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Kandi Sridhar, Said Bouhallab, Thomas Croguennec, Denis Renard, Valérie Lechevalier-Datin

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Future Challenges for Cereal Science and Technology

Application of high-pressure and ultrasound technologies for legume proteins as wall material in microencapsulation

Kandi Sridhar, Saïd Bouhallab, Thomas Croguennec,
Denis Renard, Valérie Lechevalier

06 July, 2022

ORCID

Introduction

- ✓ Legume proteins are important in today's Europe for food & feed production
- ✓ Major European strength
- ✓ Encouraging European Union (EU) policies for the production of protein and leguminous plants in the EU's agriculture sector.
- ✓ Legume proteins: sustainable and economic resources to address the challenge of providing healthy, sustainable, and affordable nutritional needs to the growing global population

Introduction

Legume protein functional properties

- ✓ Recently, legume proteins are highly focused for their easy availability, hypo-allergenicity, excellent techno-functional properties, and emulsifying ability (wall forming and gelling),
- ✓ Green trend to replace animal-derived proteins (e.g., whey protein, gelatin, and casein) in encapsulation process

Introduction

Problems associated with legume proteins

- ✓ Poor solubility
- ✓ Lower functionality
- ✓ Less viscosity
- ✓ Unpleasant grassy and beany flavor, compared to animal-derived proteins, limiting their use as biopolymers for the encapsulation processes

- ✓ Transformation of legume protein functionality is an important phenomenon for a wide range of scientific and industrial applications used in encapsulation.

Legume protein modification approaches

- ✓ Various emerging technologies have therefore attracted in modification of legume protein functionality with favorable emulsification and encapsulation properties
- ✓ food industries can accept them as a low-cost, sustainable, and
- ✓ Nature-inspired biopolymers.
- ✓ Biopolymers could potentially be used to encapsulate a wide variety of bioactive compounds and control their triggered release, which further increase the nutritional value of food through fortification/enrichment.

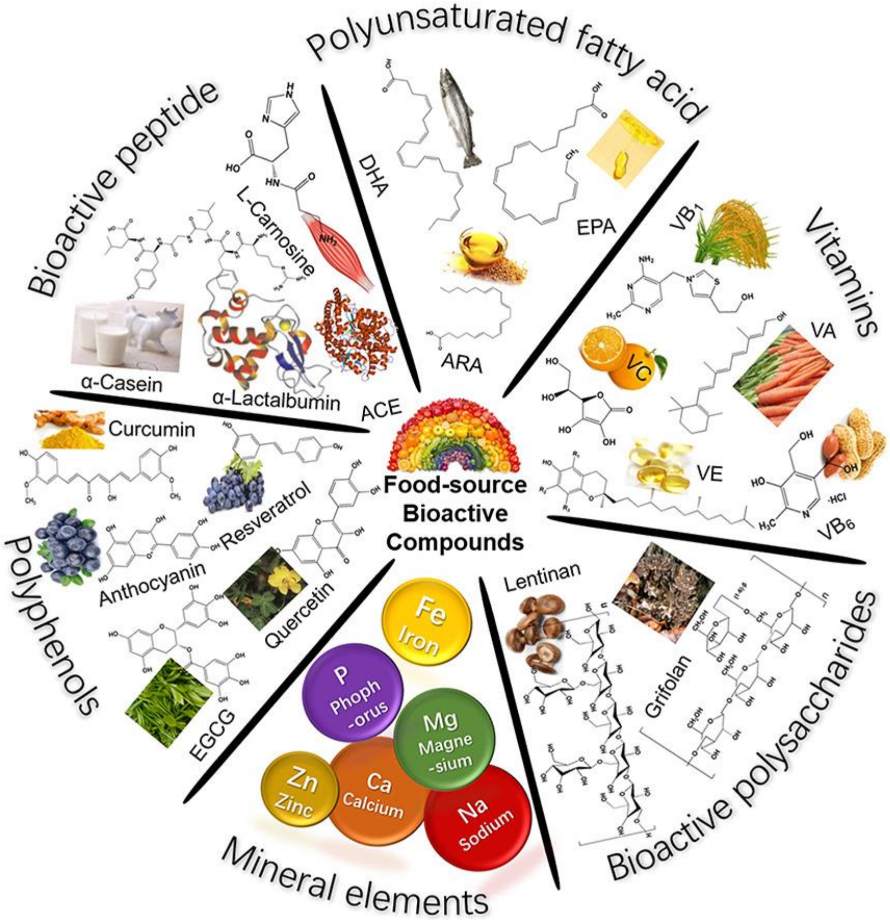
Problems associated with bioactive compounds

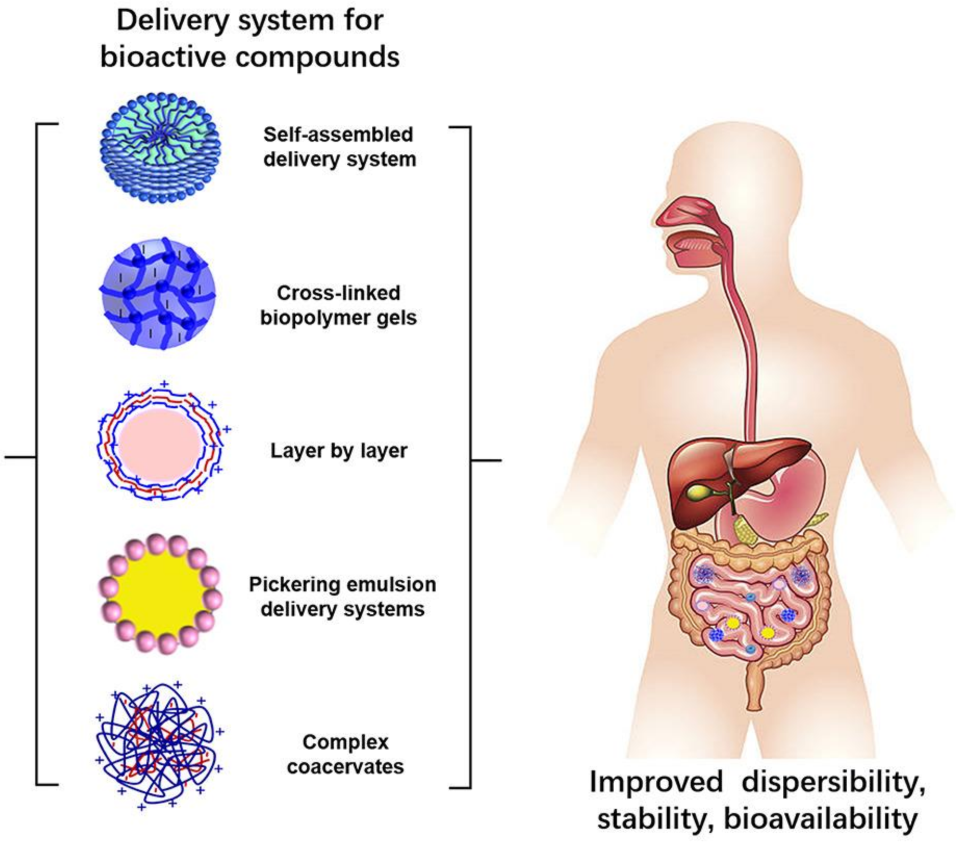
Extracted bioactive compounds and their protection from….

- Light
- Temperature
- different pH
- Poor solubility
- High water solubility
- Less bioavailability

Microencapsulation

Coating materials **Core materials** **Microcapsule**





in ethylacetate

phase (water and PVA) while stirring to form an emulsion

Filtration

Packaging ← Sieving ← Drying ← Washing

Research Project

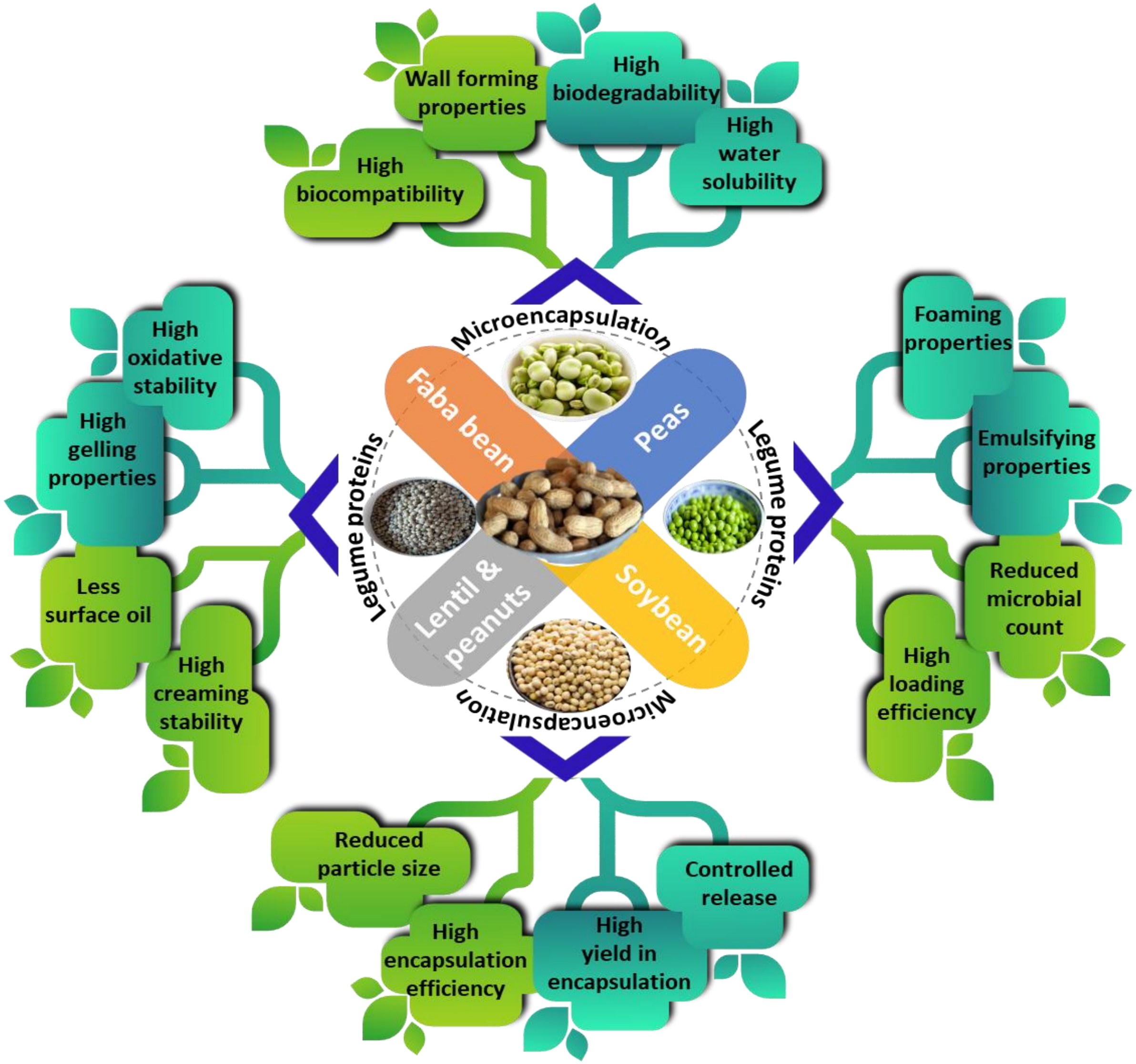
Microencapsulation properties of legume proteins: An integrated valorization towards sustainable plant-based functional food systems in Europe

Specific objectives

- To understand the potential of legume proteins (lupine and pea) as wall materials in microencapsulation applications (WP1)
- To modify and optimize functional properties of legume proteins for microencapsulation process (WP2)
- To study the applicability of microcapsules with modified legume proteins in fortification using functional pancake as a model food: *In vitro* digestion and release kinetics (WP3)

MELON

Native legume proteins in microencapsulation



High biocompatibility

Wall forming properties

High biodegradability

High water solubility

High oxidative stability

High gelling properties

Less surface oil

High creaming stability

Foaming properties

Emulsifying properties

Reduced microbial count

High loading efficiency

Microencapsulation

Legume proteins

Faba bean

Peas

Lentil & peanuts

Soybean

Legume proteins

Microencapsulation

Reduced particle size

High encapsulation efficiency

High yield in encapsulation

Controlled release

Figure 1. Properties of legume proteins (native) as carrier materials in microencapsulation

High-pressure and ultrasound technologies for legume protein functionalities

Table 1. Recent studies dealing with high-pressure and ultrasound technologies for improvement of legume protein functionalities[1]

Method	Protein source	Treatment conditions	Findings	Reference
HPP	Red kidney bean	• Pressure of 200, 400, and 600 MPa for 15 min at 23°C • The average pressurization rate = 20 to 25 s per 100 MPa and de-pressurization time = <5 s	• Increased WHC, foaming, and emulsification properties at > 600 MPa • Changes in the secondary structure of β-sheets • Increased G' and G" with higher denaturation temperature of 105°C • Little changes were observed in protein structure at pressure of 200 and 400 MPa	Ahmed et al. (2018)
	Bambara bean	• Pressure of 200, 300, 400, 500, and 600 MPa at 22°C and pH of 4.50, 7, and 9	• Vicilin was the major protein • Structural changes were observed at different pH • Decreased the total number of hydrogen bonds • Exposure of tryptophan tyrosine residues • Stable protein structure was observed up to 600 MPa • Partial unfolding, dissociation of subunits, and protein aggregation were reported at different pH and HPP treatments	Mune Mune et al. (2020)
	Pea protein	• Pressure of 200, 400, and 600 MPa for 5 min at 23°C	• Formation of high molecular weight protein aggregates • High foaming capacity • Decreased intensity of the 11S protein band • Low particle size of 26-68 µm and foaming capacity of 81% with increased stability	Chao et al. (2018)
US	Pea and soy protein isolates	• Acoustic intensity of ~34 W cm^2 (20 kHz and an amplitude of 95%) for 2 min	• Reduced protein size of 187 to 298 nm and intrinsic viscosity of 0.31 dL/g with no change in the primary structure molecular weight profile of proteins	O'Sullivan et al. (2016a)
	Soy protein isolate	• Acoustic intensity of ~ 34 W cm^2 (20 kHz and an ultrasonic amplitude of 95%) for 2 min	• Reduced protein aggregate size of ~200 nm and intrinsic viscosity of 0.27 dL/g with no change in the primary structure molecular weight profile of proteins • Significant reduction in emulsion droplet size of 0.10 to 10 µm and lower interfacial tension of 12 to 0.20 mN/m with high stability at all concentrations over a 28-day storage at room temperature	O'Sullivan et al. (2016b)
	Soy protein isolate and pea protein concentrate	• 20 kHz with ultrasound power (562.50, 637.50, or 712.50 W) and exposure time (120, 360 or 600 s)	• Improved the OHC • Improved techno-functional properties with increase in dispersibility of protein materials	Omura et al. (2021)

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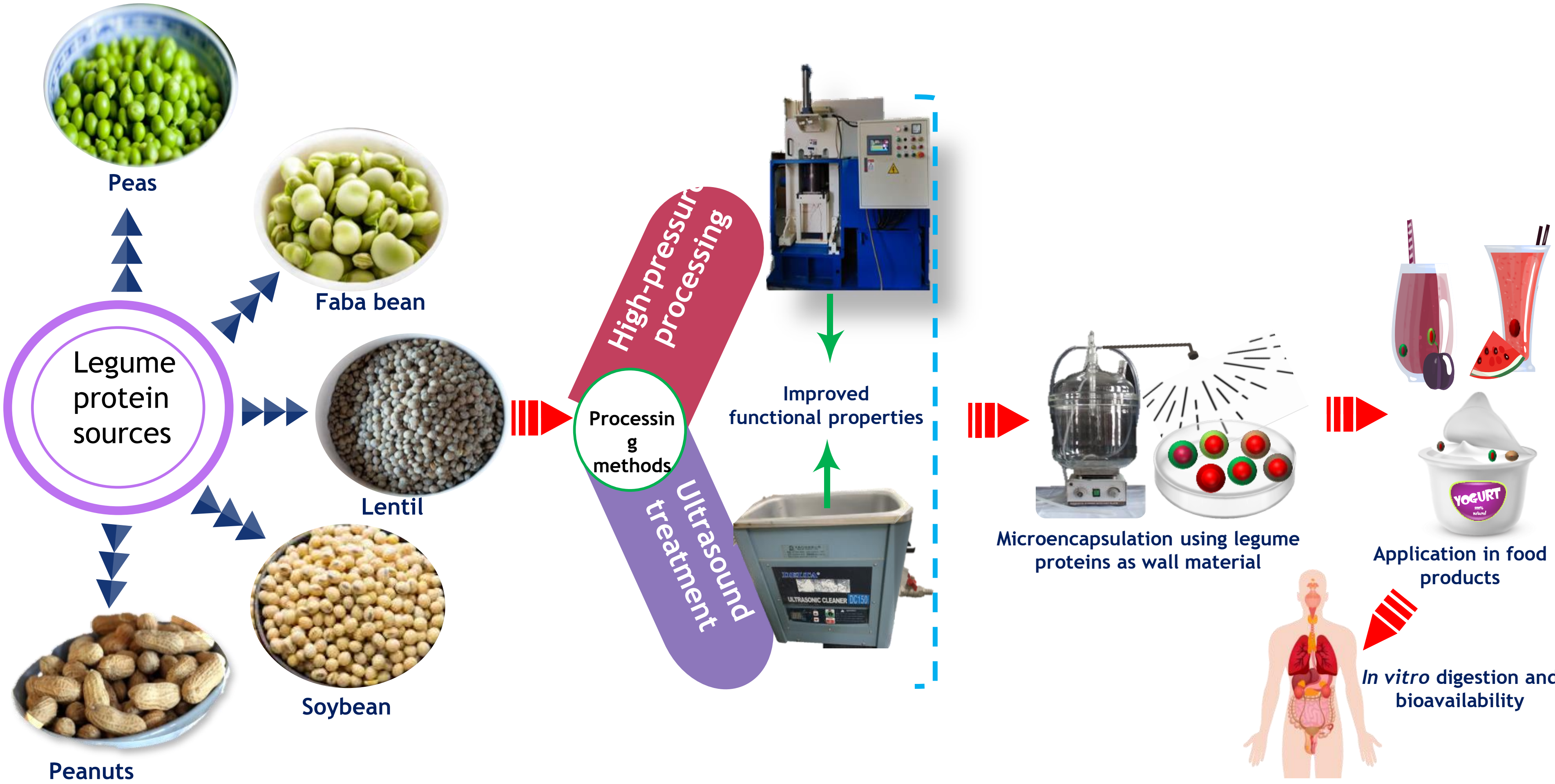
[1] HPP = High pressure processing, US = ultrasonication.



Legume protein sources

Peas

Faba bean

Lentil

Soybean

Peanuts

Processing methods

High-pressure processing

Ultrasound treatment

Improved functional properties

Microencapsulation using legume proteins as wall material

Application in food products

In vitro digestion an bioavailability

High-pressure and ultrasound technologies for legume proteins as wall material in microencapsulation

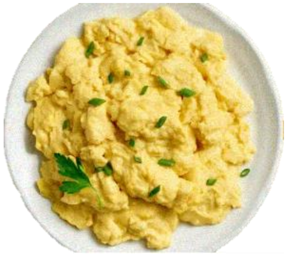
Evolving consumer market and global legume market trends

- Growing demand for legume proteins (native and/or modified) due to consumer willingness towards a higher proportion of plant-based healthier foods and a further reduction in food loss and waste
- Development of consumer-oriented food product formulations, such as encapsulated licorice root extract beverage and yogurt

Nutralys® L85M: pea protein for meat-free products (Roquette)

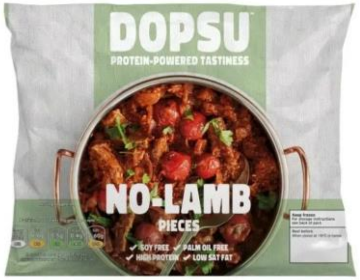
Banza Pizza (Banza®)

Plant-based pork (OmniFoods®)

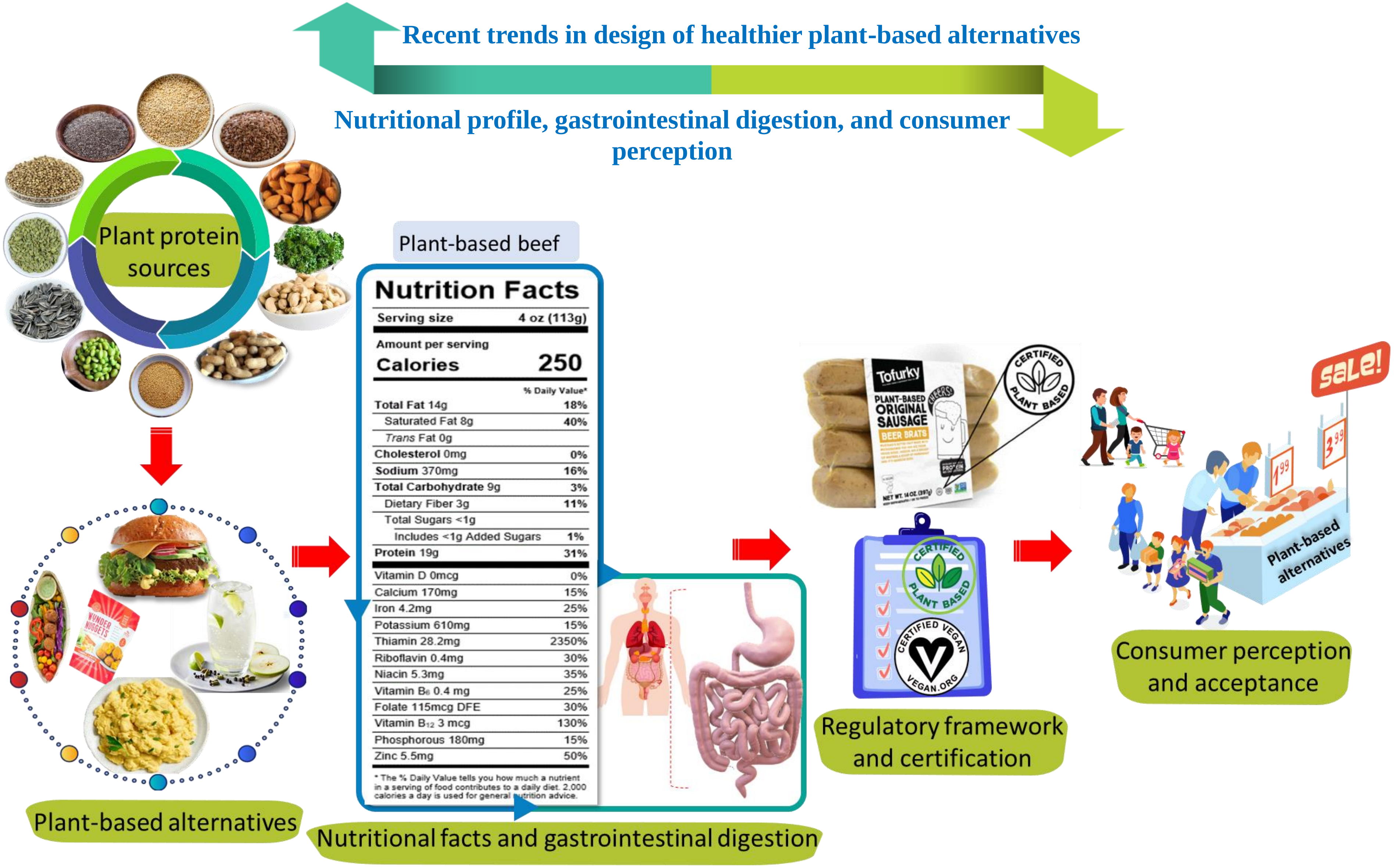


Plant-based egg substitute (Nabati®)

Plant-based nuggets, bites, and strips (Tyson Foods®)



Dopsu^{TM} (Plant-based duck, lamb, pork, and beef) (ABP Food Group®)



Recent trends in design of healthier plant-based alternatives

Nutritional profile, gastrointestinal digestion, and consumer perception

Plant protein sources

Plant-based alternatives

Plant-based beef

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 9g	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_6 0.4 mg	25%
Folate 115mcg DFE	30%
Vitamin B_{12} 3 mcg	130%
Phosphorous 180mg	15%
Zinc 5.5mg	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.

Nutritional facts and gastrointestinal digestion

Regulatory framework and certification

Consumer perception and acceptance

Conclusions and take-home message

- ✓ Emerging technologies (HPP and US) to legume proteins for the improvement in encapsulation properties and their application in design of novel foods
- ✓ The use of legume proteins as wall materials allowed the development of novel functional foods enabling the controlled release of bioactive compounds at a specific target site
- ✓ Consumer interest in shifting towards more sustainable and clean-label plant-based diets made a way for growth in the legume protein market

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Thank you for your incomparable attention !!!

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