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Sustainable Food Proteins Course
Minneapolis – October, 2025

Lecture #3
Product Development Landscape & Alternative Meat Product Case Studies

Credit: Adobe Photostock 2025

Today's agenda:

- Plant-based ingredients
- Mimicking for plant-based formulation
- Designing and commercializing plant-based foods
- Case study challenges of developing meat alternatives

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Plant Based Food Development the Numbers

$8.1 B

The U.S. retail market for plant-based foods is worth $8.1 billion.

6 in 10

6 in 10 U.S. households purchased plant-based foods in 2023, similar to the prior year.

1.1%

Plant-based foods made up 1.1 percent of total retail food and beverage dollar sales in 2023.

95%

95% of households that bought plant-based meat and seafood in 2023 also bought animal-based meat.

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Plant-Based Food Market Sales

Key plant-based category sales metrics and purchase dynamics

2023

	Dollar sales	1-yr. dollar growth	2-year dollar growth	Dollar share	Unit sales	1-yr. unit growth	Unit share	Household penetration	Repeat rate
Total plant-based foods	$8.1B	-2%	4%	1.1%*	1.8B	-9%	0.9%*	62%	81%
Plant-based meat and seafood	$1.2B	-12%	-13%	0.9%**	215MM	-19%	1.2%**	15%	62%
Plant-based milk	$2.9B	1%	9%	14.5%	744MM	-8%	12.9%	44%	79%

Sales data note: The data presented in this graph is based on custom GFI and PBFA plant-based categories that were created by refining standard SPINS categories. Due to the custom nature of these categories, the presented data will not align with standard SPINS categories. *Share values for the total plant-based foods category are out of total food and bev sales (frozen, grocery, refrigerated, produce, and protein powders/bars). Share values of individual plant-based categories are out of their respective total plant-based plus animal-based category. **SPINS does not report non-UPC animal-based meat counter sales. To calculate the plant-based meat share of the total meat category, dollar and unit volume assumptions for non-UPC animal-based meat counter sales are added to SPINS UPC animal-based meat sales. Household data note: SPINS uses a separate process from the sales data to pull household panel data which may result in minor category differences.

Source: Sales data—Total market = SPINS Natural Supermarket Channel + SPINS Conventional Multi Outlet Channel + SPINS Convenience Channel (powered by Circana) | 52 Weeks Ending 12-3-2023.

Household data—National Consumer Panel (powered by Circana), All Outlets, 52 weeks ending 12-3-23

SPINS gfi Good Food Institute

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Plant Based Ingredients

YES

- Nuts
- Seds
- Grains
- Legumes/beans
- Fruit and vegetable-based
  Vegetable oils
- Hydrocolloids/gums from vegetable derived sources

NO (Vegan defined)

- Dairy ingredients
  - ✓ Milk, Whey +Casein
- Animal/meat
  - ✓ All types Gelatin/collagen
- Fish
- Honey

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Protein and Plants

Proteins are polymers of amino acids.

The many protein types differ by size, shape, composition, biofunction, behavior in food...

Each plant species has a unique composition of protein types.

Plants also contain non-protein components including starch, fiber, and oil.

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Farm to Fork Process

Ref.: Aimutis, W.R. and Shirwaiker, R.A. (2025). *Front. Plant Sci*. 16:1626856

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Protein Source Type

Legume / Pulse / Oilseed

- Soy*
- Pea*
- Canola
- Chickpea
- Fava Bean
- Lentil
- Mung Bean
- Navy Bean
- Peanut
- Sunflower

Vegetable / Fruit / Nut / Cereal

- Wheat*
- Almond
- Corn
- Oat
- Potato
- Quinoa
- Rice
- Sorghum

*indicates a major plant protein source used as a benchmark.

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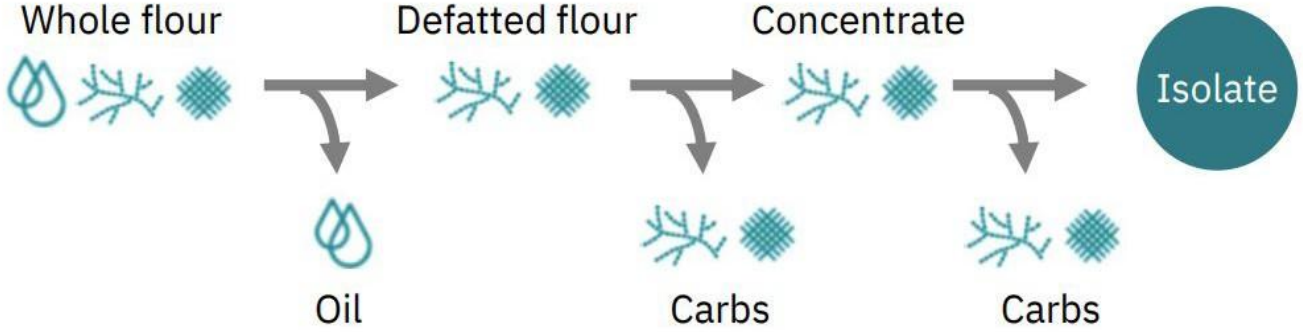
Ingredient Extraction

Commercial proteins are complex mixtures—properties depend on source and process.

Proteins are often **extracted** to improve their properties.



Extraction methods can influence:

- Protein types recovered
- Properties
- Yield

Processing can also influence protein functionality via **denaturation**, **hydrolysis**, **modification**, and **cross-linking**.

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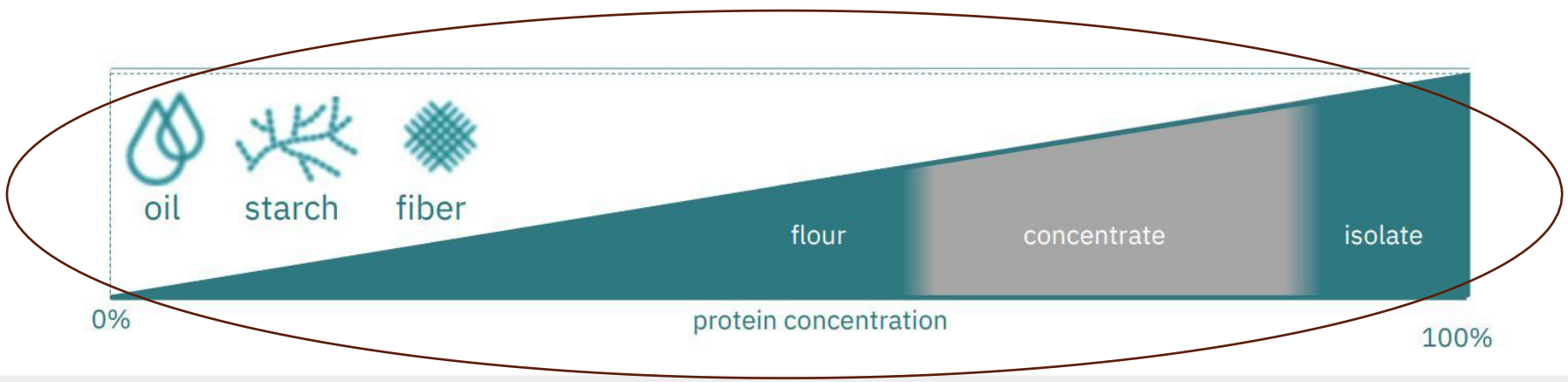
Ingredient Complexity



Protein
Fiber
Starch
Oil

Reduce

- extrusion die slip
- starch texture
- fiber mouthfeel
- antinutritional components

Enhance

- protein gel strength (less network disruption)
- formulation flexibility
- protein nutrient density
- digestive tolerance

Challenges

- maintaining functionality
- cost
- natural perception

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How to explore the plant protein profiles

The following plant protein profiles represent the most widely available sources. Each of the profiles contains a color-coded comparison on select metrics, and details about **sourcing**, **properties**, **nutrition**, **applications**, a breakdown of **dry composition**, and **product examples.** The below key categorizes performance on each metric. Soy, pea, and wheat are featured first as major benchmark proteins, followed by profiles organized by protein type (legume / pulse / oilseed; vegetable / fruit / nut / cereal).

Key: Plant Protein Sources Summary

	Protein Concentration	PDCAAS	Allergen Risk	Commercial Stage	Flavor	Functionality	Cost (/kg protein)	Global Crop Volume (MMT)
Excellent	>30%	>0.8	Usually mild, low pop.	Commodity	Flavorless	Low conc. effect	<$2	>100
Good	20-30%	0.6-0.79	↕	Large	↕	↕	$2-4	10-99
OK	10-20%	0.40-0.59	↕	Small	Acceptable	↕	$5-9	1-9
Low	5-10%	0.20-0.39	↕	Start-up	↕	↕	$10-19	0.1-0.9
Poor	<5%	<0.20	Severe in sig. pop.	R&D	Objectionable	Water insoluble	>$20	<0.1

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Plant protein sources summary

Protein	Protein Concentration	PDCAAS	Allergen Risk	Commercial Stage	Flavor	Functionality	Cost (/kg protein)	Global Crop Volume (MMT)
Soy	Excellent	Excellent	Poor	Excellent	Low	Excellent	Good	Excellent
Pea	Good	Good	OK	Good	OK	Good	Good	OK
Wheat	OK	OK	Poor	Excellent	OK	Excellent	Excellent	Excellent
Canola	Good	Excellent	Poor	OK	OK	Good		Good
Chickpea	Good	OK	OK	Good	OK	Good	Low	Good
Fava Bean	Good	OK	Low	OK	OK	OK	Low	OK
Lentil	Good	OK	OK	OK	OK		Low	Good
Lupin	Excellent	OK	Poor	OK	Low	OK		OK
Mung Bean	Good	OK	OK	Good	Good	Good	Low	OK
Navy Bean	Good	Good	OK	Poor	Good	OK		Low
Peanut	Good	OK	Poor	OK	Good	Good		Good
Sunflower	Good	Good	Excellent	OK	OK	Good	Low	Good
Almond	Good	Low	Low	OK	Good	OK	Low	OK
Corn	OK	Low	Excellent	OK	Good	Low	Low	Excellent
Oat	OK	Good	Good	OK	Good	Low		OK
Potato	Low	Excellent	Excellent	Good	OK	Good	Low	Excellent
Quinoa	OK	Good	Good	Poor	OK	Good	Low	Low
Rice	Low	OK	Excellent	Good	Good	OK	OK	Excellent
Sorghum	Low	Low	Excellent	Poor	Good	Poor		Good

Excellent
Good
OK
Low
Poor

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Considerations for Ingredient Selection

There are many considerations when choosing the optimum plant protein ingredient, including:

- Protein content & quality
- Nutrition & claims
- Allergenicity, intolerance
- Consumer perception
- Source (geographic, commercial)
- Historical use
- Certifications
- Availability
- Safety
- Regulatory
- Functionality
- Familiarity with use
- Cost
- Aroma, flavor, texture, mouthfeel, color

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Soy

Type: ***Legume / Oilseed***

A gold standard plant protein

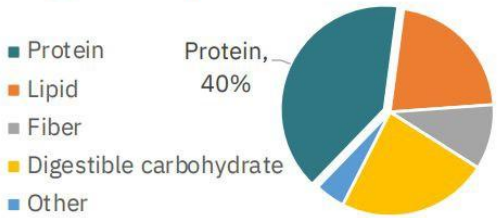
Sourcing

- Grown in Brazil, US, Argentina
- GM: herbicide & insect tolerant
- Poor soil tolerance, fixes nitrogen
- Flour 50–60%, concentrate 65–80%, isolate > 90% protein
- Low consumer acceptance

Nutrition

- PDCAAS 0.84
- Limiting AA: Lys, Met & Cys
- FDA claim: heart disease risk reduction
- Phytoestrogens
- Antinutritive factors: Trypsin inhibitors & hemagglutinin
- Allergenicity: Major

Dry Composition



Properties

- Viscosity & water binding
- Gelation
- Emulsification & foaming
- Flavor-binding
- Earthy & bitter/astringent off-flavors

Applications

- Diverse, e.g., dressing, beverage powder, plant-based creamer, frozen dessert, soup, whipped topping, formula
- Texturized for meat replacement/ extension

PRODUCT EXAMPLES

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Pea

Type: ***Legume / Pulse***

Fastest-growing plant protein

Protein Nutrition				●	
Allergenicity			●		
Flavor			●		
Functionality				●	
Cost				●	
Crop Supply			●		

Sourcing

- Mostly dry, whole, yellow peas
- New varieties in northern regions
- Increases soil nutrients, lowers disease
- Available as air classified flour, concentrate, hydrolyzed, texturized
- Cleaner than soy (no hexane extraction)

Nutrition

- PDCAAS 0.64
- Limiting AA: Met & Cys, high Lys
- Fiber, protein, thiamin, folate, P, K
- High BCAA (for muscle repair)
- Antinutritive factors: lectins, trypsin inhibitors, phytic acid
- Allergenicity: Low, possibly due to limited use

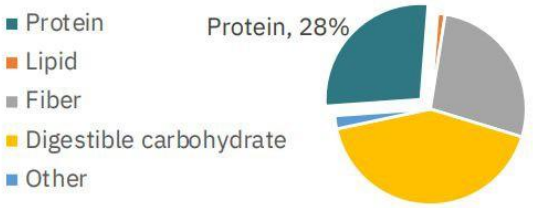
Properties

- Emulsification
- Gelling
- Foaming
- Lower solubility/functionality vs. soy
- Beany flavor

Applications

- Broad applications, e.g., pasta, bakery goods, extruded snacks
- Meat extender/texturizer

Dry Composition



PRODUCT EXAMPLES

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Plant proteins with growth potential

Protein	Protein Concentration	PDCAAS	Allergen Risk	Commercial Stage	Flavor	Functionality	Cost (/kg protein)	Global Crop Volume (MMT)
Sunflower	🟢	🟢	🟢	🟡	🟡	🟢	🟠	🟢
Potential to be cost effective (byproduct of 3rd biggest oilseed). Needs scale-up & commercial development.								
Mung Bean	🟢	🟡	🟡	🟢	🟢	🟢	🟠	🟡
Scale-up needed for cost improvement. Excellent properties & starch byproduct used for noodles & other foods.								
Potato	🟠	🟢	🟢	🟢	🟡	🟢	🟠	🟢
Rice	🟠	🟡	🟢	🟢	🟢	🟡	🟡	🟢
Attractive attributes. Volume can expand until available precursor from starch processing is consumed.								
Duck Weed	🟢	🟢	🟢	🟡	🟢	🟢	🔴	🔴
Sustainable, excellent properties. Needs scaling and commercial development to increase volume & decrease cost.								
Chickpea	🟢	🟡	🟡	🟢	🟡	🟢	🟠	🟢
Navy Bean	🟢	🟢	🟡	🔴	🟢	🟡		🟠
Oat	🟡	🟢	🟢	🟡	🟢	🟠		🟡
Great potential if byproduct utilization (starch) is improved.								

Alternative plant proteins need a competitive value proposition to bring about growth.
To compete directly with wheat and soy a major question is how well they texturize.

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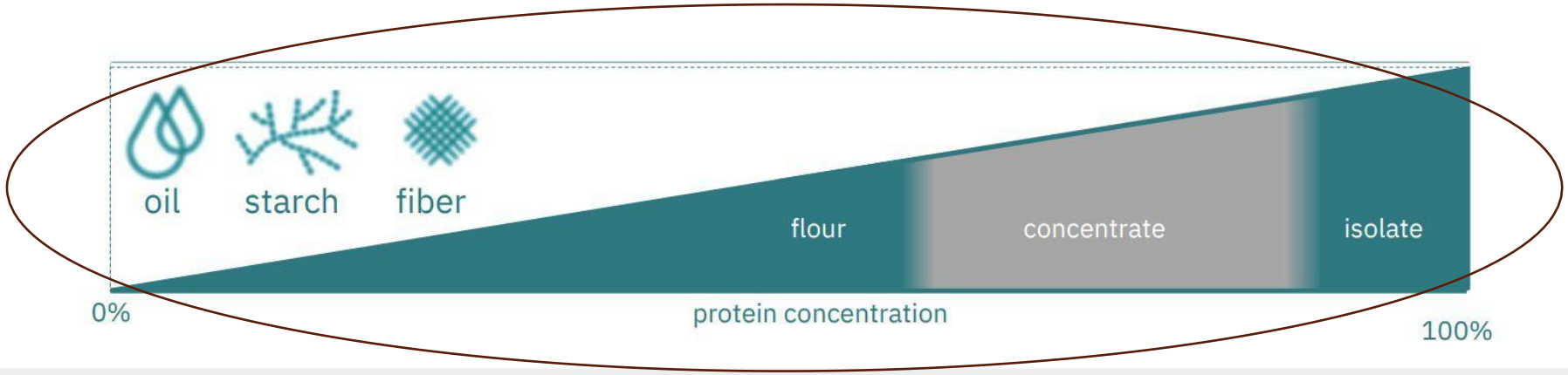
Bringing it Together: Ingredient Complexity



Protein
Fiber
Starch
Oil

Reduce

- extrusion die slip
- starch texture
- fiber mouthfeel
- antinutritional components

Enhance

- protein gel strength (less network disruption)
- formulation flexibility
- protein nutrient density
- digestive tolerance

Challenges

- maintaining functionality
- cost
- natural perception

Finished Product

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Food Product Development Process

Market Assessment/ Analysis

Identification of White Space

Selection of Target Segment and Product

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Considerations in developing a plant-based food product

- Ingredient selection
- Clean label needs
- Ability to mimic animal-based version
- Serving size
- Finished product format
- Nutritional targets
- Shelf life/stability
- Flavors/Organoleptic
- Allergens
- Labelling/regulations
- Finished product specifications

Are you trying to match/mimic a current product, or is this a new innovation?

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Plant-based Ingredient Nomenclature

Key Terms

- Plant-Based
- Plant-forward
- Animal-free
- Vegetarian
- Vegan
- Animal replacement products (APR's)

Descriptors/Drivers

- Food security
- Sustainable/regenerative
- Planet-friendly
- Better-for-you/H&W
- Animal welfare considerations
- Cleaner labels
  - ✓ Free from antibiotics/hormones
- Food safety
  - ✓ Cleanliness/food borne illness

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Functionality Matters

Proteins are often expected to have useful attributes:

- Dispersibility
- Solubility
- Viscosity
- Gelation
- Emulsification
- Foaming
- Water holding
- Oil holding

These functions may be dependent on:

- Solvent (e.g. pH, salt, Aw)
- Temperature
- Time
- Pressure
- Shear
- Concentration

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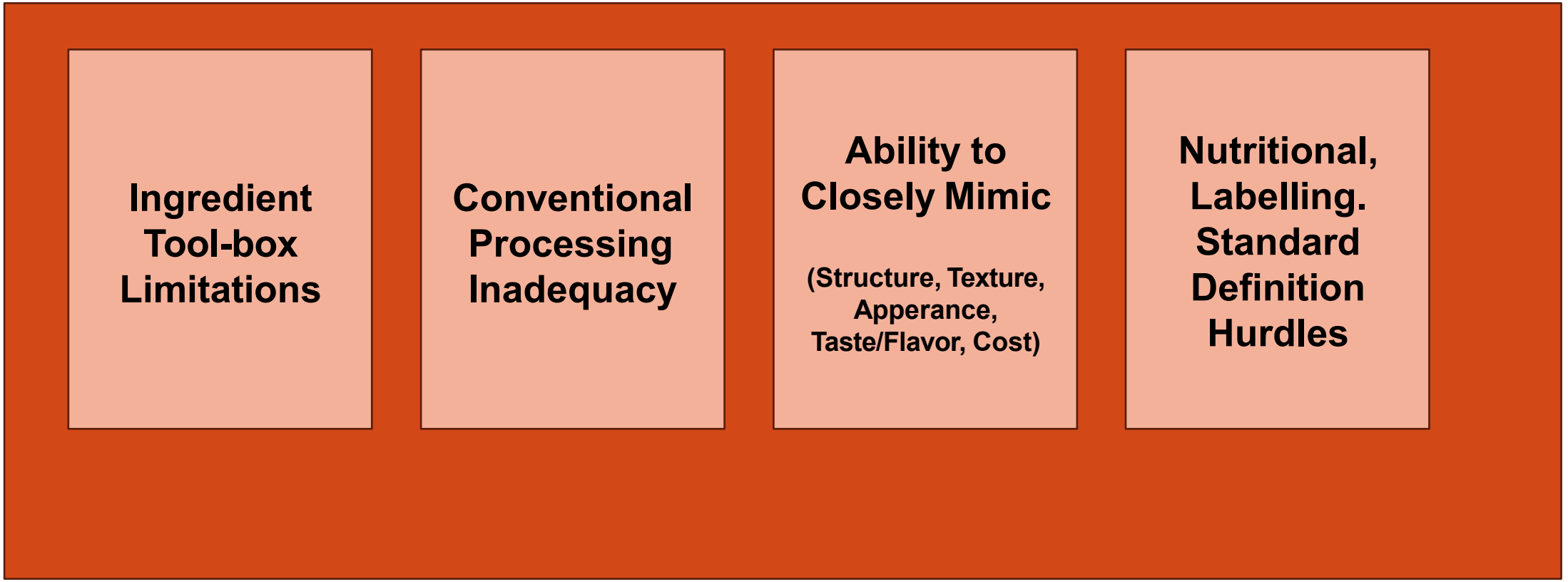
Plant Based Food Development Challenges



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Food Product Strategy

Target market

Product purpose

Target audience

Defining features and benefits

Roadmap creation for development, launch and marketing

The product strategy guides the entire development process by providing a clear direction and decision-making framework focused on customer requirements.

1. **Ideation:** Generate innovative product ideas through brainstorming, market research, or identifying market gaps.
2. **Defining the Project:** Conduct initial research on product ideas, consumers, technology, and the market to define the project.
3. **Concept Development:** Summarize the product's target market, positioning, features, and benefits. This stage often involves collaboration between consumers, product designers, marketers, food technologists, and engineers.
4. **Product Design Specifications:** Develop specifications that prioritize consumer-relevant metrics like safety and food regulations, including metrics related to production or distribution.
5. **Feasibility Study:** Create an operational plan based on product concept and design specifications to understand the product's feasibility.
6. **Process, Distribution, and Marketing Identification:** Determine manufacturing steps, effective distribution methods, and marketing strategies by understanding the target market and related demographics.

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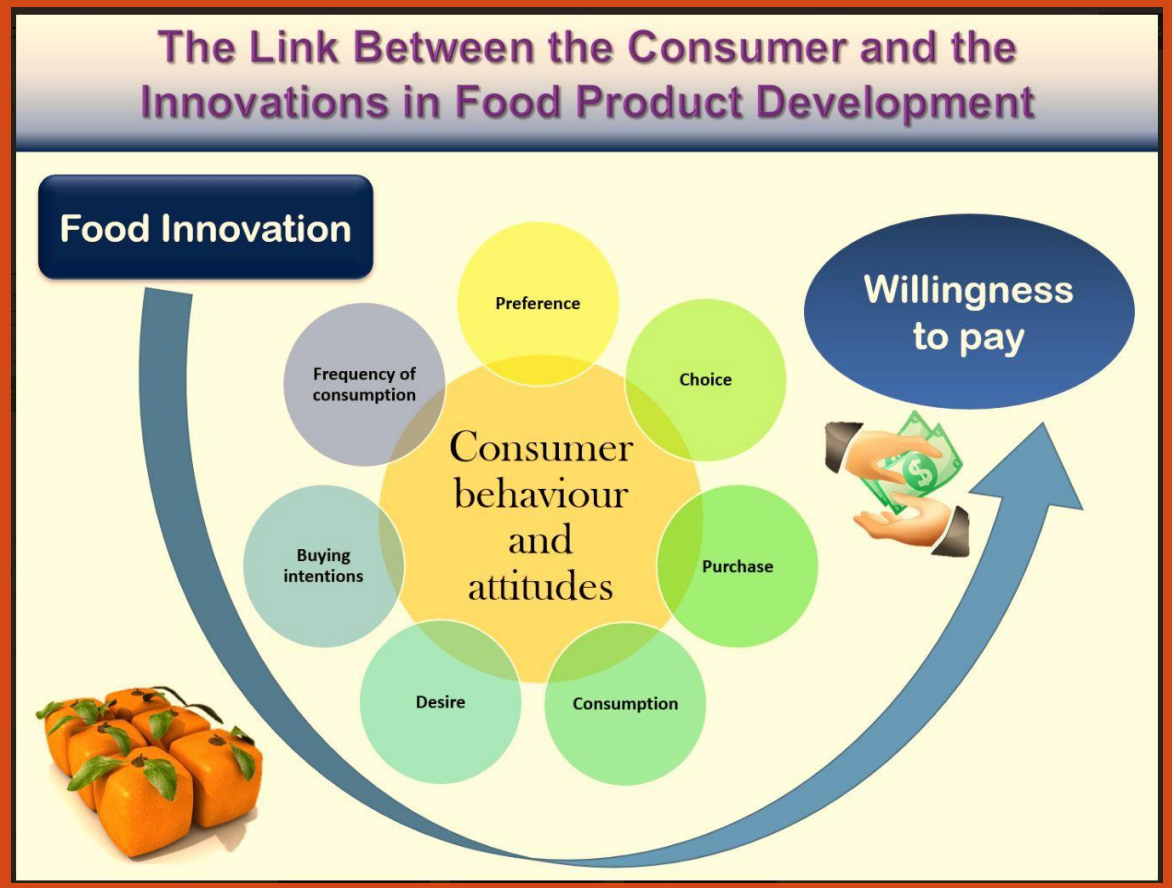
Consumer Trials

Sensory trials with consumer groups to determine likelihood of product success in the market



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Food Product Launch

The product launch is a critical and often expensive phase where planning, research, and development come to fruition.

Establishing a launch date, deciding on packaging and labeling, and developing marketing strategies to create awareness and interest among the target audience.

Conducting taste tests and gathering feedback are crucial for refining the product.

A well-executed launch can establish a loyal customer base and ensure long-term success.

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Sustainable Food Proteins Course
Minneapolis – October, 2025

Case Study
The Challenge of Developing Meat Alternatives

Brian Klopf
Sustainable Protein Lead
Mars, Inc., Chicago, IL

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Case Study Format

Marketing Insight and Product Brief	Ingredient Tool-box Limitations	Conventional Processing Inadequacy	Ability to Closely Mimic (Structure, Texture, Apperance, Taste/Flavor, Cost)	Nutritional, Labelling. Standard Definition Hurdles
• White Space • Work with Client/Marketing • Gold standard?	• Protein • Hydrocolloids • Flavor System • Color System	• Mixing – Paddle, Bowl, Ribbon • Forming – stuffer, casing (types) • Cooking (types) • Packaging (types)	• Consumer expectation • Cooking • Flavor/Off-flavor • Shelf-Life • Cost	• Ingredient List • Consumer acceptance • Regional guidelines • Claims

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Case Study #1

Sausage Link Formulations with Pea Protein

Marketing Insight and Product Brief	Ingredient Tool-box Limitations	Conventional Processing Inadequacy	Ability to Closely Mimic (Structure, Texture, Apperance, Taste/Flavor, Cost)	Nutritional, Labelling. Standard Definition Hurdles
• Uncooked coarse sausage • Retail Market • Refrigerated	• Pea Protein • Methylcellulose • Natural Flavors • Seasoning Blend • Colors from ingredients & natural colors	• Mixing – Paddle Mixer • Forming – stuffer + alginate casing • Chilled • Biodegradable Packaging	• Faster cooking, some casing peeling • Pea protein smell/flavor • Product structure loss • Longer Shelf-Life	• Long ingredient list • High consumer liking • 16g protein and 35% less fat claims • No Soy and No Gluten claims

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Case Study #1

Sausage Link Formulations with Pea Protein

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Case Study #2

Sausage Patty Formulations with Mycoprotein

Marketing Insight and Product Brief	Ingredient Tool-box Limitations	Conventional Processing Inadequacy	Ability to Closely Mimic (Structure, Texture, Apperance, Taste/Flavor, Cost)	Nutritional, Labelling. Standard Definition Hurdles
• RTE breakfast patty • Ref. Retail	• Fy Mycoprotein + Soy protein • Modified Food starch • Seasoning blend • Natural Color System	• Mixing – Paddle • Patty former • Smokehouse cooked • Thermoformed plastic (6) & product filled	• Similar shape & flavor for consumer • Fast cooking + flavor loss • High cost-mycoprotein • Shelf-Life similar	• High protein and high fiber • 11g protein and 75% less fat claims • US region only – FDA LONO

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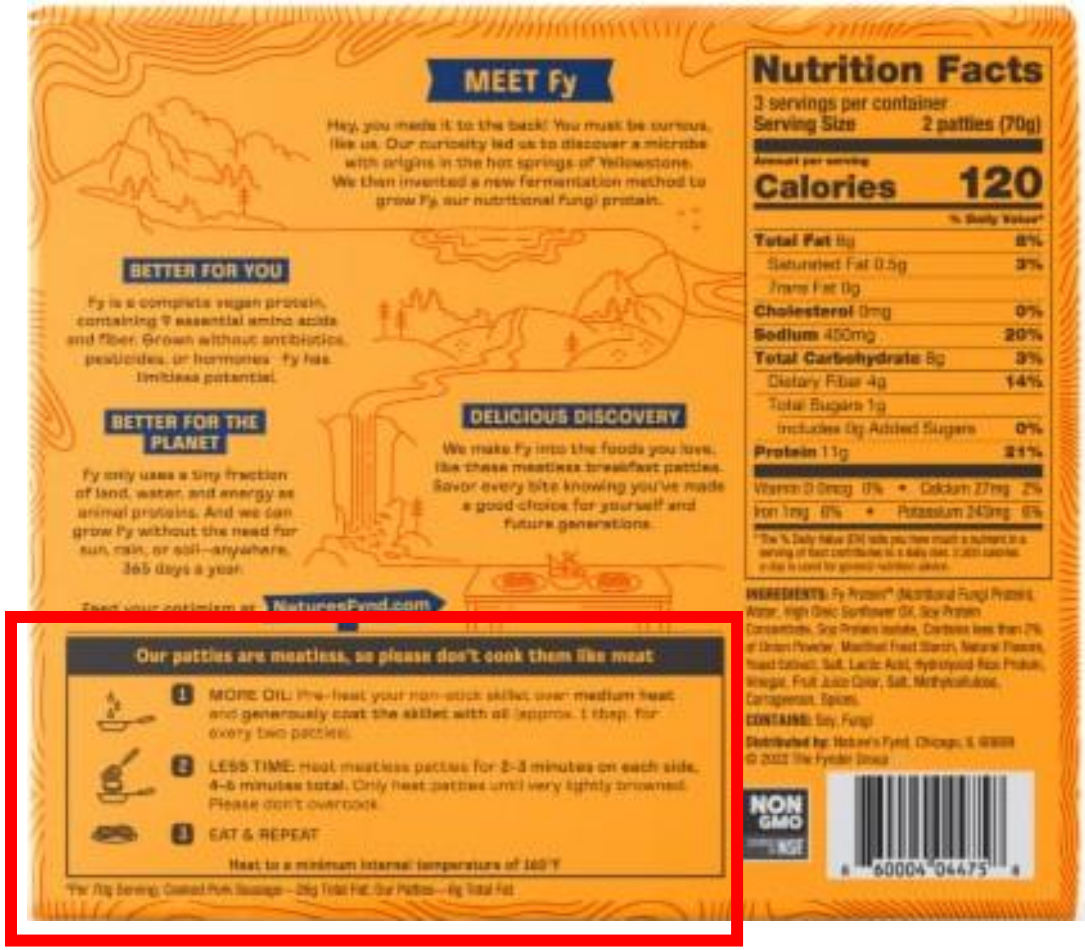
Case Study #2
Sausage Patty Formulations with Mycoprotein



Appendix