saturated fat, sodium



Real bacon has about around 35% protein

# HEALTH BENEFITS?

# NUTRITIONAL IMPLICATIONS



Real salmon has about  
around 20% protein

Nutrition Facts	
Serving Size: 1 slices (85g)	
Amount Per Serving	
Calories 170	Calories from Fat 41
% Daily Value*	
Total Fat 4.5g	7%
Saturated Fat 1g	5%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 610mg	25%
Total Carbohydrates 32g	11%
Dietary Fiber 9g	36%
Sugars 0g	
Protein 0.5g	
Vitamin A	0%
Vitamin C	0%
Calcium	2%
Iron	0%
* Percent Daily Values are based on a 2000 calorie diet.	
INGREDIENTS: WATER, OLIVE OIL, KONJAC POWDER, PEA STARCH, POTATO STARCH, PEA PROTEIN, SEA SALT, ORGANIC AGAVE NECTAR, SEAWEED POWDER, FENUGREEK, ALGINATE(FROM SEAWEED), PAPRIKA, CALCIUM HYDROXIDE.	

PB salmon has  
< 1% protein



# HEALTH BENEFITS?

## NUTRITIONAL IMPLICATIONS



### Ingredients

Water, Coconut Oil, Modified Potato Starch, Gluten Free **Oat** Fibre, Maize Starch, Salt, Modified Maize Starch, Calcium, Thickeners (Carrageenan, Guar Gum), Natural Flavourings, Acidity Regulators (Lactic Acid, Sodium Lactate), Colour (Carotenes).

Long ingredient list

### Nutrition information

#### Per 100g

Energy	1297kJ/313kcal
Fat	25.9g
of which Saturates	21.6g
Carbohydrate	18.3g
of which sugars	0.1g
Protein	0.1g
Salt	1.6g
Calcium	150mg (19% RI)

PB cheese has  
> 20% sat fat

PB cheese has < 1%  
protein

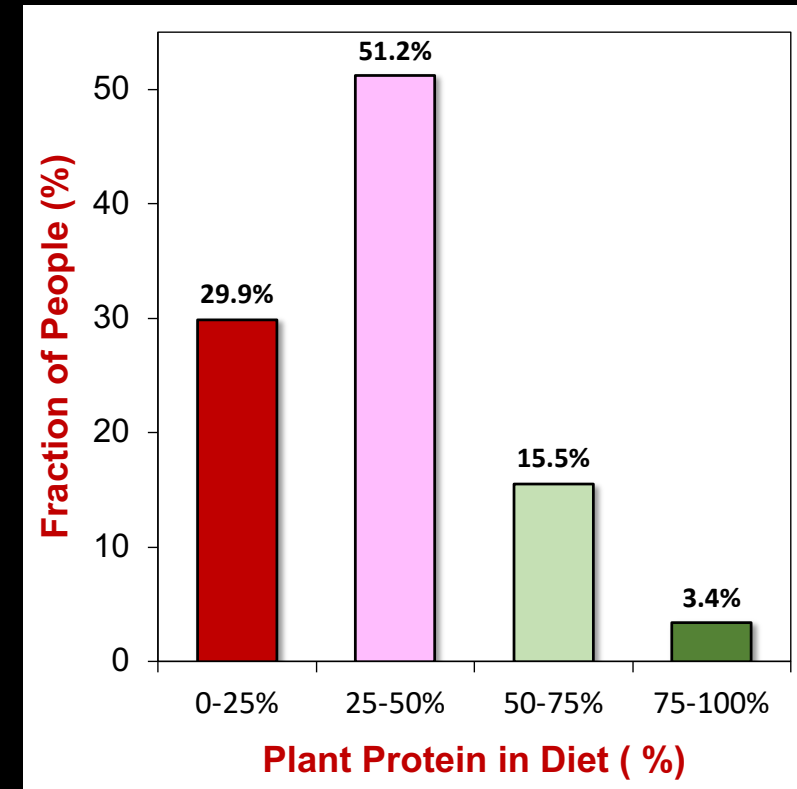
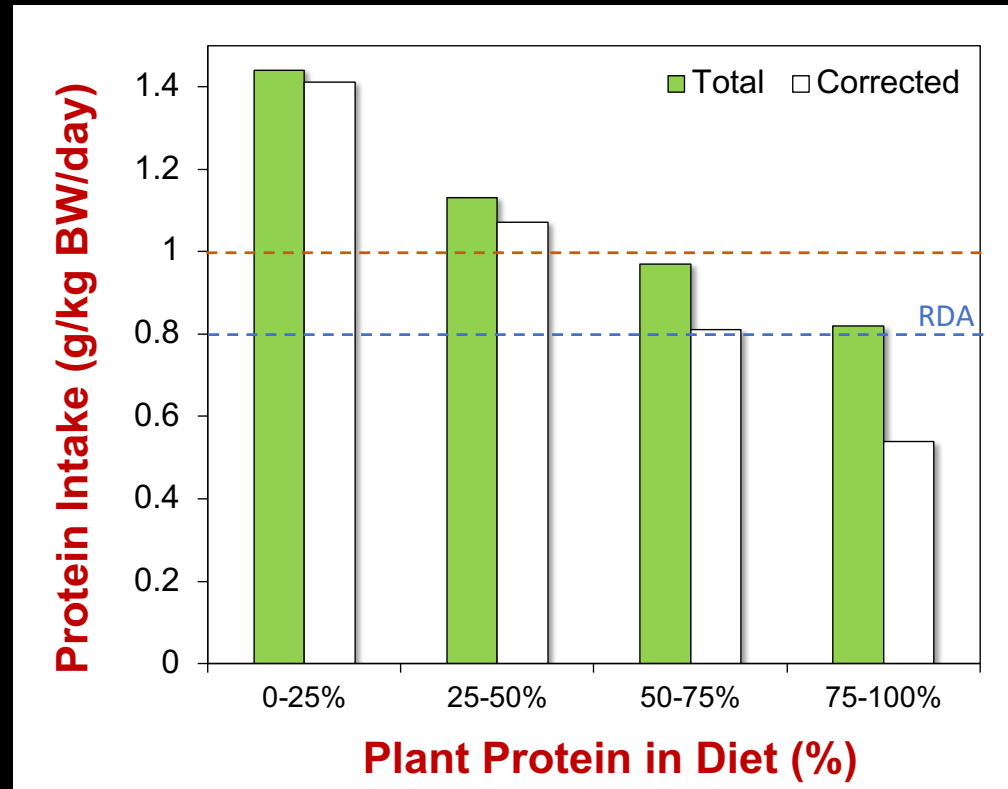
# ARE NEXT-GENERATION PLANT-BASED FOODS UNHEALTHY?



**It  
Depends**

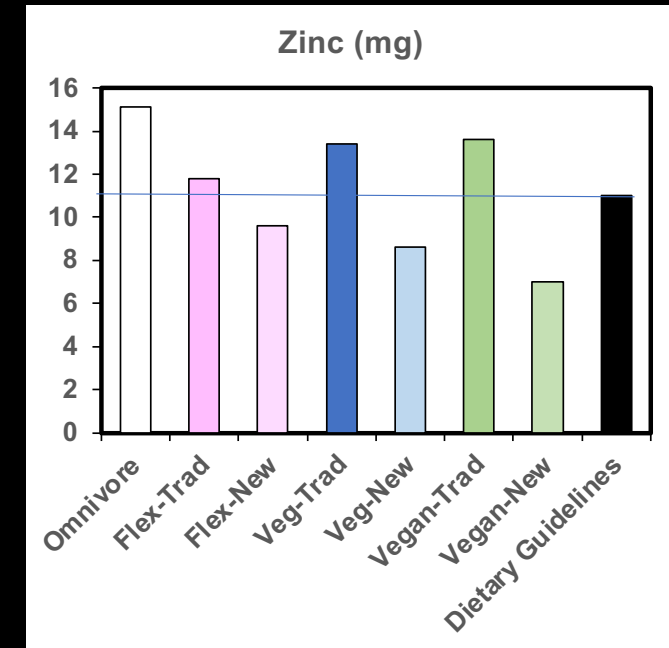
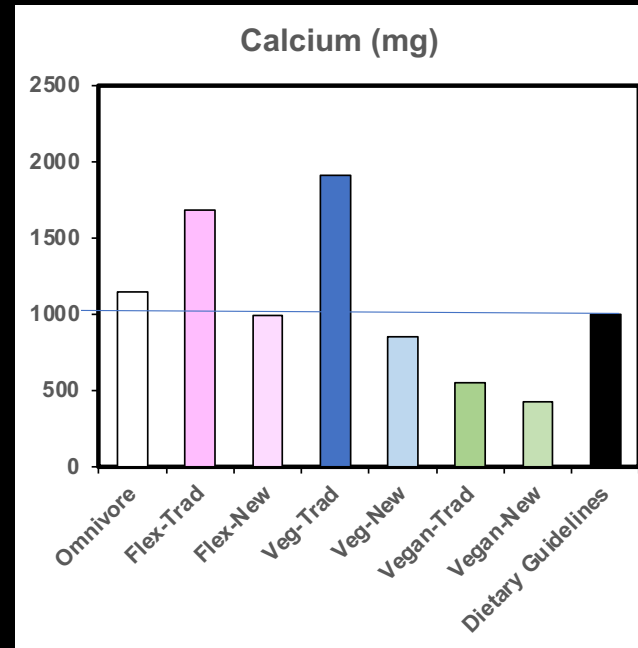
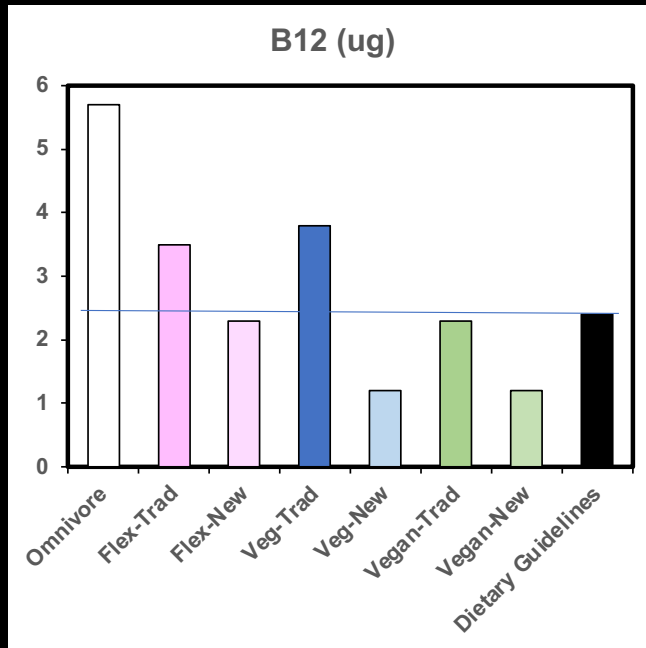


# POTENTIAL PROTEIN DEFICIENCY



Marinangeli et al. (2021). The effect of increasing intakes of plant protein on the protein quality of Canadian diets. *Applied Physiology, Nutrition, and Metabolism*, 46(7), 771-780.

# POTENTIAL MICRONUTRIENT DEFICIENCY



## Potential micronutrient deficiencies

- Vitamin B<sub>12</sub>, Calcium, Zinc, Magnesium, Potassium

# DESIGNING HEALTHIER NEXT-GENERATION PLANT-BASED FOODS

## Macronutrient Composition

- Fats, Proteins, Carbohydrates

## Micronutrient Composition

- Vitamins and Minerals

## Nutraceutical Fortification

- Dietary Fibers, Probiotics, & Phytochemicals



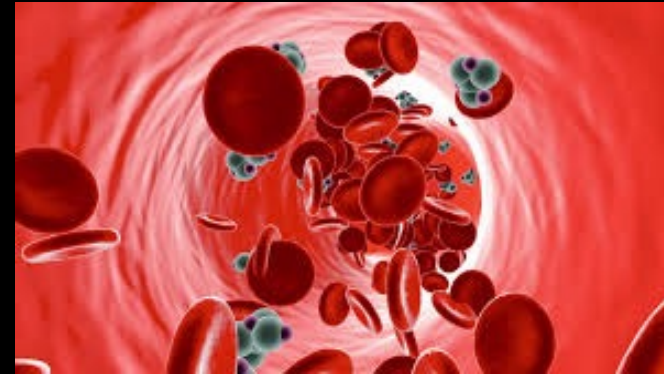
# DESIGNING HEALTHIER NEXT-GENERATION PLANT-BASED FOODS

## Digestibility

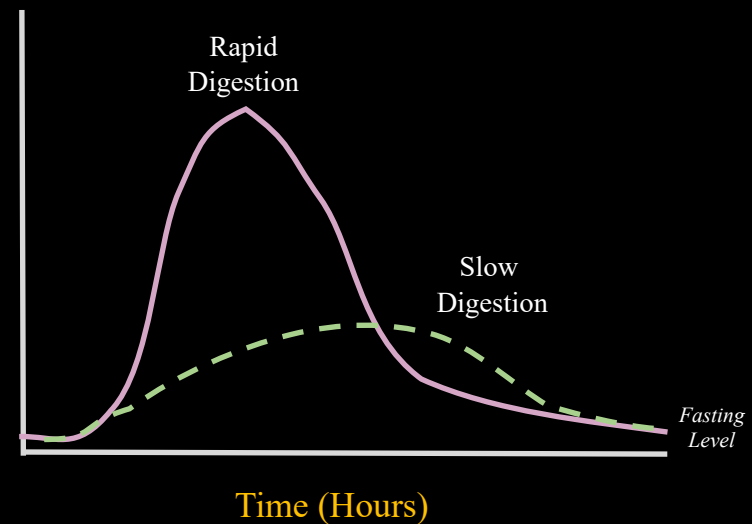
- Fats, Proteins, Carbohydrates

## Bioavailability

- Vitamins and Minerals
- Nutraceuticals



Blood  
Nutrient  
Levels




# PLANT-BASED MEAT SEAFOOD

## OMEGA-3 FORTIFIED SCALLOPS



SCALLOP	
<i>Nutrition Facts</i>	
PER 100g	69 KCAL
0.5g	FAT
3.2g	CARBOHYDRATE
12g	PROTEIN
392mg	SODIUM
24mg	CHOLESTEROL
0%	VITAMIN A
0%	VITAMIN C
1%	CALCIUM
2%	IRON



# MIMICKING REAL SEAFOOD: MULTISENSORIAL ENGINEERING

# Sound

## Bubbling & Evaporation



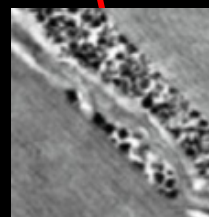
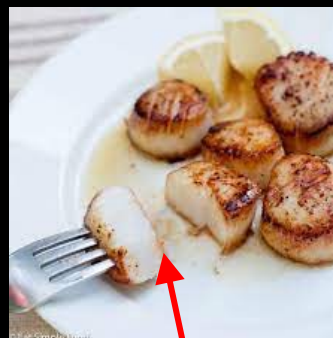
# Texture

# Small & Large Deformation



# Mouthfeel

## Breakdown/Texture-Time

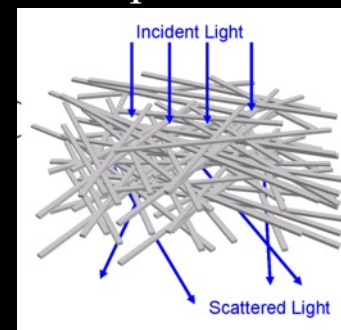


# Microstructure

## Organization

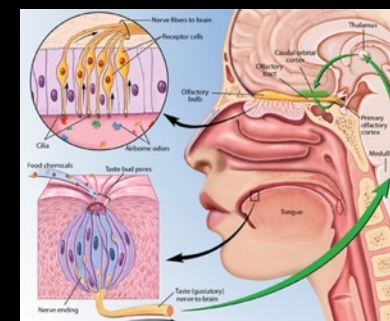
## Appearance

# Light Absorption & Scattering



## Aroma

## Specific Volatile Profile



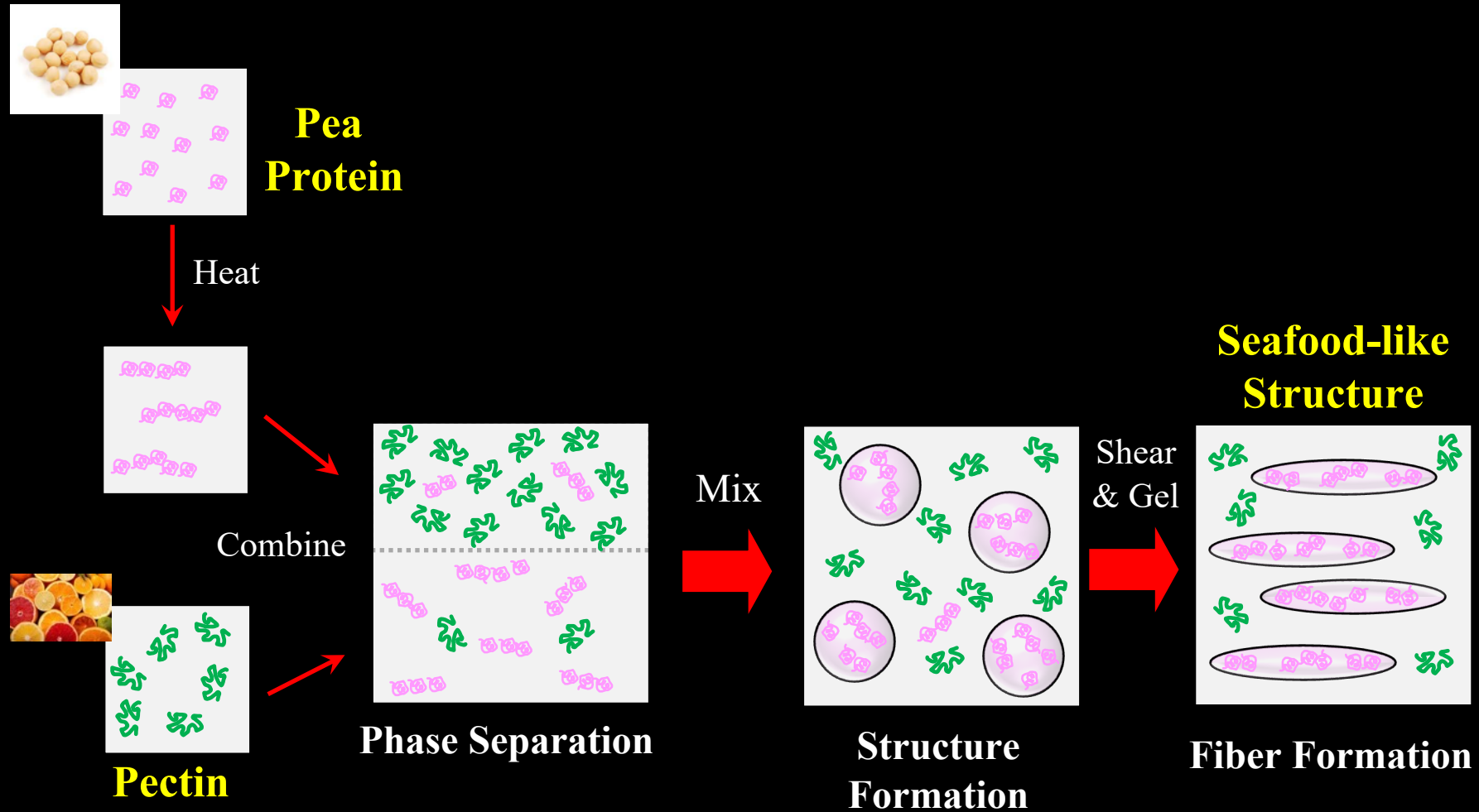
# Taste

## Specific Tastant Profile

## What is the structural basis of deliciousness?



# MIMICKING MICROSTRUCTURE: SOFT MATTER PHYSICS APPROACH

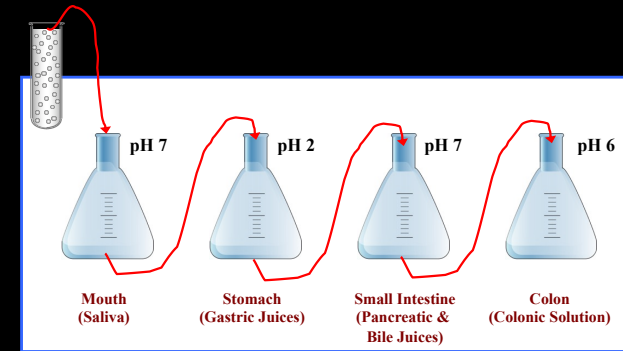


# PLANT-BASED SCALLOP

## OMEGA-3 FORTIFIED



# PLANT-BASED SCALLOP DIGESTIBILITY

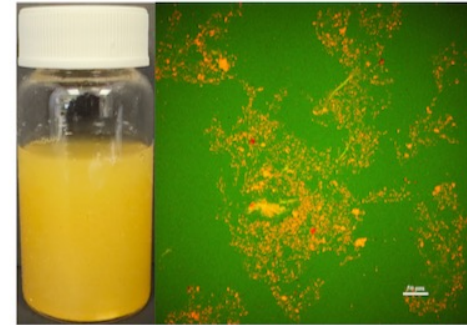
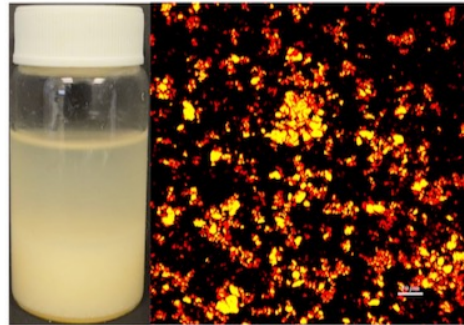
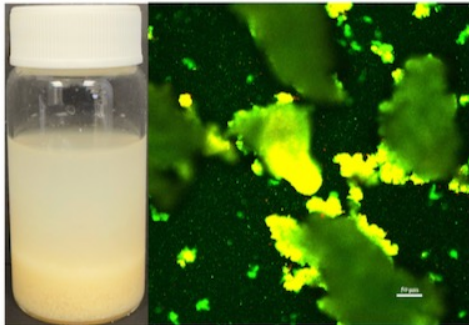


**Mouth**

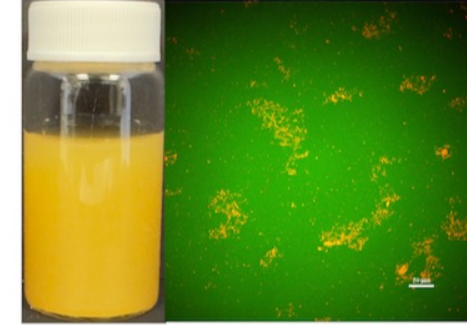
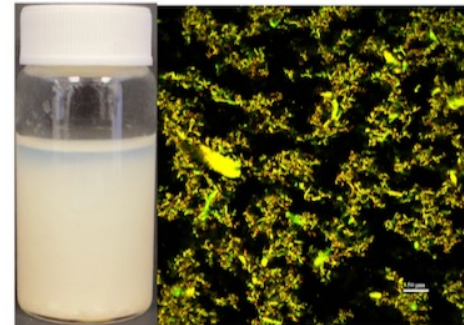
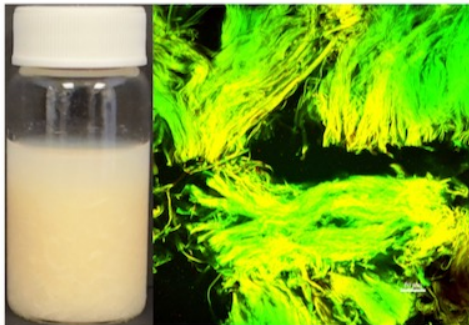
**Stomach**

**Small Intestine**

**PB Scallop**

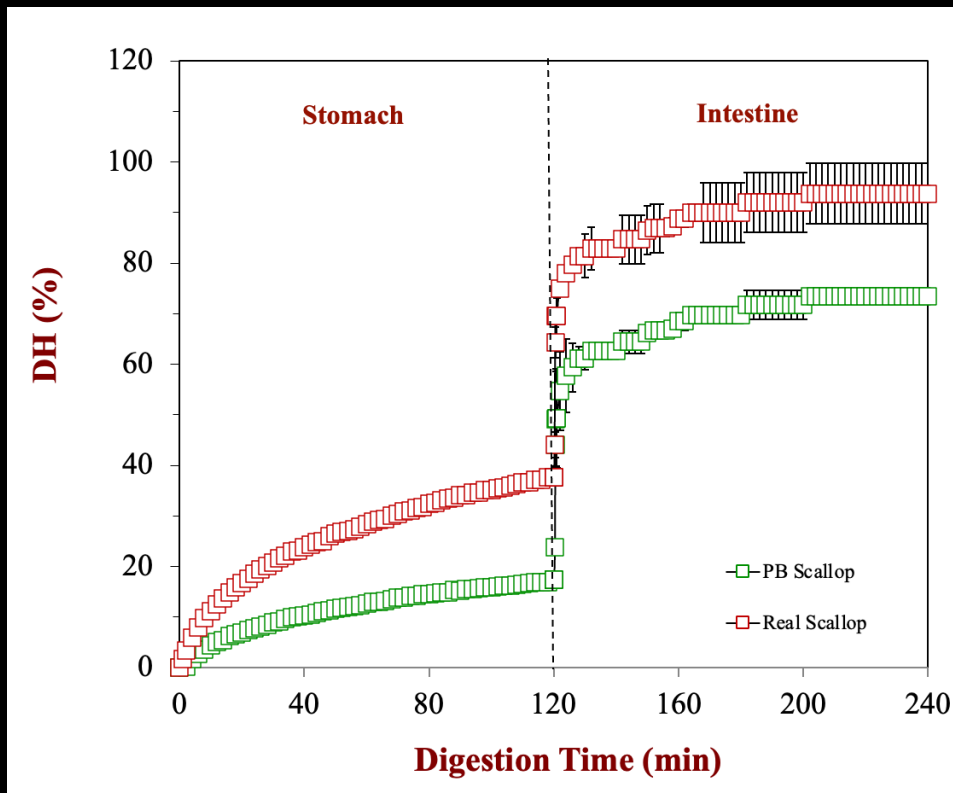


**Real Scallop**



Microstructure of real and plant-based scallop in oral , gastric, and intestinal stage

# PLANT-BASED SEAFOOD DIGESTIBILITY



Protein hydrolysis of plant-based and real scallop in simulated gastrointestinal tract.



# PLANT-BASED MEAT DIGESTIBILITY



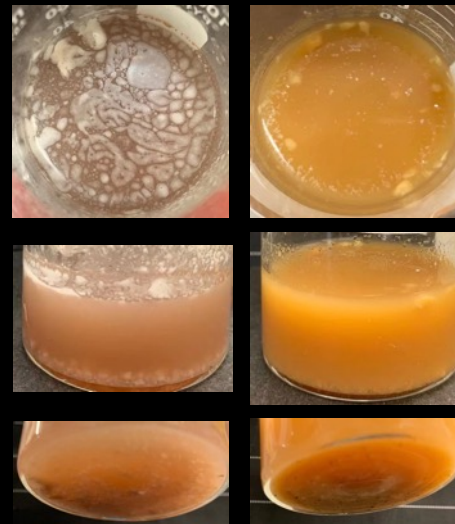
Mouth



Real  
Beef

PB  
Beef

Stomach



Real  
Beef

PB  
Beef

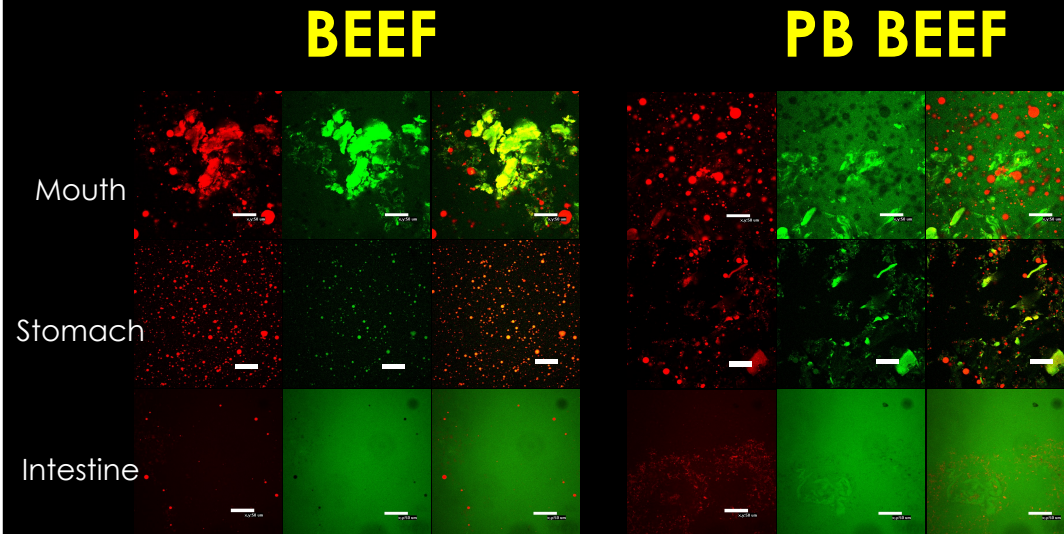
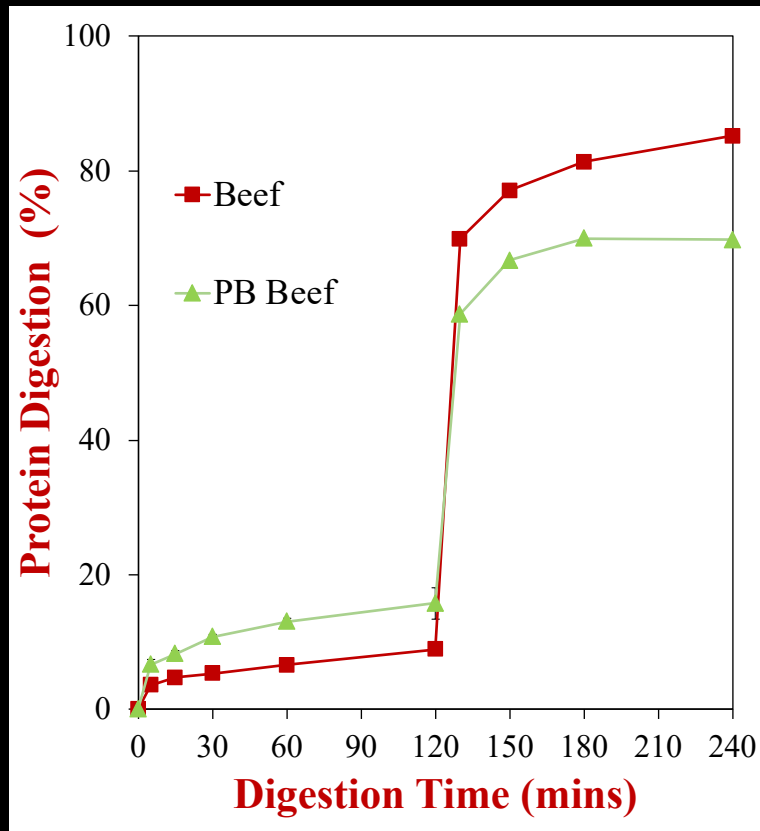
Small Intestine



Real  
Beef

PB  
Beef

# PLANT-BASED MEAT DIGESTIBILITY

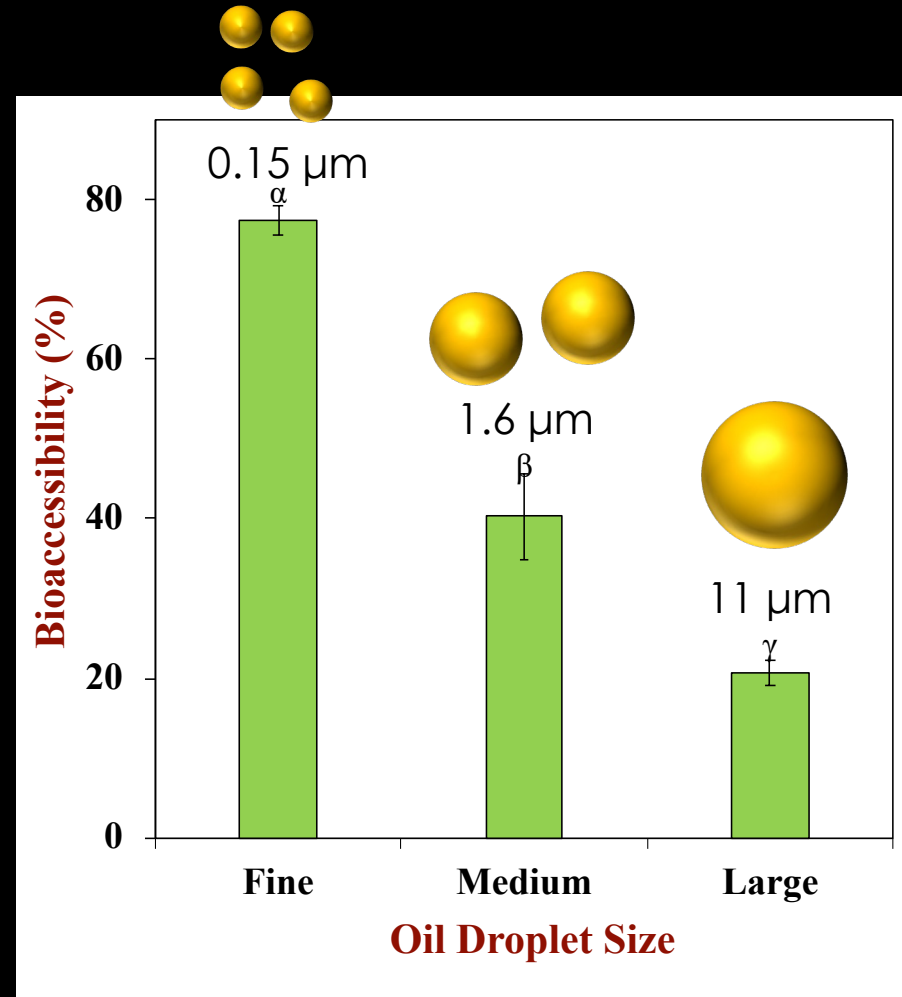


Zhou et al (2021). Digestibility and Gastrointestinal Fate of Meat versus Plant-Based Meat Analogs: An in Vitro Comparison  
*Food Chemistry* 364(2):130439



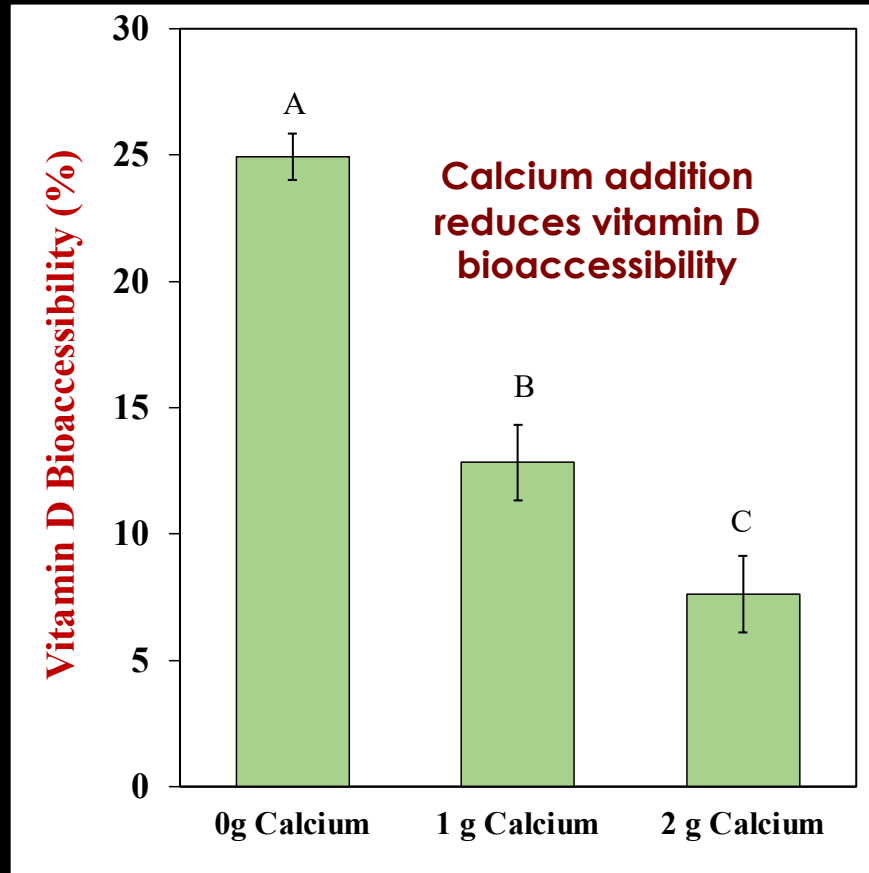
# PLANT-BASED MILK

## Fortification

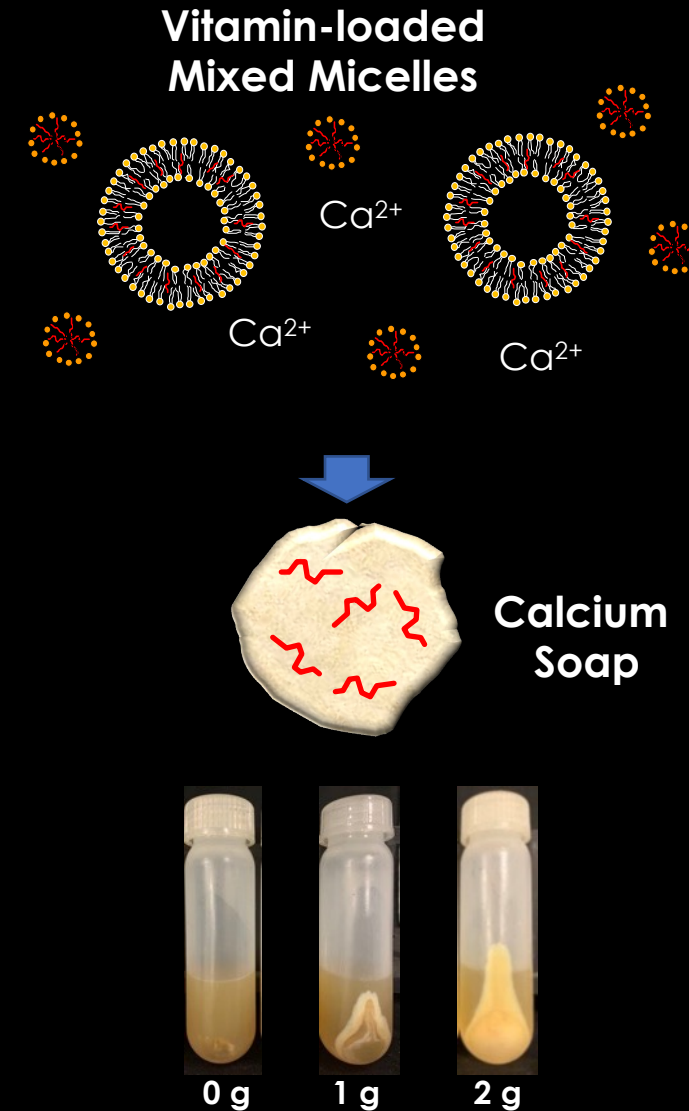


Tan et al. (2021). Bioaccessibility of oil-soluble vitamins (A, D, E) in plant-based emulsions: Impact of oil droplet size. *Food & Function* 12(9)

# PLANT-BASED MILK FORTIFICATION

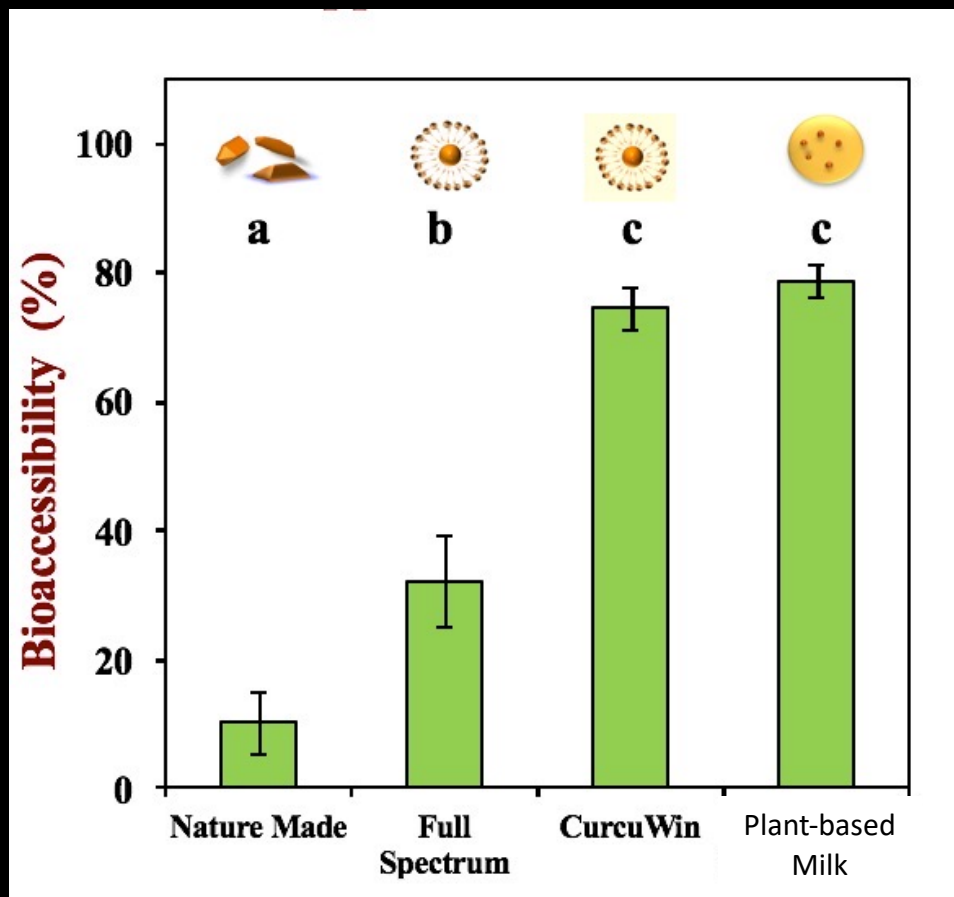


**Vitamin D-fortified Almond Milk**



Zhou et al. (2021). Fortification of Plant-Based Milk with Calcium May Reduce Vitamin D Bioaccessibility: An In Vitro Digestion Study. J. Agric. Food Chem. 69, 4223

# PLANT-BASED MILK FORTIFICATION



Plant-based milk gives higher bioaccessibility than commercial curcumin supplements

## Bioaccessibility:



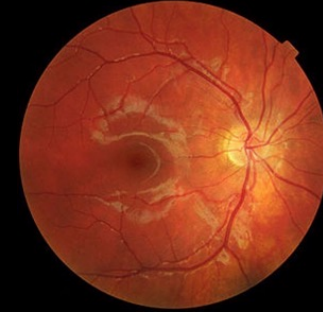
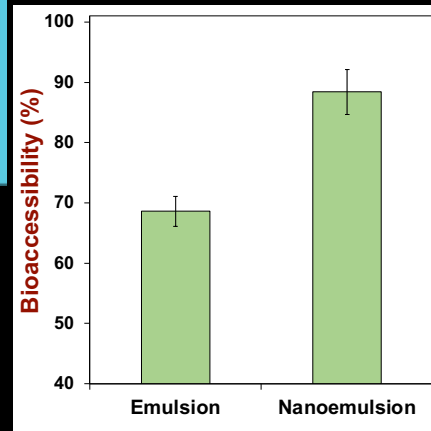
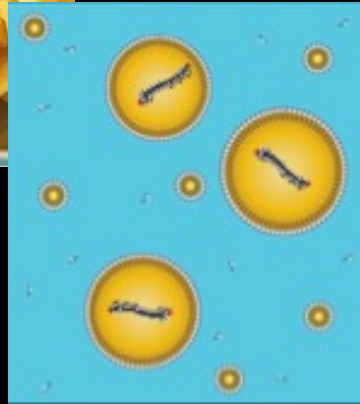
Zheng et al. (2018). Impact of Delivery System Type on Curcumin Bioaccessibility: Comparison of Curcumin-Loaded Nanoemulsions with Commercial Curcumin Supplements. J. Agric. Food Chem, 6, 10816-10826

# PLANT-BASED EGG

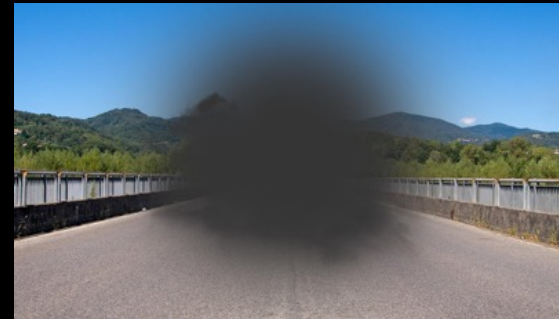
## FORTIFICATION FOR IMPROVED HEALTH



**PERSONALIZED  
NUTRITION**



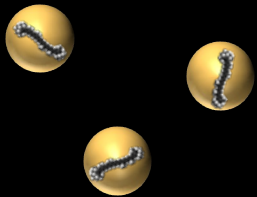
**MACULAR  
DEGENERATION**



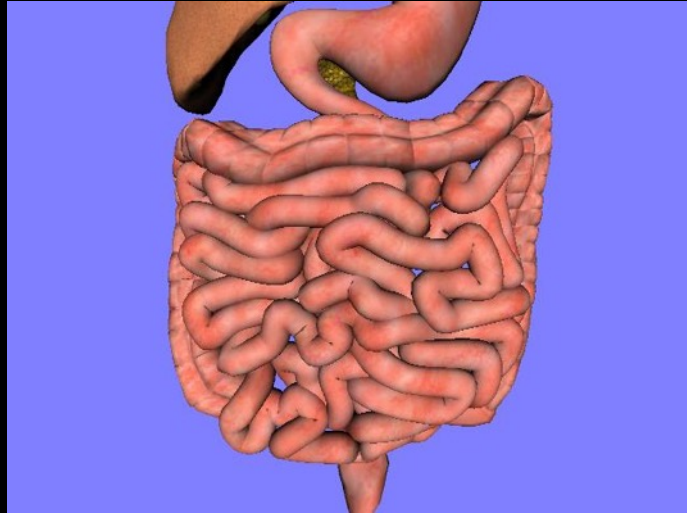
# Food Delivery Systems: For Nano to Nano to Nano



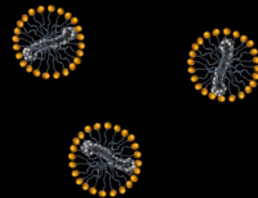
**Food**



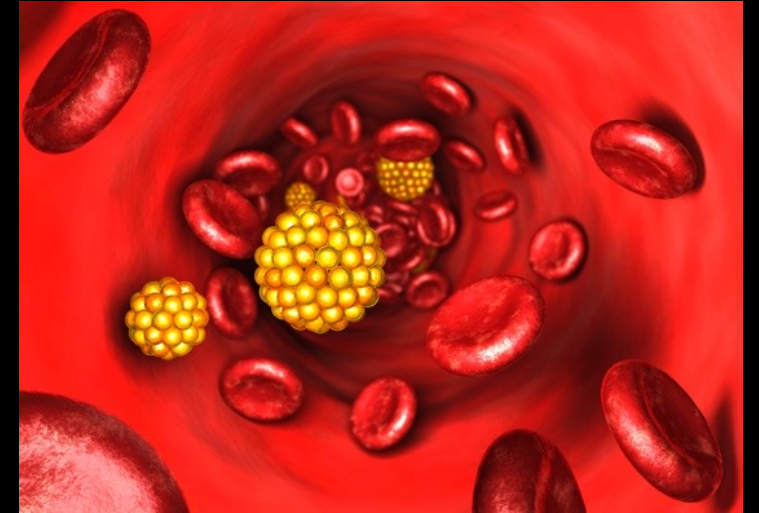
**Nano-fat**



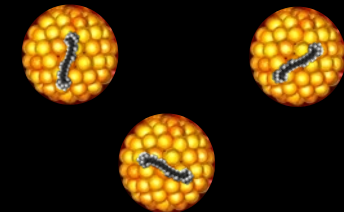
**Intestine**



**Micelles**



**Blood Stream**



**Chylomicrons**

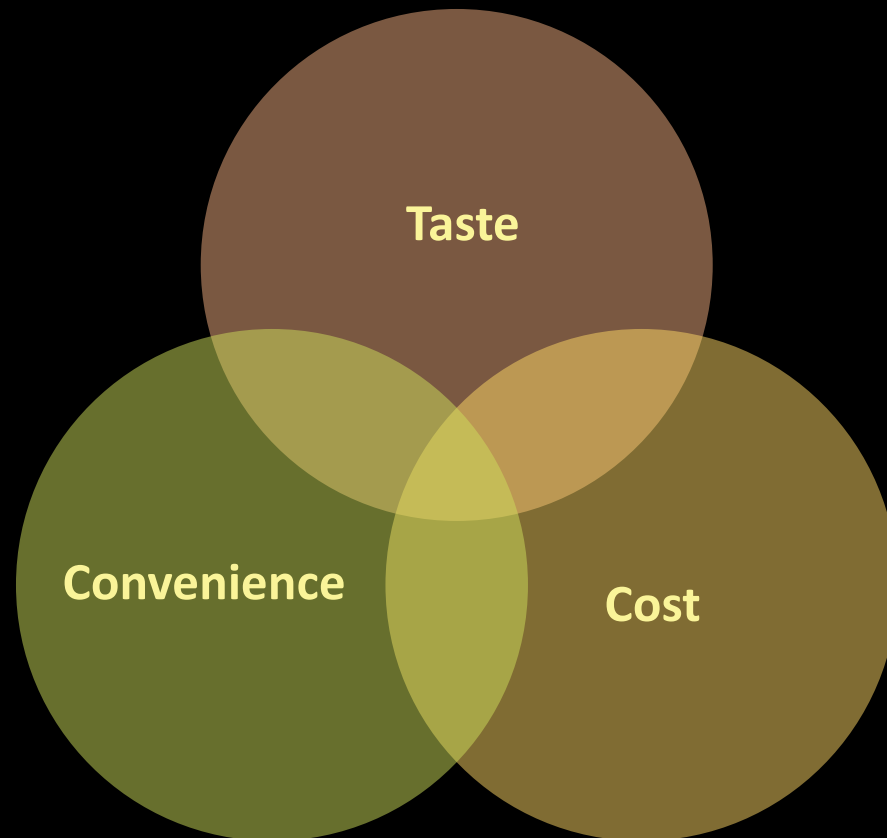




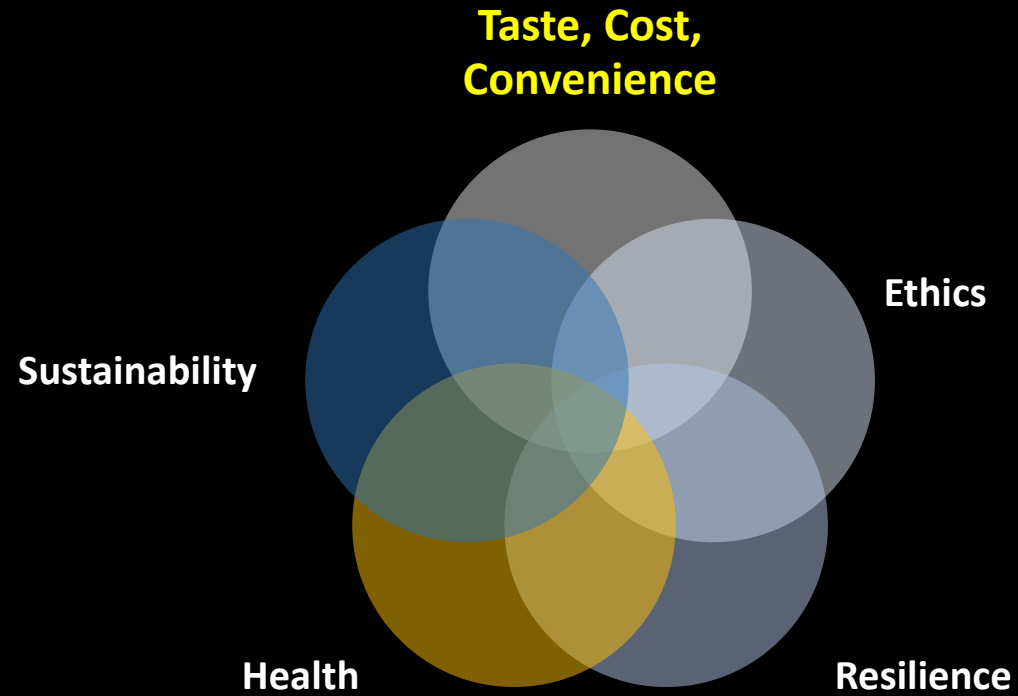
CLIMAX

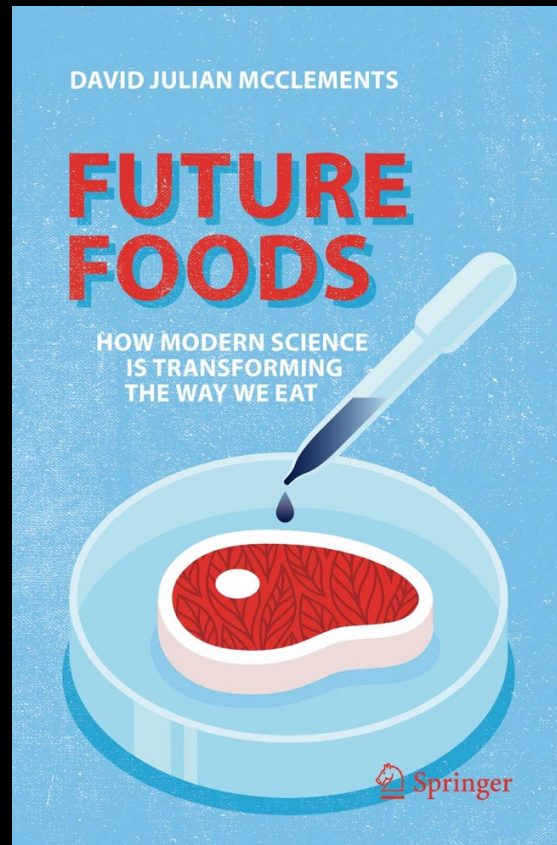


# Food Science & Engineering: The Old Paradigm

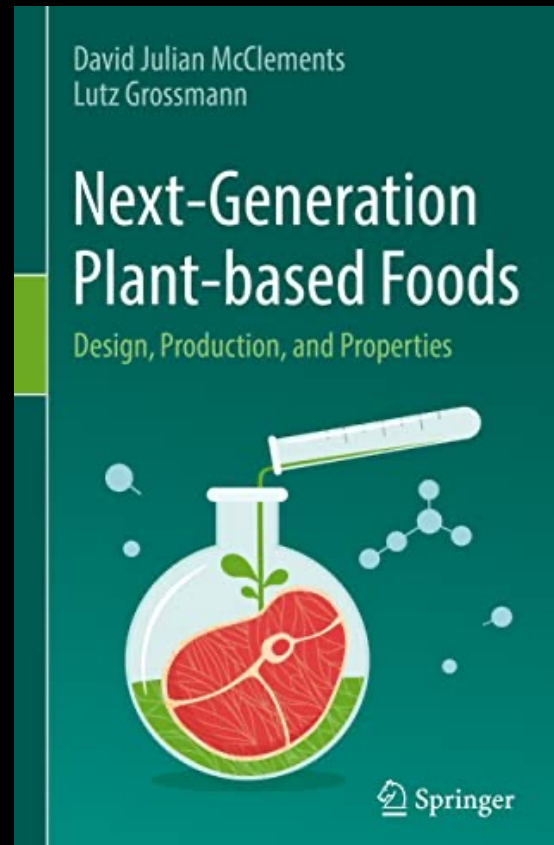


# Food Science & Engineering: The New Paradigm

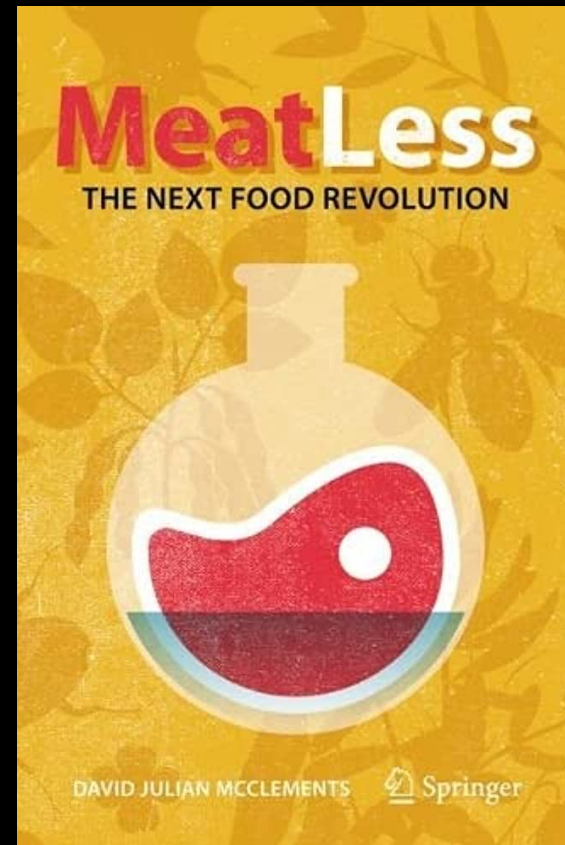




2019



2022



2023



# Acknowledgements

