UNIVERSITY OF ALBERTA

DEPARTMENT OF AGRICULTURAL, FOOD & NUTRITIONAL SCIENCE

FACULTY OF AGRICULTURAL, LIFE & ENVIRONMENTAL SCIENCES

Value-added processing and applications of oat proteins

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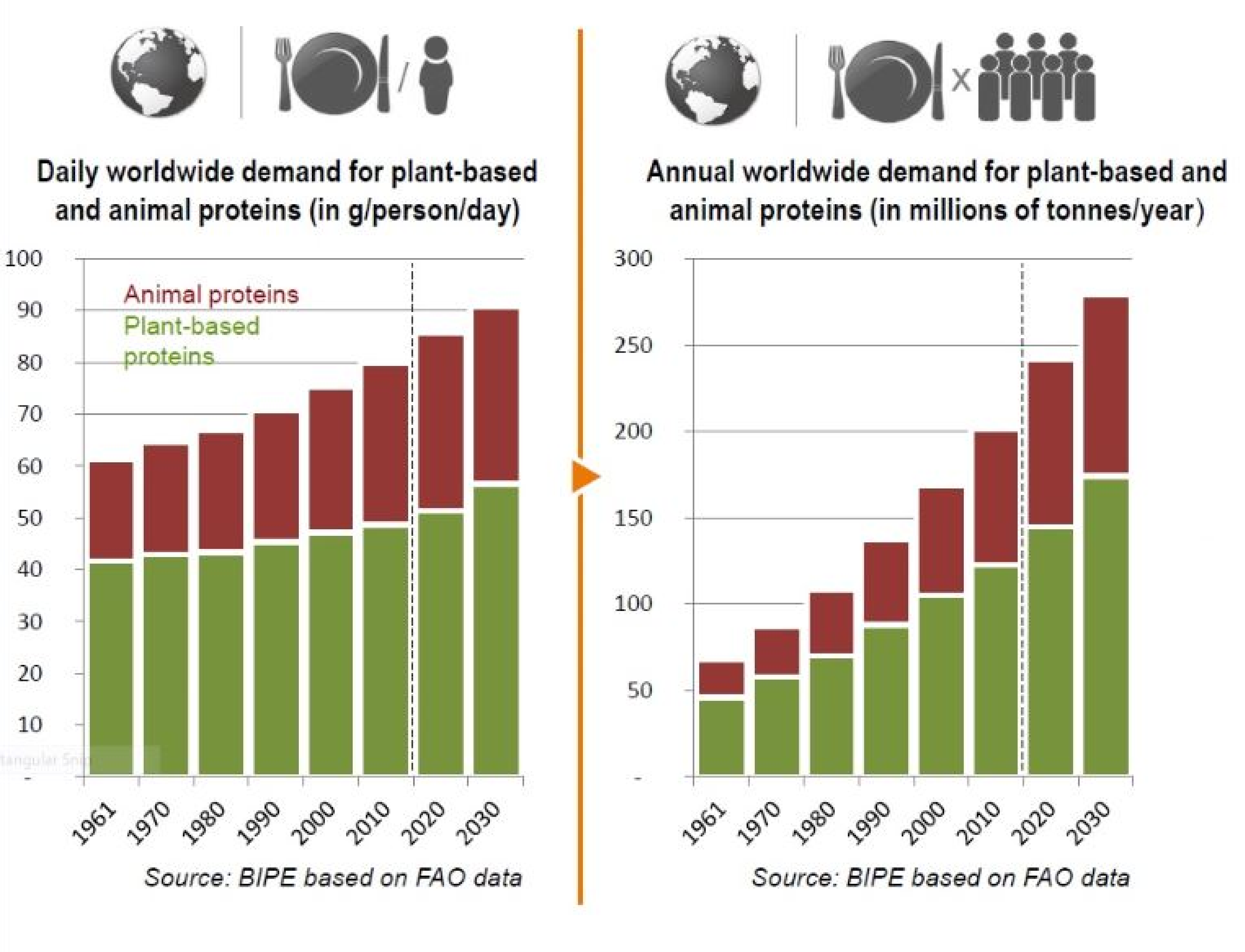
Global plant protein market

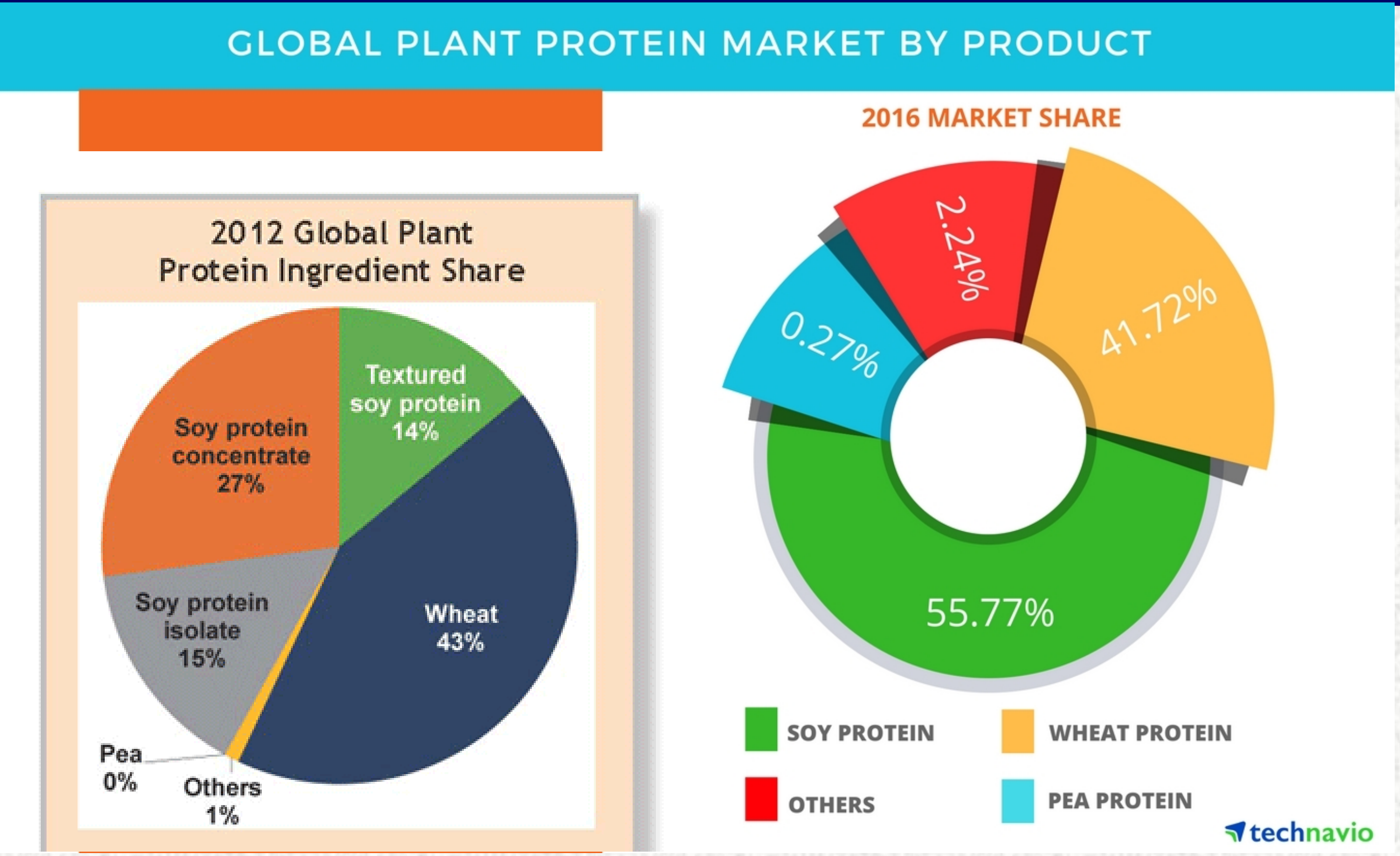


2010-2030 plant protein will grow by 43%

Health awareness

Sustainability

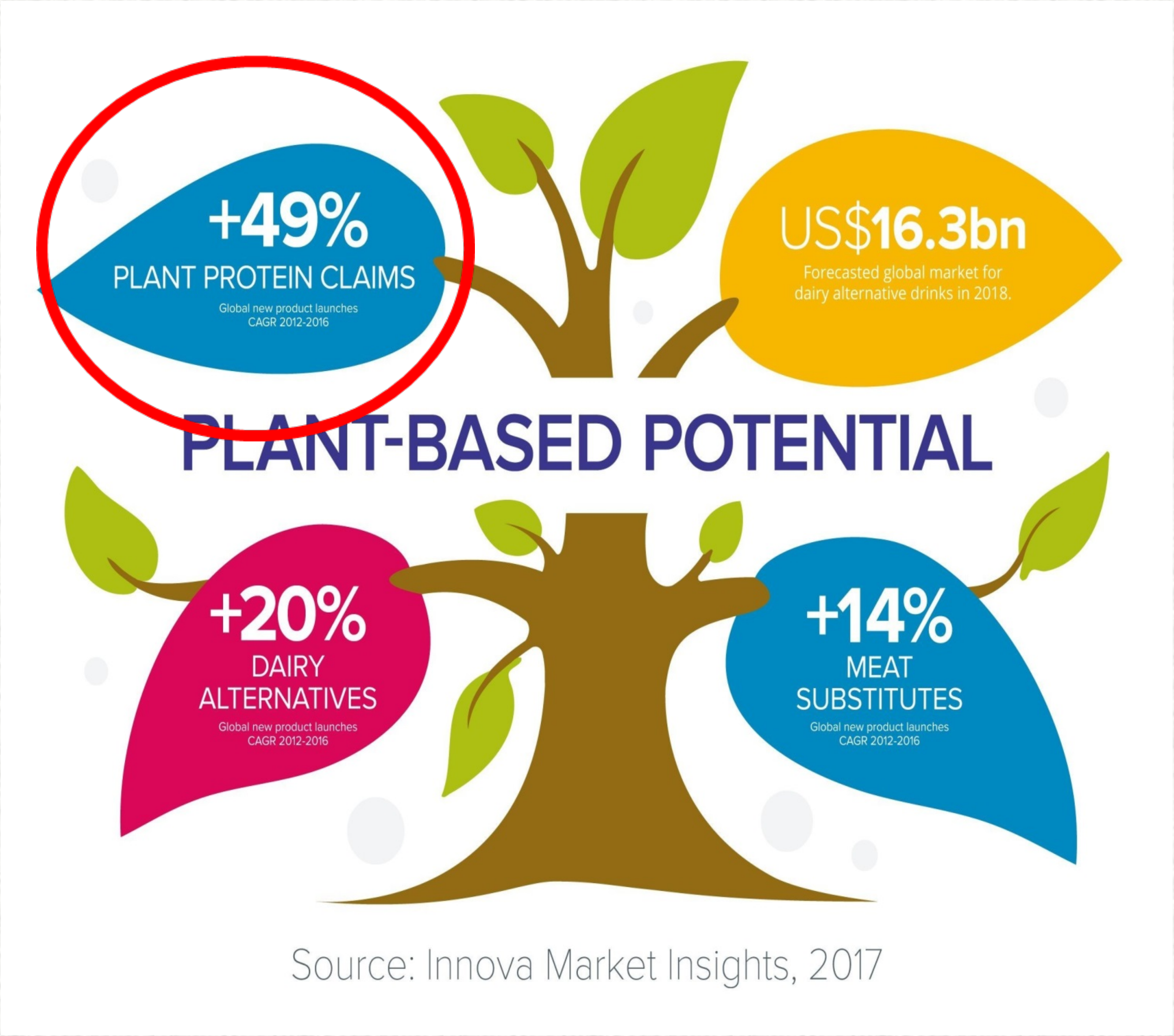
Global plant protein market



USD $8.35 billion in 2016

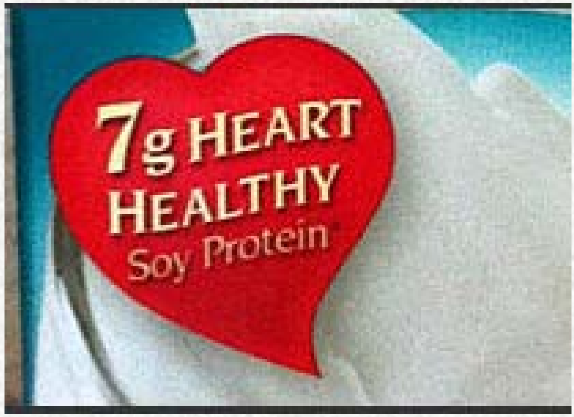
USD $14.22 billion in 2022

Global plant protein market



Health claim

- “Diets low in saturated fat and cholesterol that include 25g of soy protein a day may reduce the risk of heart disease” (US FDA, 1999).



- American Heart Association (AHA, 2000) endorsed the use of soy foods for people with elevated cholesterol

- Protein claims: good source of protein, high in protein

Food fortified with protein

U.S. Nutrient Content Claims (21CFR 101.54)

A food or beverage product may claim the following:

- "Added Protein"
- "Extra Protein"
- "Fortified with Protein"
- "Enriched in Protein"
- "More Protein"

...if it contains more-than 10% of the protein DRV value than the reference serving size of that food (RACC: Reference amounts customarily consumed per eating occasion) normally contains.

A food or beverage product may claim the following:

- "Good Source of Protein"
- "Contains Protein"
- "Provides Protein"

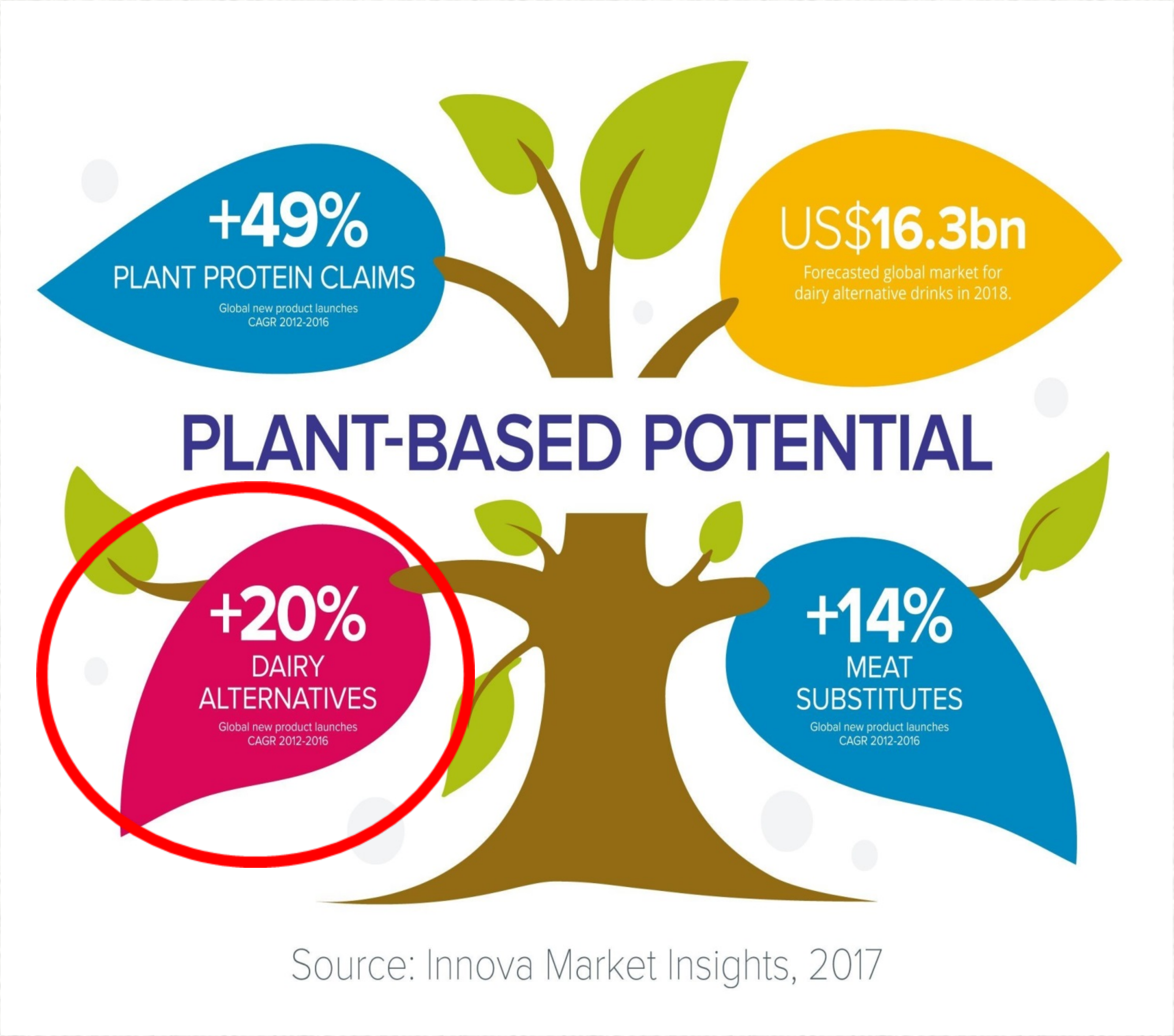
...if it contains more-than 10% of the DRV for protein (> 5g) per reference serving size (RACC).

A food or beverage product may claim the following:

- "Excellent Source" of Protein"
- "Rich Source of Protein"
- "High Source of Protein"

...if it contains more-than 20 of the DRV for protein (> 10g) per reference serving size (RACC)

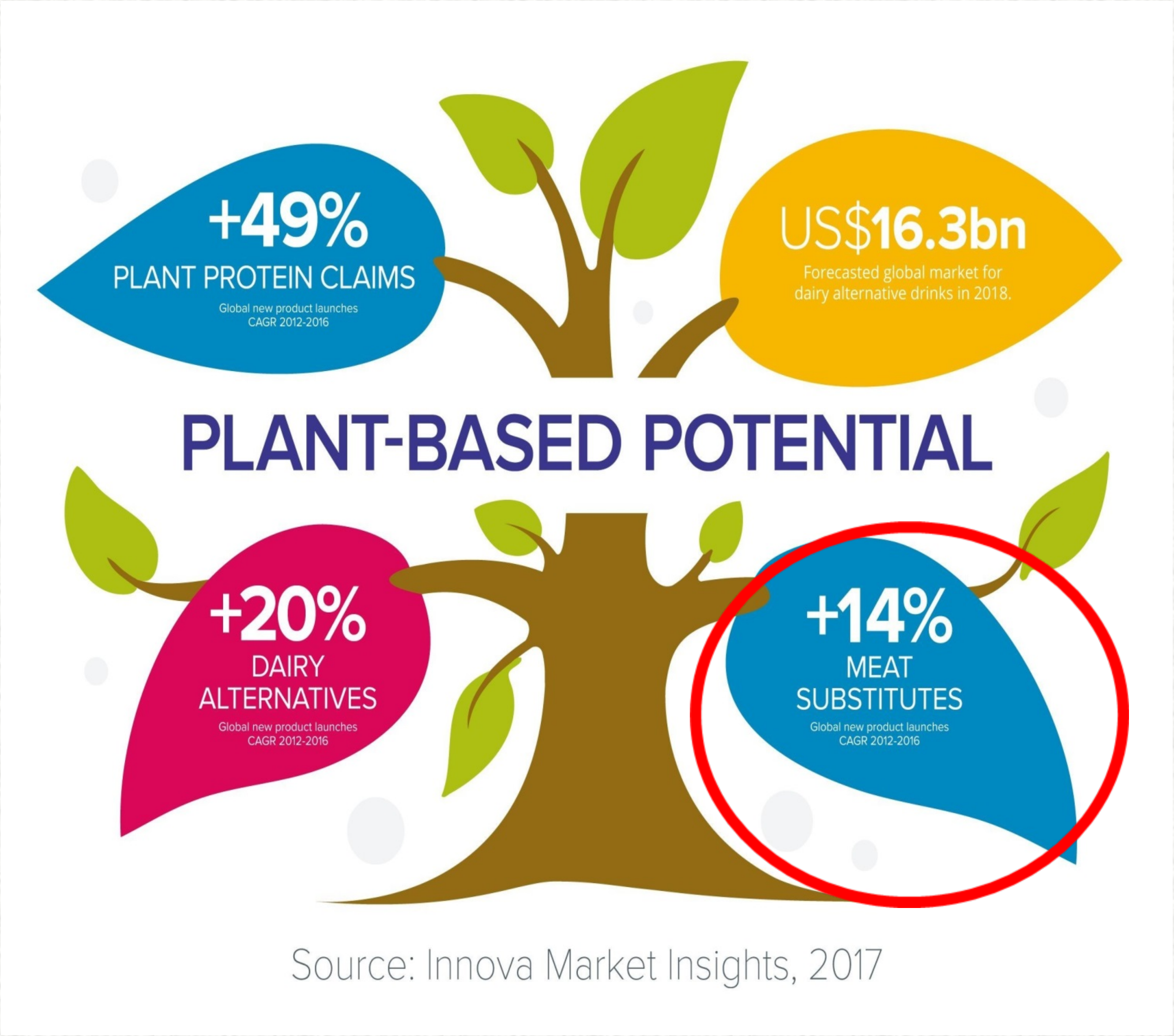
Global plant protein market



Plant protein product samples

Food and Beverages

Global plant protein market



Plant protein product samples

Plant protein product samples

Dietary supplements

Animal feed

Global plant protein market

ADM

Cargill

DUPONT

Ingredion

glanbia

Hampton Creek

Oats protein quality

- Availability (3 Million tonnes/year in Canada)
- Protein content (13-25%)- protein% comparable to pea for some variety
- Globulin protein as major protein component with good solubility and functional properties
- High quality (highest Lys) among cereal proteins, nearly equivalent in quality to soy protein (WHO)
- Tolerated by the majority of people suffering from celiac disease
- Neutral flavor and taste

Oat protein functional properties

Egg and Dairy Protein Functionality

- Structure
- Strength
- Texture/mouthfeel
- Coloration
- Emulsification
- Gelation
- Film-forming
- Foaming
- Water control
- Viscosity
- Flavor
- Opacity / turbidity
- Particle suspension
- Adhesion
- Agglomeration

Oat protein Functionality

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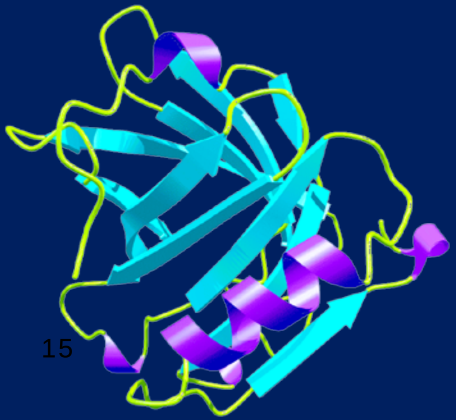
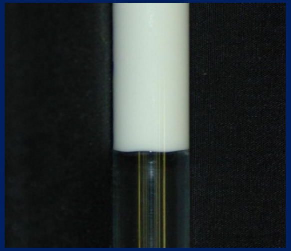
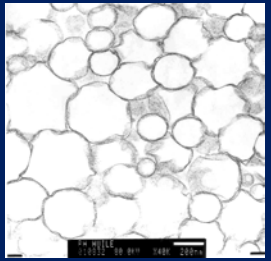
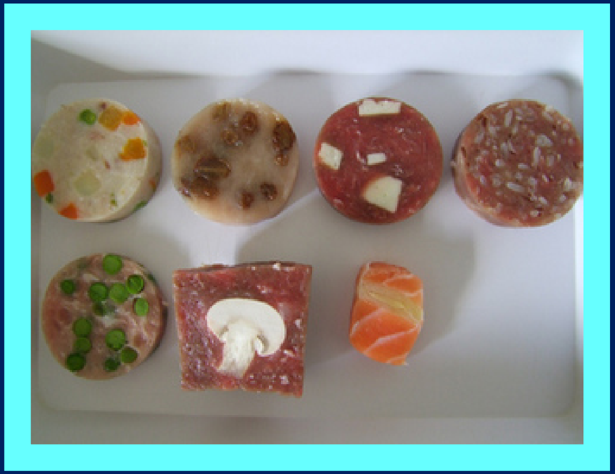
Protein gels in foods









Meat and fish binders

Fat substitutes

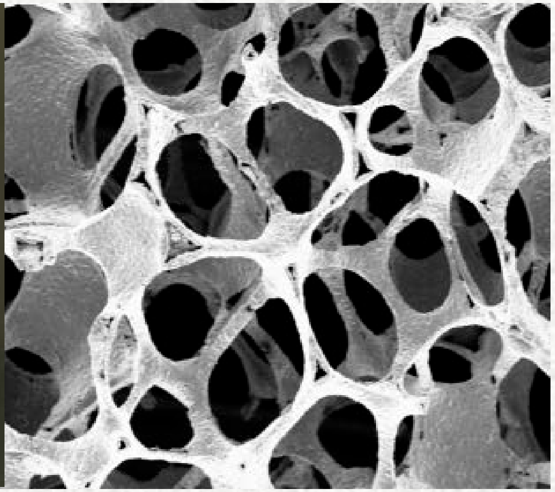
Meat analogues

Oat protein heat induced gels

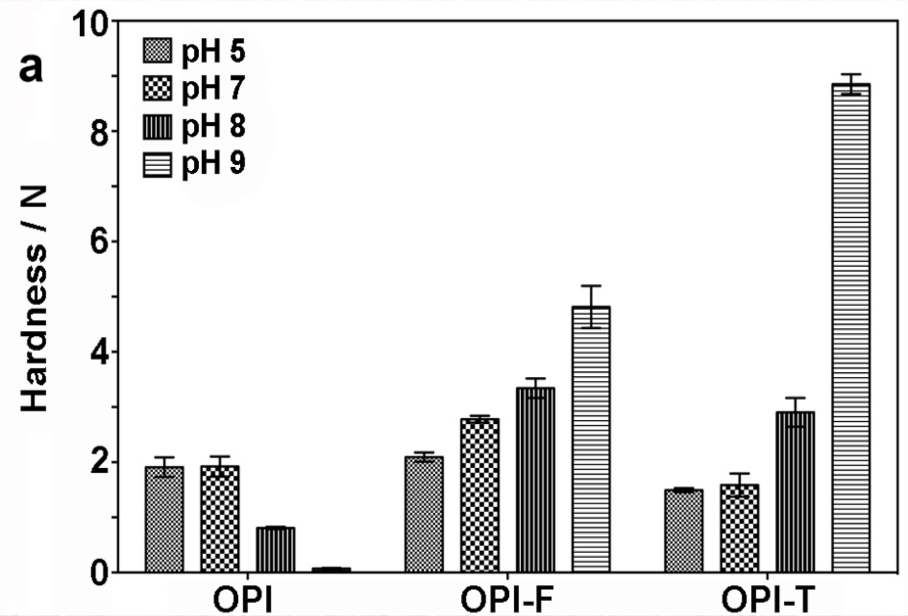
OPI solution
(15%, w/v)

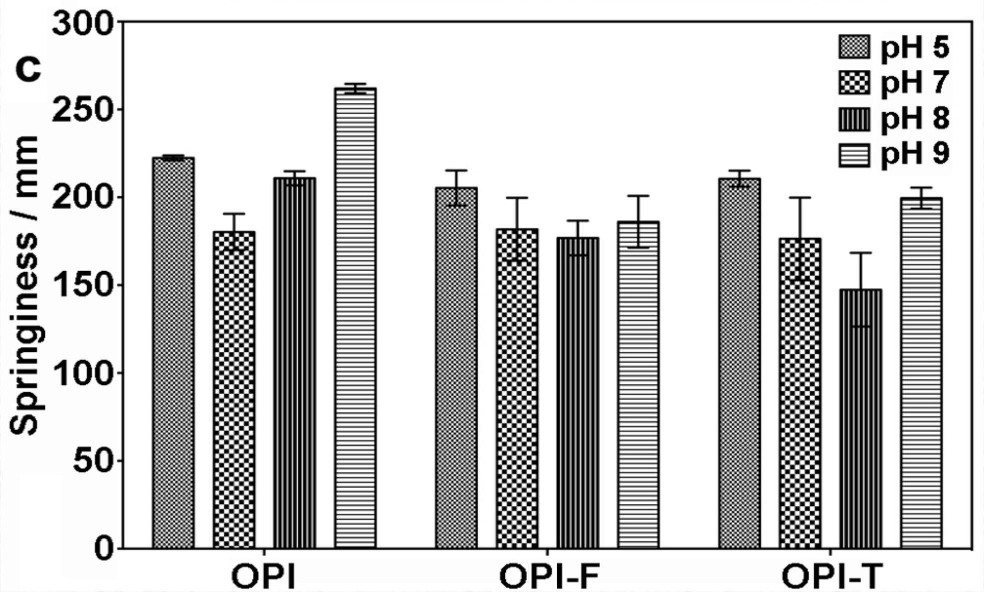
pH 8

115^{o}C, 15min



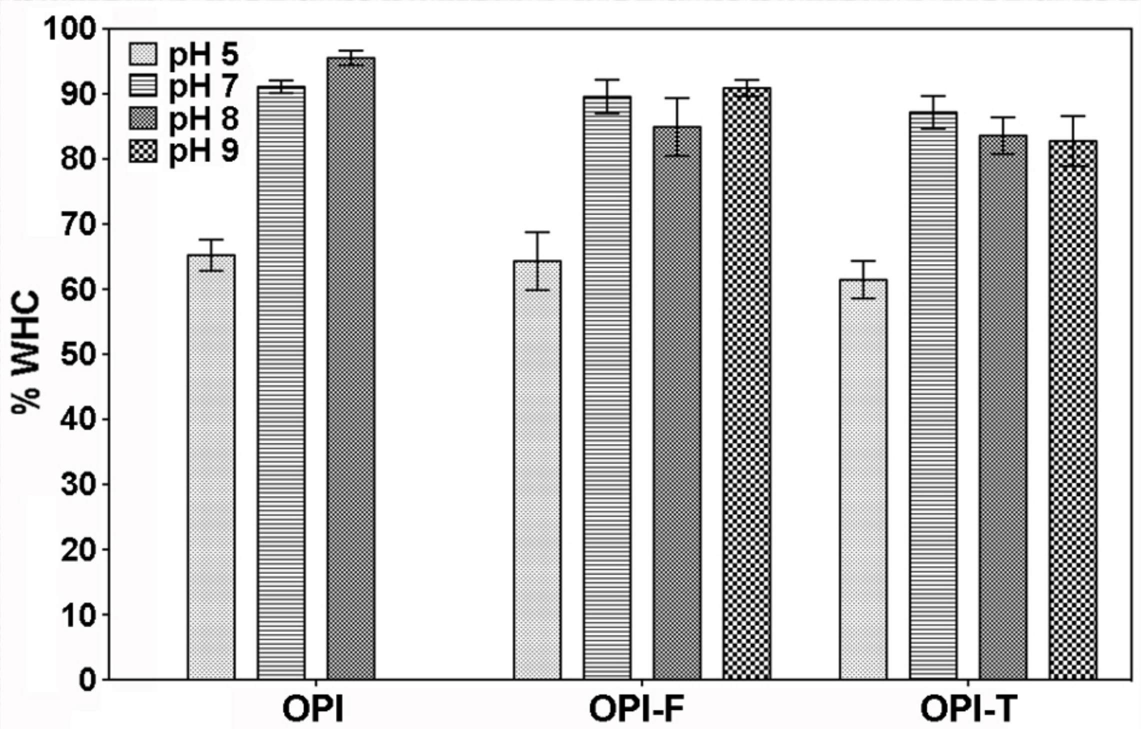
Oat protein gel texture





Soy: 2.1 – 2.6 N at neutral pH
Egg white: 8.70 N at pH 9

Oat protein gel water-holding capacity



Soy protein (82.2%)

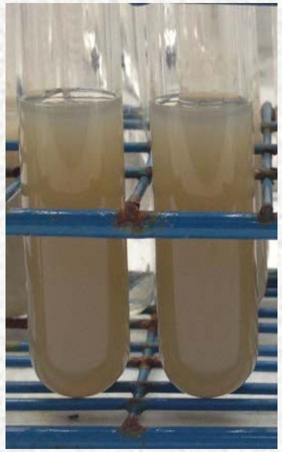
Whey protein (~88%)

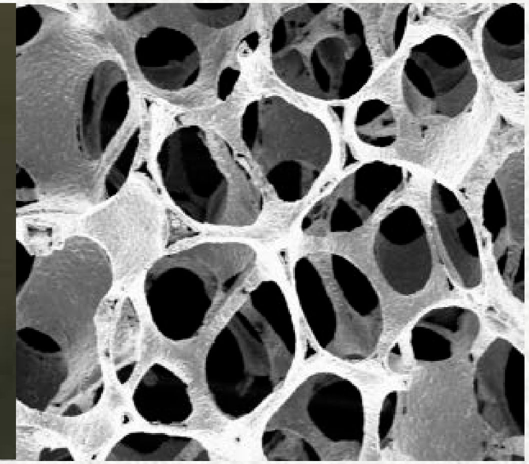
Oat protein heat induced gels

pH 8

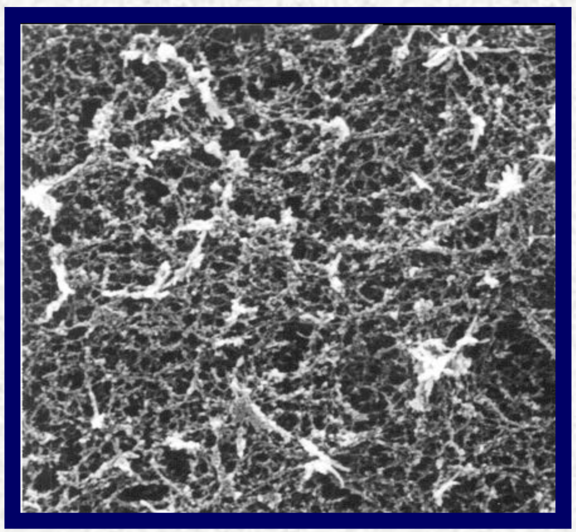
OPI solution
(15%, w/v)

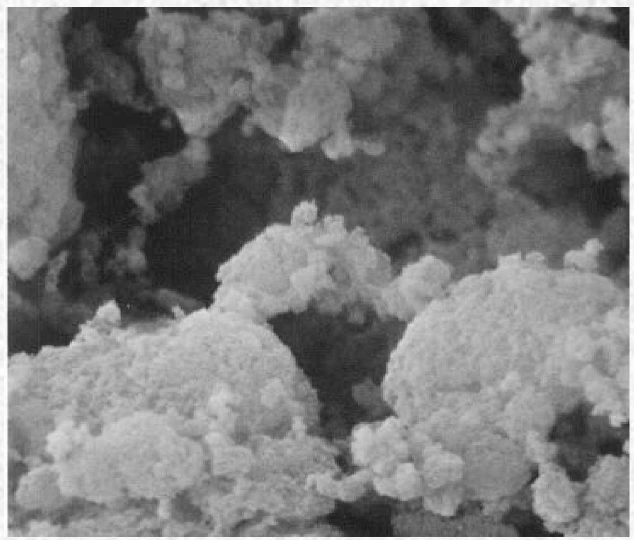
115^{o}C, 15min





Oat gel network





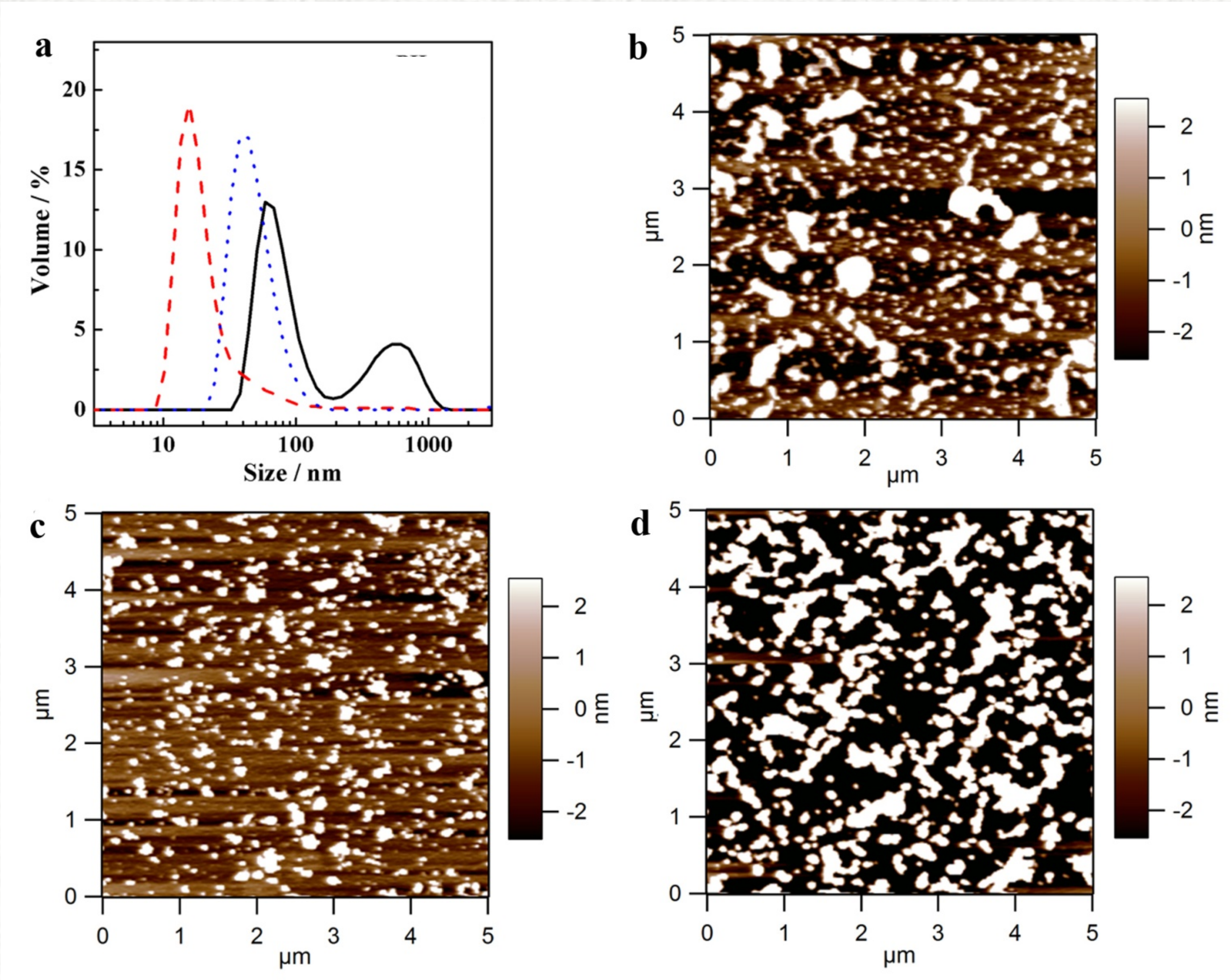
Mechanical strength

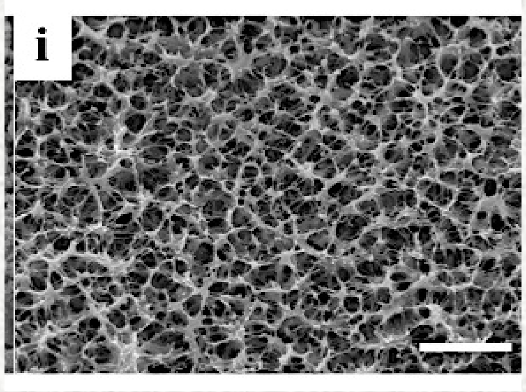
Water-holding

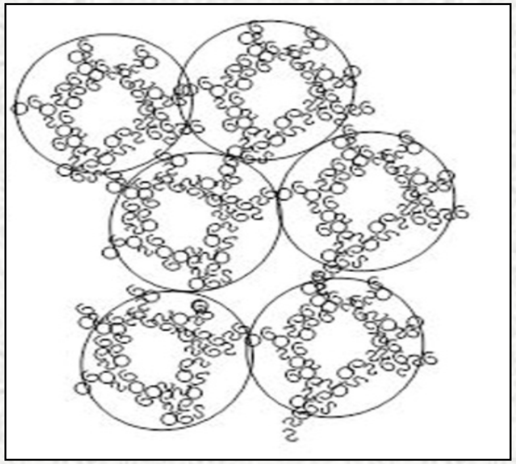
Transparent/opage

Soy gel network

Oats protein networks







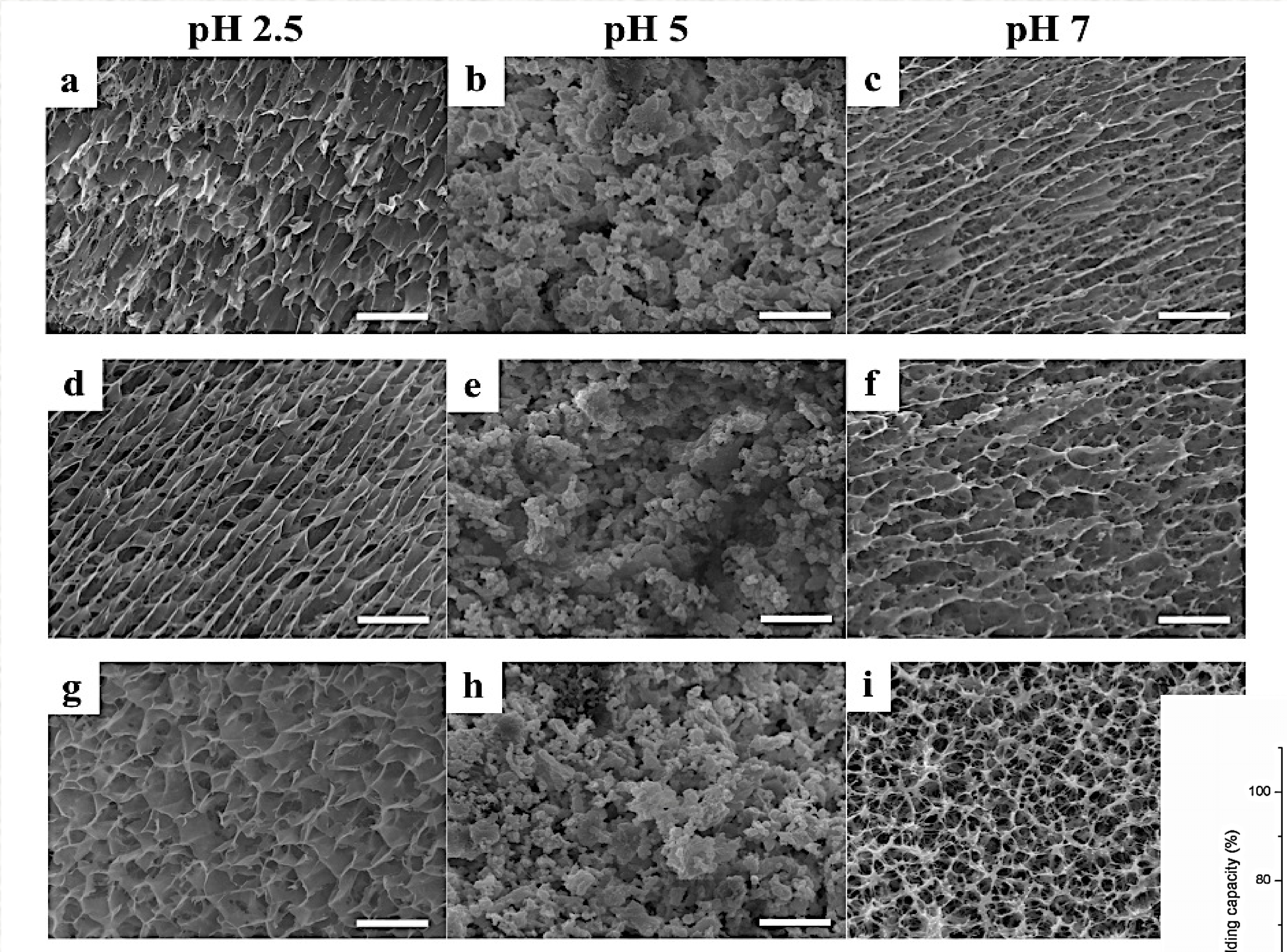
Oat protein-polysaccharide complex gel texture

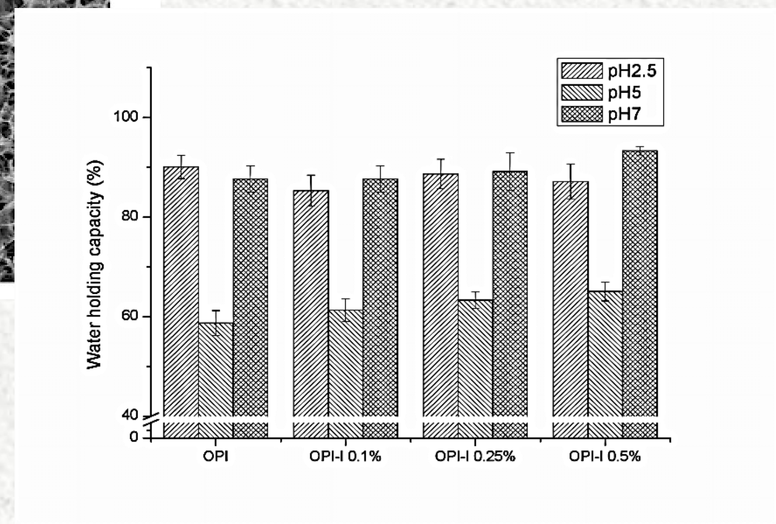
		pH 2.5		pH 5		pH 7	
	Compressive stress (kPa)						
	OPI	1.53	±0.27	10.19	±1.32	11.29	±3.49
	OPI-I	1.47	±0.11	9.63	±1.03	13.93	±1.95
0.1%	OPI-I	2.07	±0.31	10.92	±2.12	14.41	±1.39
0.5%	OPI-I	2.19	±0.38	14.16	±2.85	22.98	±1.12
	Cohesiveness						
	OPI	0.41	±0.03	0.67	±0.01	0.55	±0.04
	OPI-I	0.47	±0.06	0.63	±0.07	0.56	±0.05
	OPI-I	0.39	±0.04	0.70	±0.02	0.55	±0.06
	OPI-I	0.26	±0.03	0.68	±0.05	0.55	±0.08
	Springiness (mm)						
	OPI	130.2	±5.37	211.1	±7.74	163.0	±15.4
	OPI-I	159.8	±21.4	193.1	±6.14	228.2	±20.4
	OPI-I	143.7	±21.1	208.1	±4.76	220.7	±9.85
	OPI-I	197.8	±17.6	208.8	±12.7	217.8	±17.4
	Gumminess (N)						
	OPI	0.08	±0.01	0.90	±0.09	0.73	±0.12
	OPI-I	0.09	±0.02	0.80	±0.10	0.90	±0.14
	OPI-I	0.10	±0.02	0.94	±0.15	1.03	±0.10
	OPI-I	0.08	±0.01	1.16	±0.13	1.68	±0.18

Soy protein/gellan gum (~12.5 kPa)

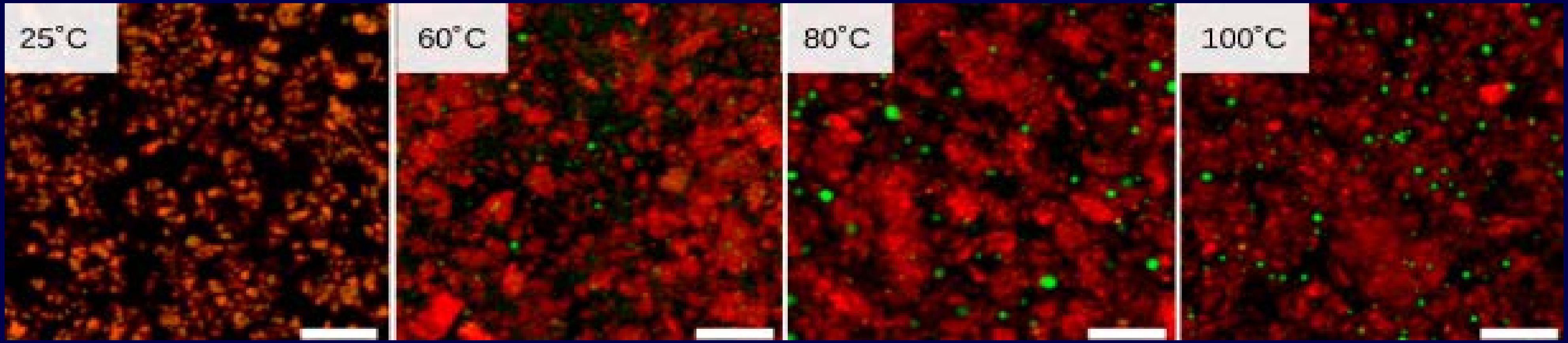
Egg white: 22-32 kPa

Oat protein-polysaccharide binary gel microstructure





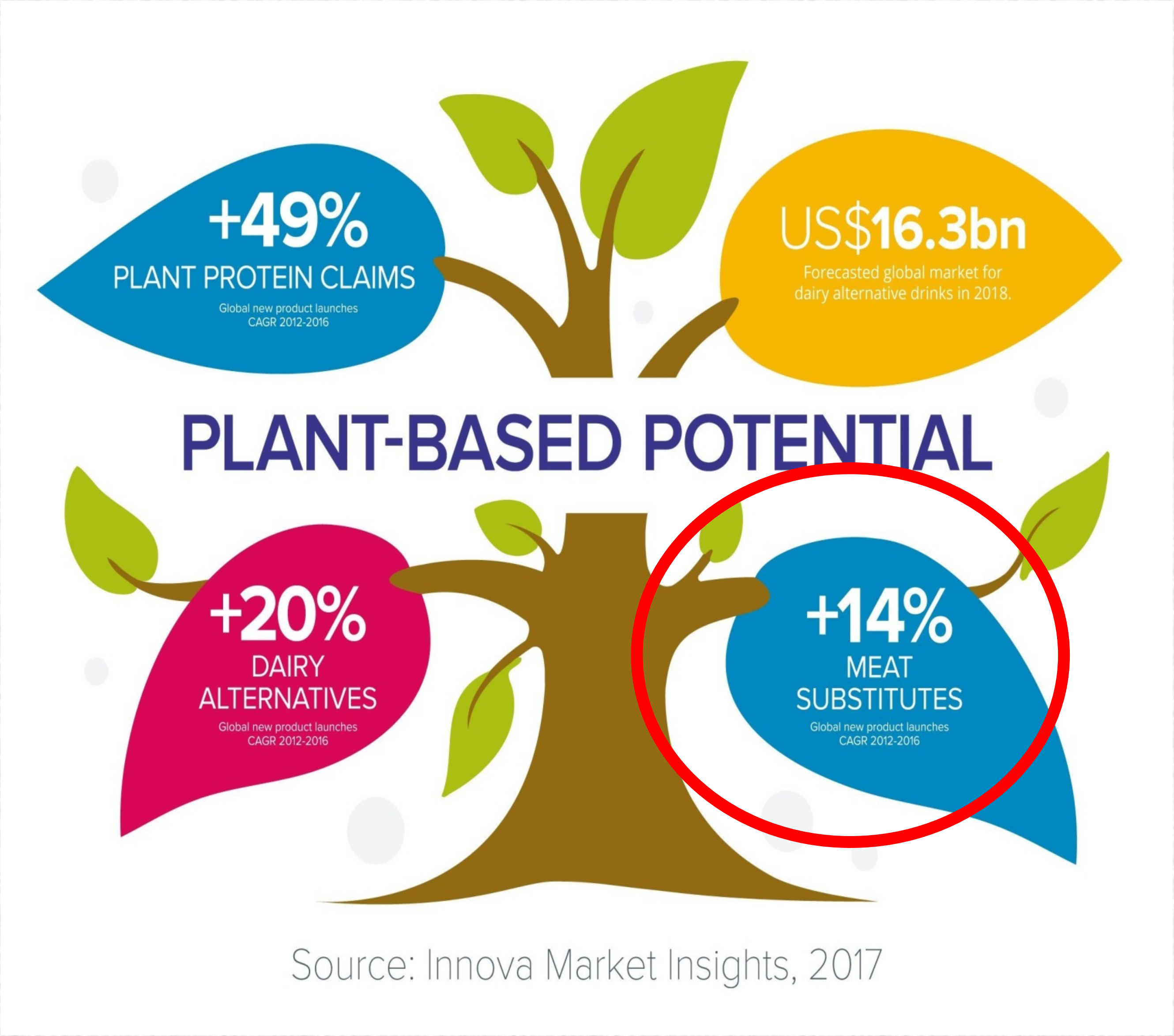
Gel formation mechanism study



Confocal microscopic photograms of oat protein gels with 0.5% inulin as a function of increasing temperature, scale bar 10 µm

- Increased interactions among protein by phase separation;
- Inulin performs a filling effect in the protein network;
- Localized interactions such as hydrogen and hydrophobic bonds may take place between protein and inulin at the phase borders.

Global plant protein market



Food application development of heat induced gels

Veggie burger

Provide texture

Reduce oil uptake during frying

Food application development of heat induced gels

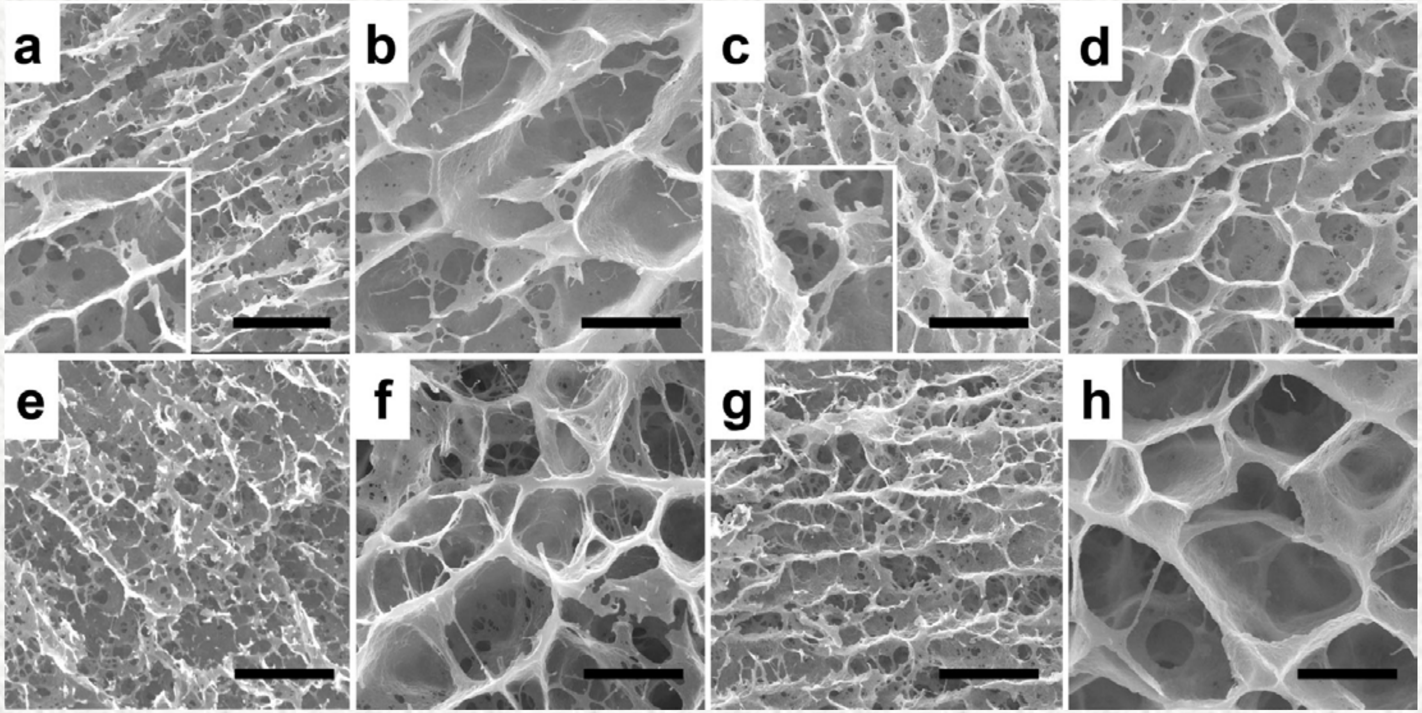
Meat binder

Hardness 9.2N

Hardness 19.8N

Cross section of the cooked pork meat ball without (left) and with (right) oat protein gelling ingredient

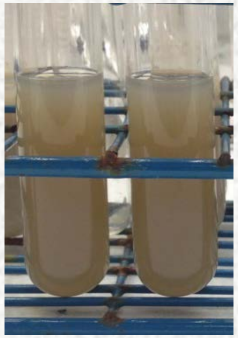
Oat protein cold-gelation



OPI solution (7%, w/v)

pH 8

115ºC, 15min



Preheated OPI solution

Add Glucono-δ-lactone (GDL)

Cooling

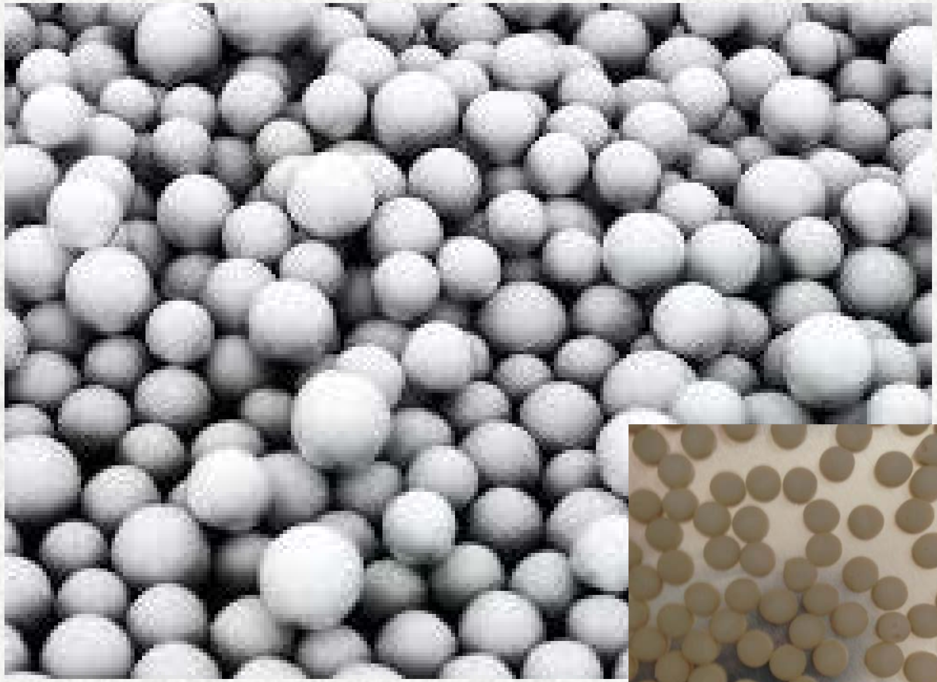
20 h

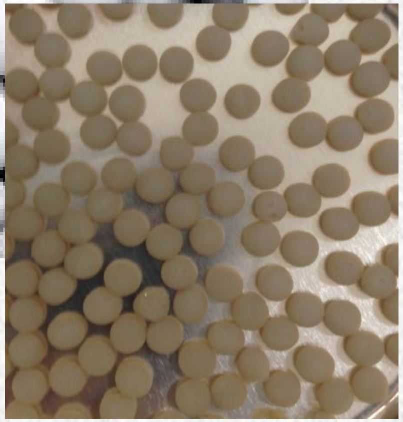
OPI gels (OG7-3, 5, 10,15)

Compressive stress:
23kPa ~30kPa

Egg white: 22-32 kPa

Food application development of cold gels





Food application development of cold gels

- **Protection of probiotics and enzyme**

Probiotics in SGF **Probiotics in SIF** **Enzymes in SGF**

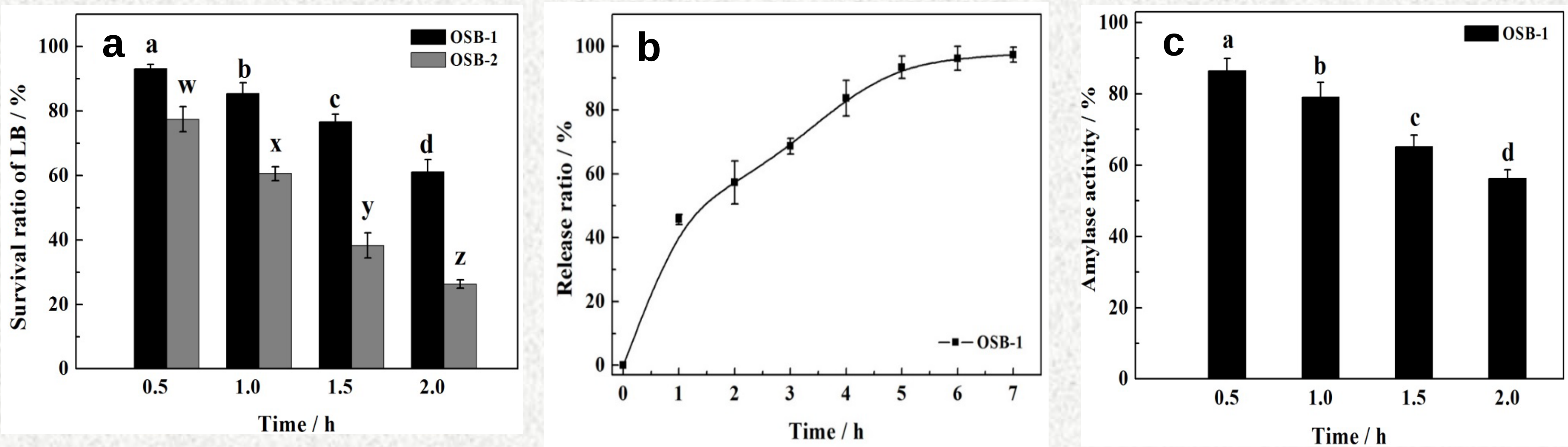
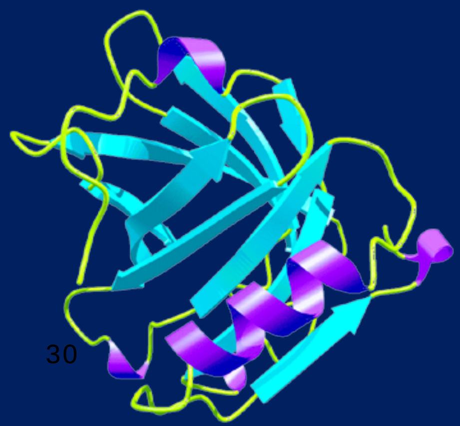
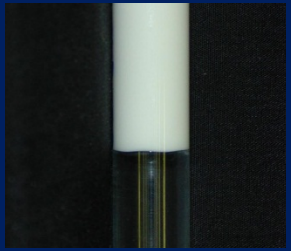


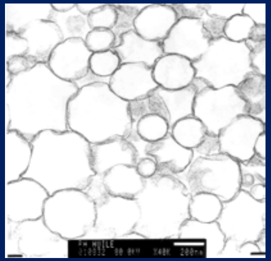
Fig.3-5. (a) Survival ratio of probiotics in SGF. (b) Release of probiotics in SIF, (c) Activity of enzymes in SGF.

- Protecting enzymes and probiotics in harsh stomach condition;
- Controlled release of bioactive compounds.

Protein emulsions in foods







Salade dressing

Creamer

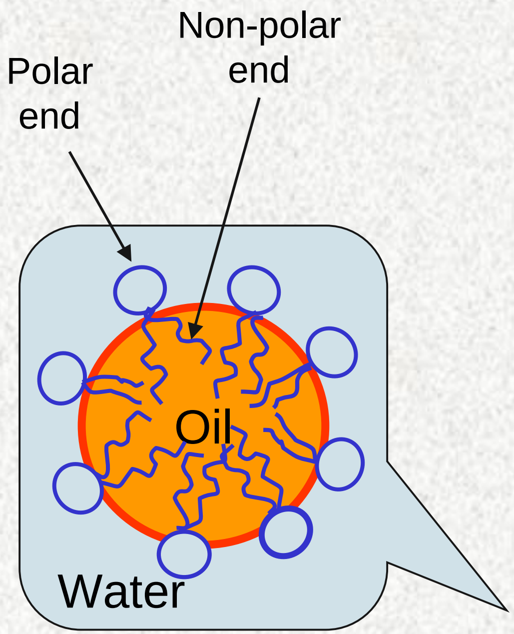
Veggie mayonnaise

Non- dairy coffee creamer

Protein suspension

Oil (e.g. coco nut oil)

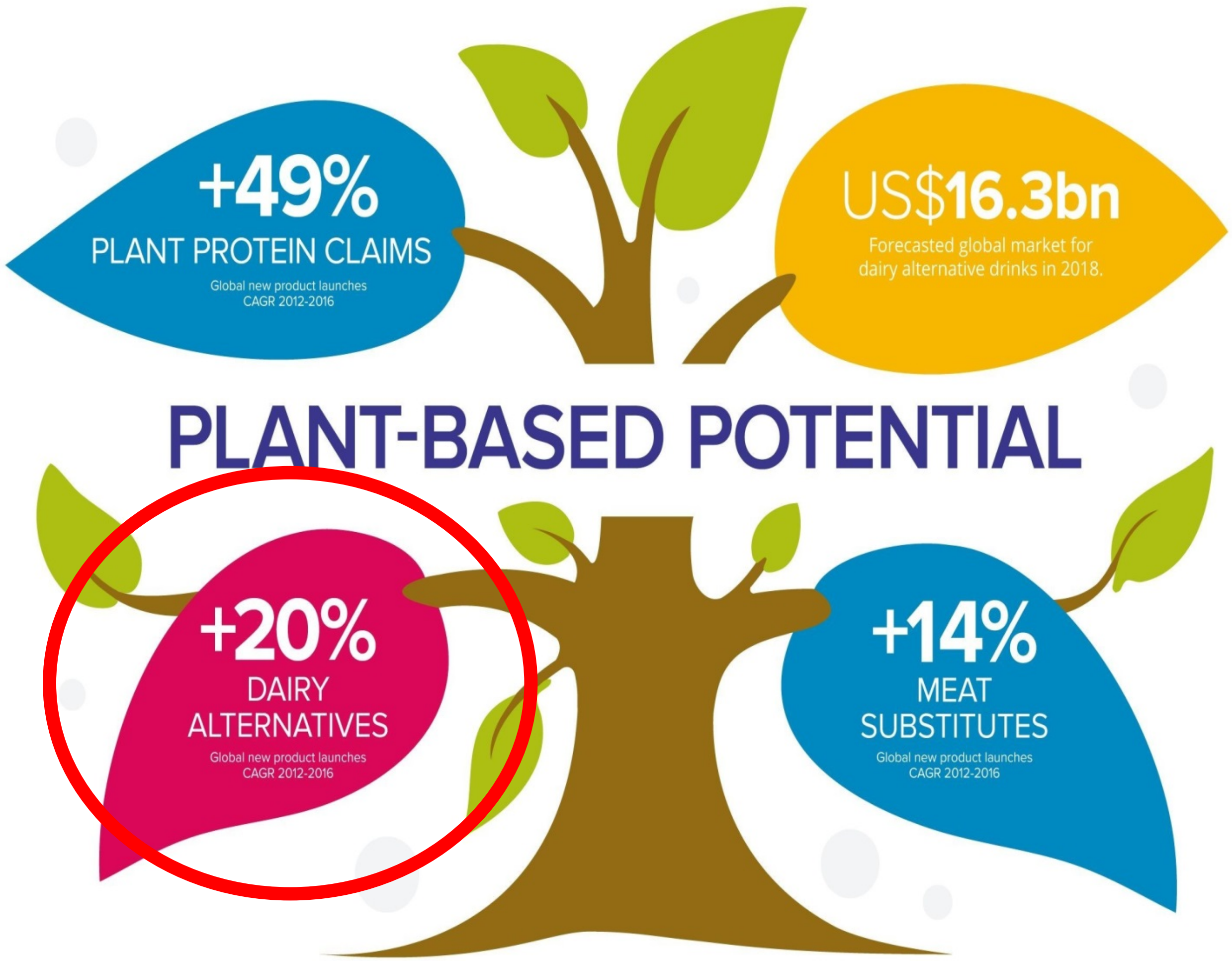
Homogenize → Spry-drying → Plant protein Coffee creamer



- Good emulsifying capacity
- Good dispersibility
- No feathering
- Good whitening
- Neutral flavor

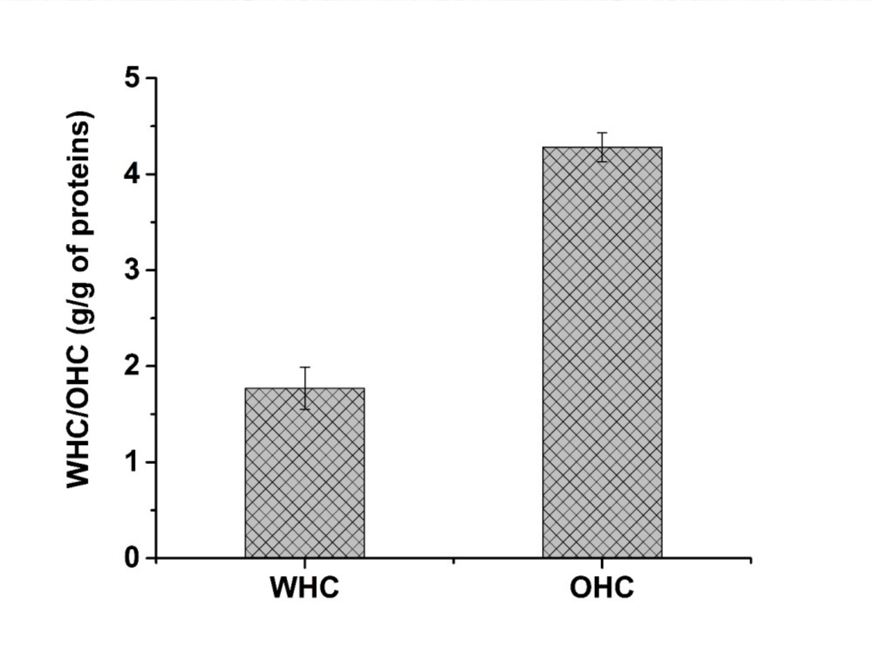
Protein can attract to both oil and water thus allowing the two to mix to form emulsions

Global plant protein market

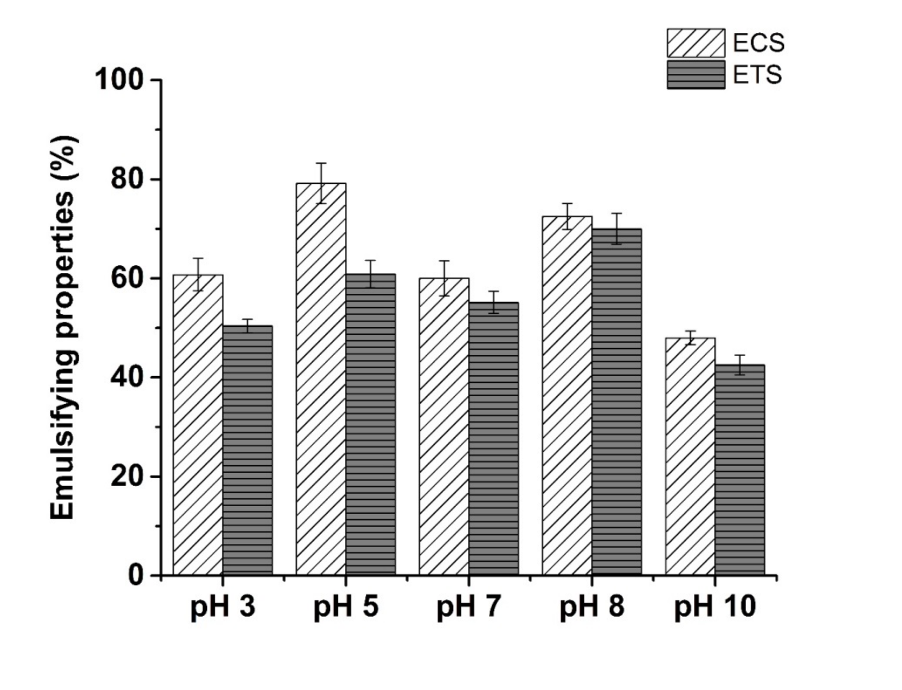


Source: Innova Market Insights, 2017

Oat protein oil-binding and emulsifying property



Water (WHC) and oil binding (OHC) capacity of oat protein



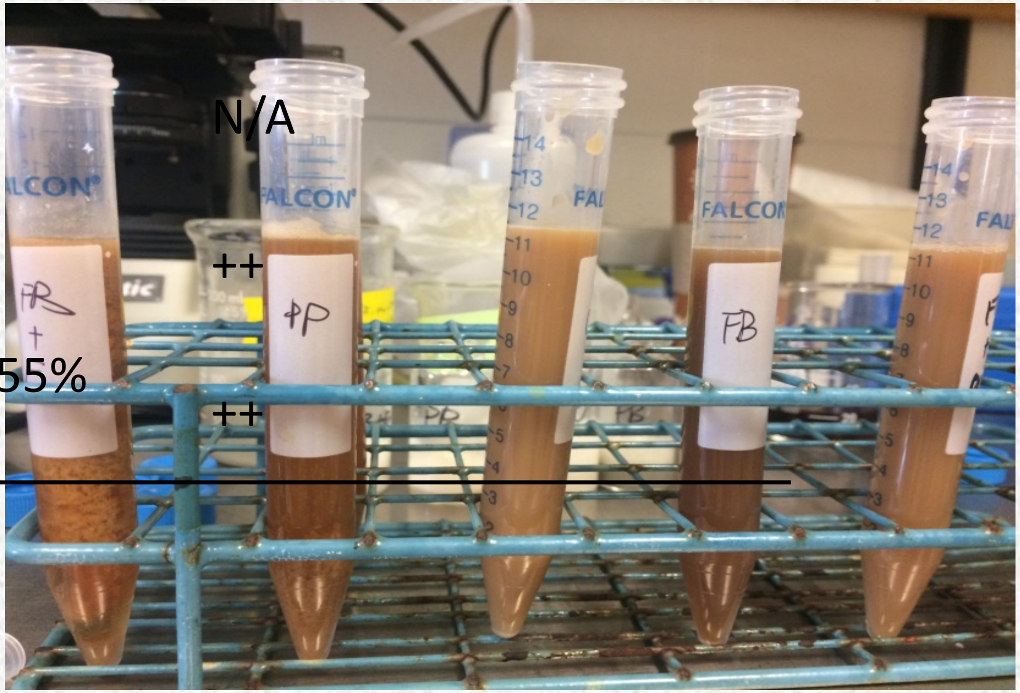
Emulsion stability after centrifugation (ECS) and thermal treatment (ETS) of oat proteins

Protein emulsion properties in coffee

Proteins	Emulsifying properties	Emulsion stability in coffee
pea protein	Good	Feathering, flocculation happen after several minutes
Faba bean protein	Good	stability for >2h
oat protein	Good	Feathering, flocculation happen after several minutes, after shaking no more flocculation appear
Canola protein fraction1	poor, phase separation happened in 5 minutes	stability for >2h
Canola protein fraction2	Good	Feathering, flocculation happen immediately

Protein emulsion properties in coffee

Formula	Feathering*	Whitening**
Faba bean protein: oil=1:1	No feathering	+
Faba bean protein: oil=1:2	No feathering	++
Faba bean protein: oil=1:3	Feathering after few minute	+++
Protein (FB:oat=1:1): oil = 1:1	Feathering	N/A
Protein (FB:oat=8:1): oil = 1:1	No feathering	++
Oat protein :oil =1:2	No feathering with 0.55% K_2HPO_4	++

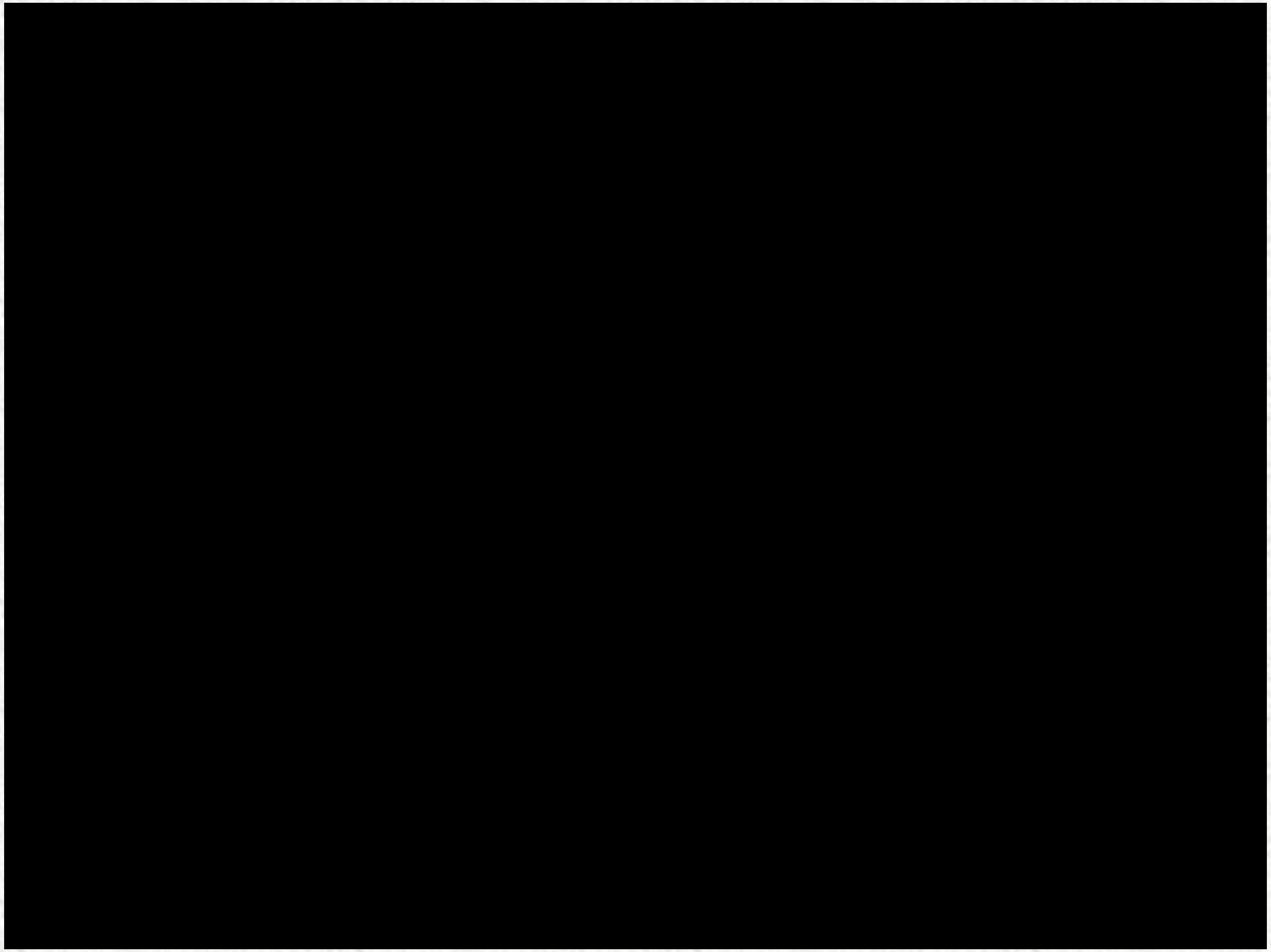


Spray-dried coffee creamer

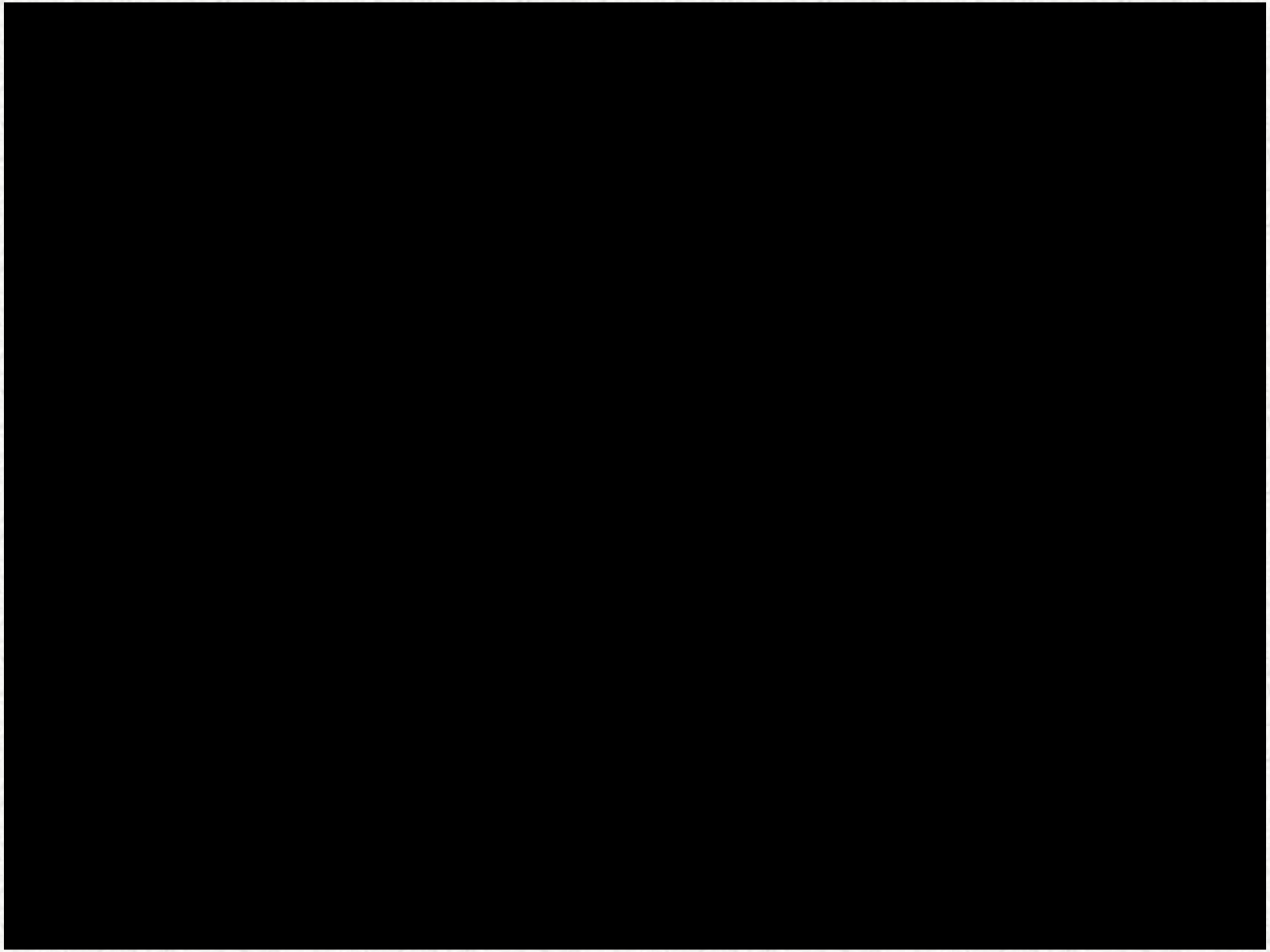
Treatments and proteins	Smell*	Colour**
Faba bean proteins from machine dehulled Faba bean	XX	brown
Industrial deflavored Faba bean protein	X	light brown
Industrial deflavored pea protein	XX	yellow
oat protein	OK	light brown
Canola protein fraction	XX	brick red

Oat protein based coffee creamer

Oat protein based coffee creamer



Oat protein based coffee creamer

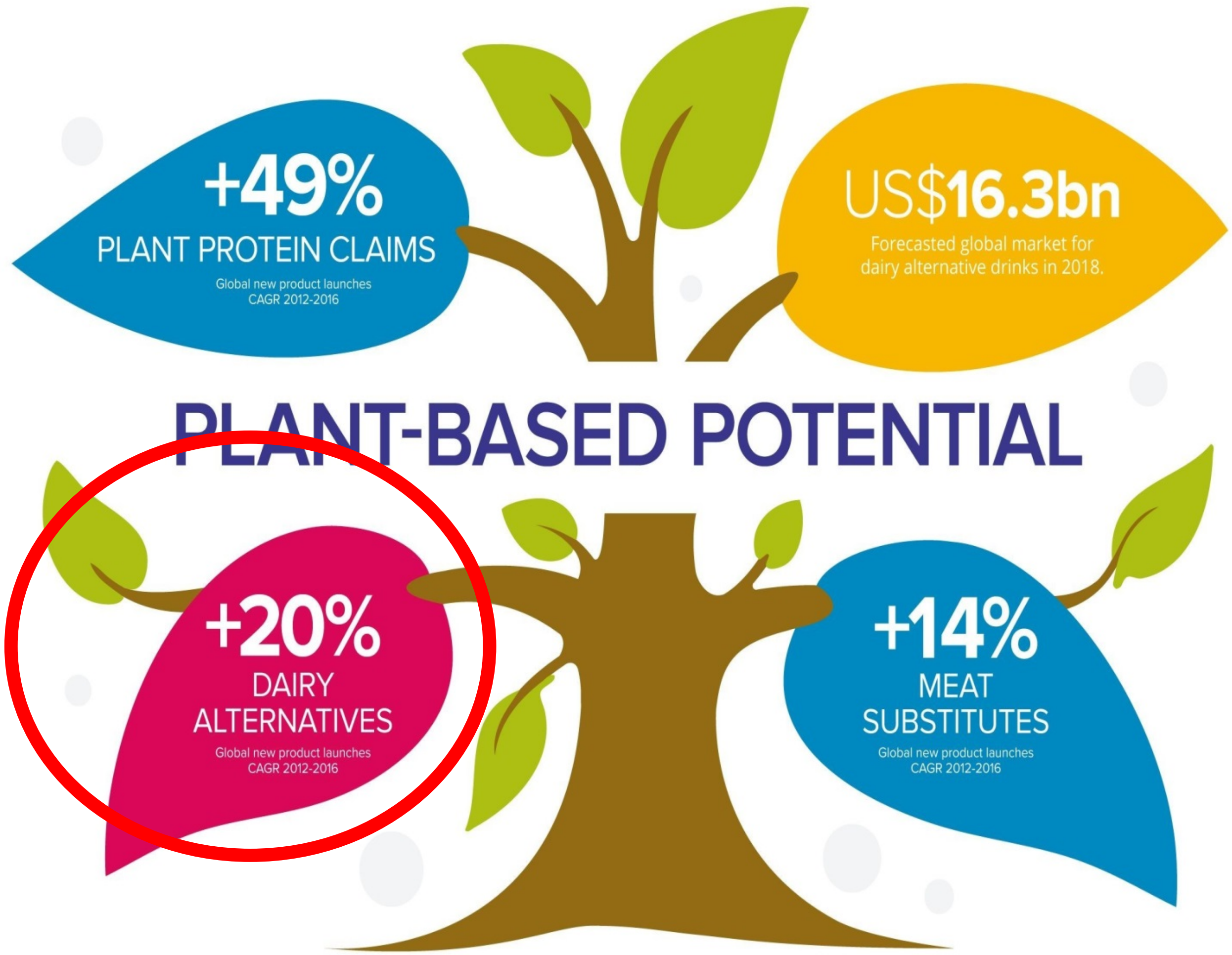


Oat beverage

•Globular protein as major protein component (good solubility) and high quality, nearly equivalent in quality to soy protein (WHO)

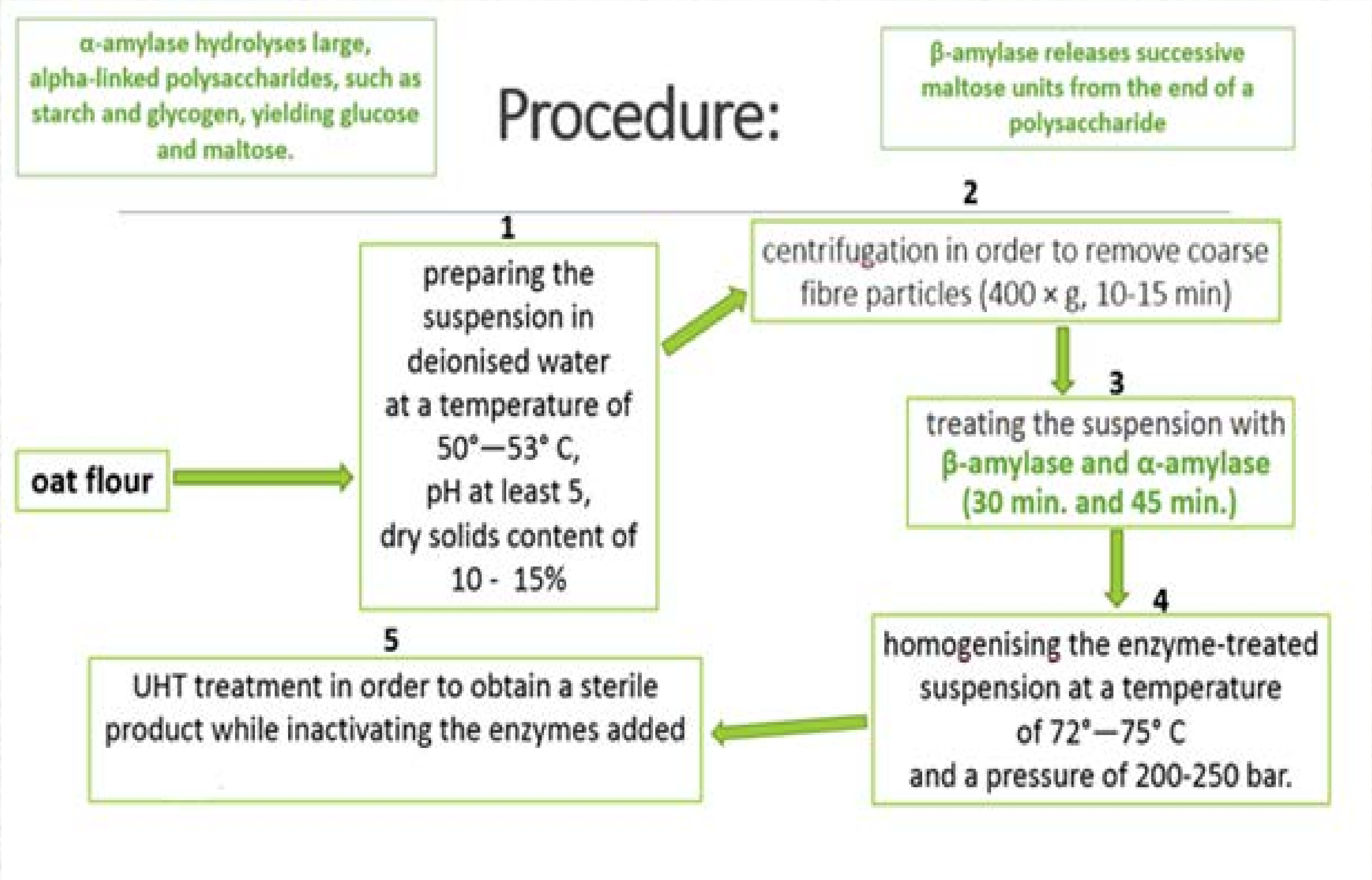
•High dietary fiber

Global plant protein market



Source: Innova Market Insights, 2017

Oat beverage



Oat beverage

- High protein + high beta-glucan
- Improve cost-effectiveness of the processing

OT3066	0	113	20.31	
OT3066	0	209	19.70	
OT3066	0	302	20.82	
OT3066	0	417	20.01	
OT3066	150	116	20.76	
OT3066	150	211	20.73	
OT3066	150	307	20.63	
OT3066	150	412	20.92	
Morrison	0	105	21.83	
Morrison	0	416	20.08	
Morrison	0	219	21.37	
Morrison	0	311	21.45	Significantly different between fertilizer treatment ($p<0.05$)
Morrison	150	319	22.69	
Morrison	150	403	22.33	
Morrison	150	108	23.20	
Morrison	150	202	22.73	

Oat beverage

- Protein + beta-glucan concentration
- Improve cost-effectiveness of the processing

SAMPLE		Starch %	Proteins %	β-glucan %	Moisture %	Other carbohydrates and fat %
Oat flour		60.71 ± 2.22	13.70 ± 0.75	3.35 ± 0.62	5.61 ± 0.22	16.64
DRY METHOD (with using sieve)	**Oat flour** with reduced amount of starch	39.69 ± 2.13	14.77 ± 0.75	9.40 ± 0.41	6.31 ± 0.12	29.84
	Starch from oat flour	69.38 ± 3.09	7.46 ± 0.44	1.29 ± 0.05	6.68 ± 0.77	15.19
WET METHOD (pH adjustment)	**Oat flour with reduced amount of starch**	**7.38 ± 1.03**	**55.19 ± 0.88**	**8.88 ± 0.17**	**0.87 ± 0.04**	**27.68**
	Starch from oat flour	77.88 ± 3.20	4.01 ± 0.14	2.24 ± 0.08	0.97 ± 0.02	14.90
Y & WET ETHOD	**Oat flour with reduced amount of starch**	**5.29 ± 0.36**	**52.24 ± 0.61**	**13.89 ± 0.94**	**0.96 ± 0.05**	**27.62**

Oat beverage

after 18 days

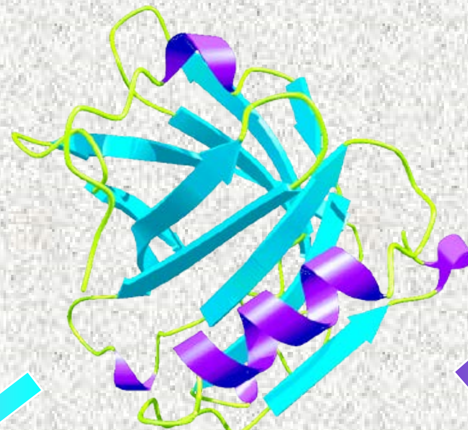
after 22 days

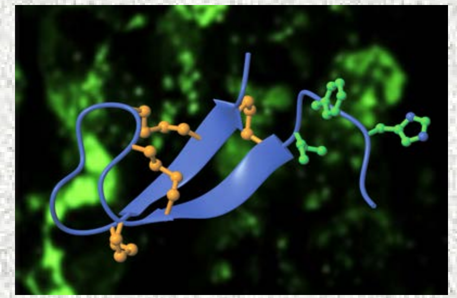
Storage stability of oat flour with reduced amount of starch

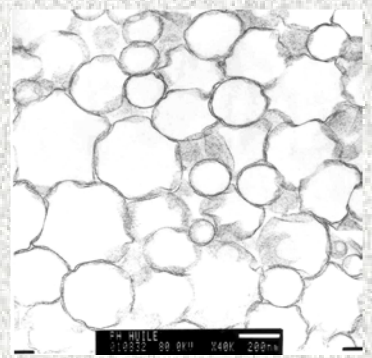
Other opportunities

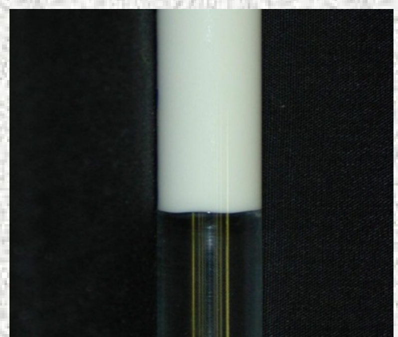
Extrusion processing (left), and dry (middle) and cooked (right) oat noodles

Oat protein value-added opportunities









Plant Protein Research

Mission

To create and develop competitive advantages for western Canadian crop resources in value-added product development with an emphasis on plant proteins

Research & Development Directions

Feedstock

- Characterize and understand feedstock attributes (different crops and varieties)
- Aligning crop component quality with product attributes demanded by market, identify and developing specialty crops for food and non-food applications

Crop & By-Product Processing

- Develop cost-effective processing to fractionate crop components.
- Advance technology to produce pure ingredients, extracts, and isolates from a wide range of Alberta based crops.
- Develop processing and utilization of by-product streams from primary processing and utilizing other supply sources: Distillers Grains, Brewing ingredients, barley leaves, straw, seed coats, hulls, etc.

Property Testing

- Evaluate unique properties and competitive advantages of crop extracts, isolates, and pure ingredients to predict their potential applications

Value-Added Applications

- Advancing technologies that convert crop components into value-added products for utilization within food, personal care, bioplastic, biomaterials, and other industrial applications
- Develop and customize the innovative technologies to meet specific industry requirements

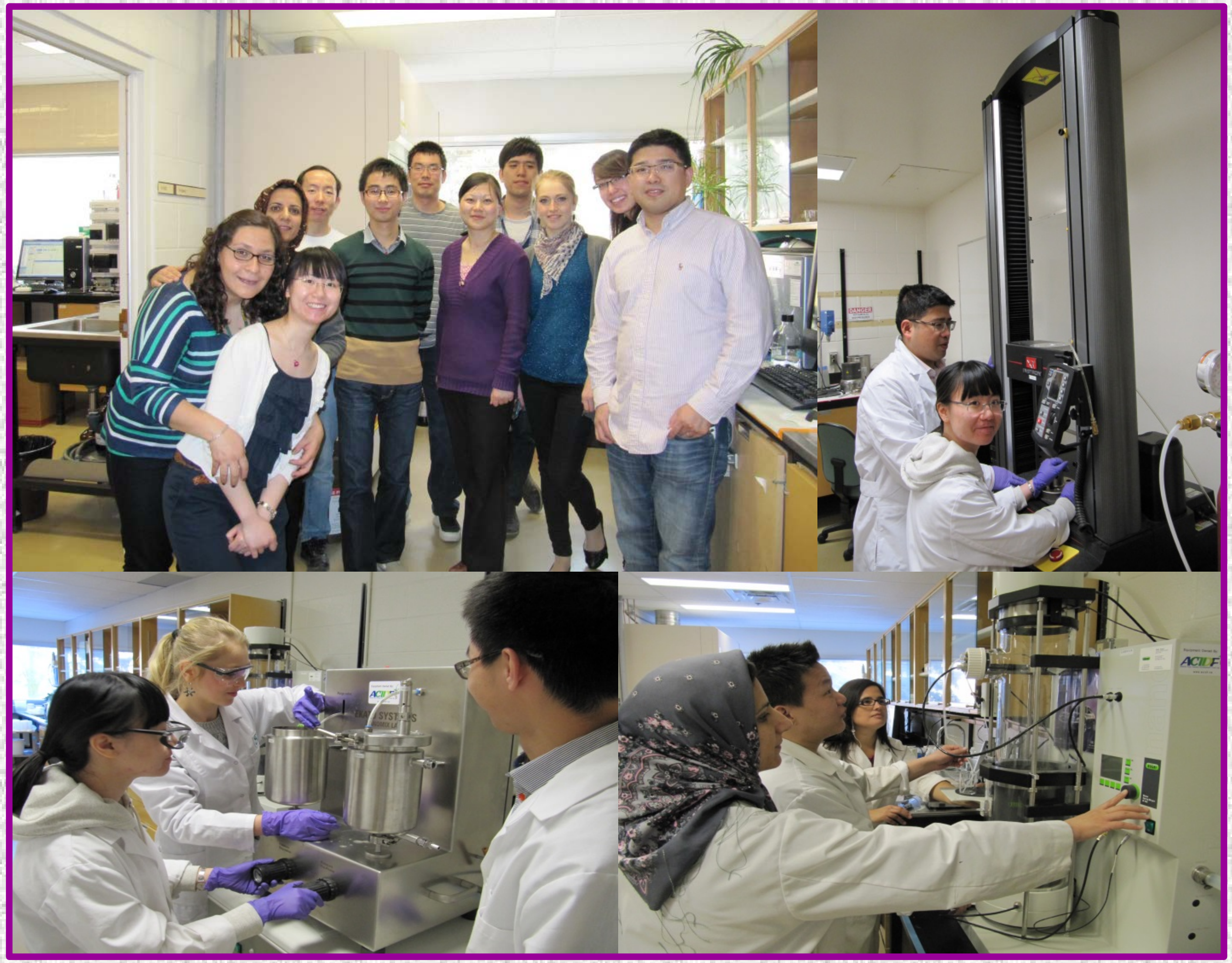
Services

- Providing industry with access to expertise, unique analytical services, and problem solving capabilities

Collaboration and/or Investment

- Ongoing access to specialized expertise and skill sets
- Direct access to innovative and cutting edge research, and new intellectual property
- Direct access to state-of-the-art equipment and facilities
- Connections with ingredient suppliers and end users

Acknowledgement



Acknowledgement

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Natural Sciences and Engineering

Research Council of Canada (NSERC)

Provincial Government:

- Alberta Crop Industry Development Fund.
- Alberta Innovates Bio Solutions

Industry partners

Prairie Oat Growers Association