Comparison of Plant Proteins and Dairy Proteins in Frozen Desserts

- ***Information for Product Developers***
- ***Phil Rakes***
- ***Agropur Ingredients***
- ***October 2020***

Agenda

- Plant vs. Dairy Ingredient Sources
- Viable Plant Proteins for Frozen Dessert Development
- Measured Emulsion Functionality Differences – Plant vs. Dairy (i.e. PSNF characterization)
- Impact of Differences on Frozen Dessert Mix Performance with Product Development Data
- Development Tips and Strategies

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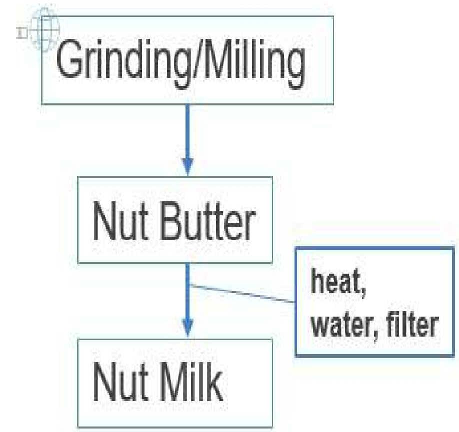
Definitions

- **Mellorine -** lower cost imitation of ice cream. Uses nonfat milk solids along with fats other than milkfat (see 21CFR 135.130) ***Considered ice cream in many locations outside the U.S.***
- **Flexitarian** – uses a combination of animal and plant based proteins and fats
- **Plant-Based Frozen Desserts** – NO CFR DEFINITON. Generally excludes dairy, eggs, and other animal based ingredients
- **Plant-Based** = Dairy Alternative = Dairy-Free = Non-Dairy = vegan
- **Plant-Based** = P-B
- **Plant-Based "milk" =** P-B liquid, suspension, etc.

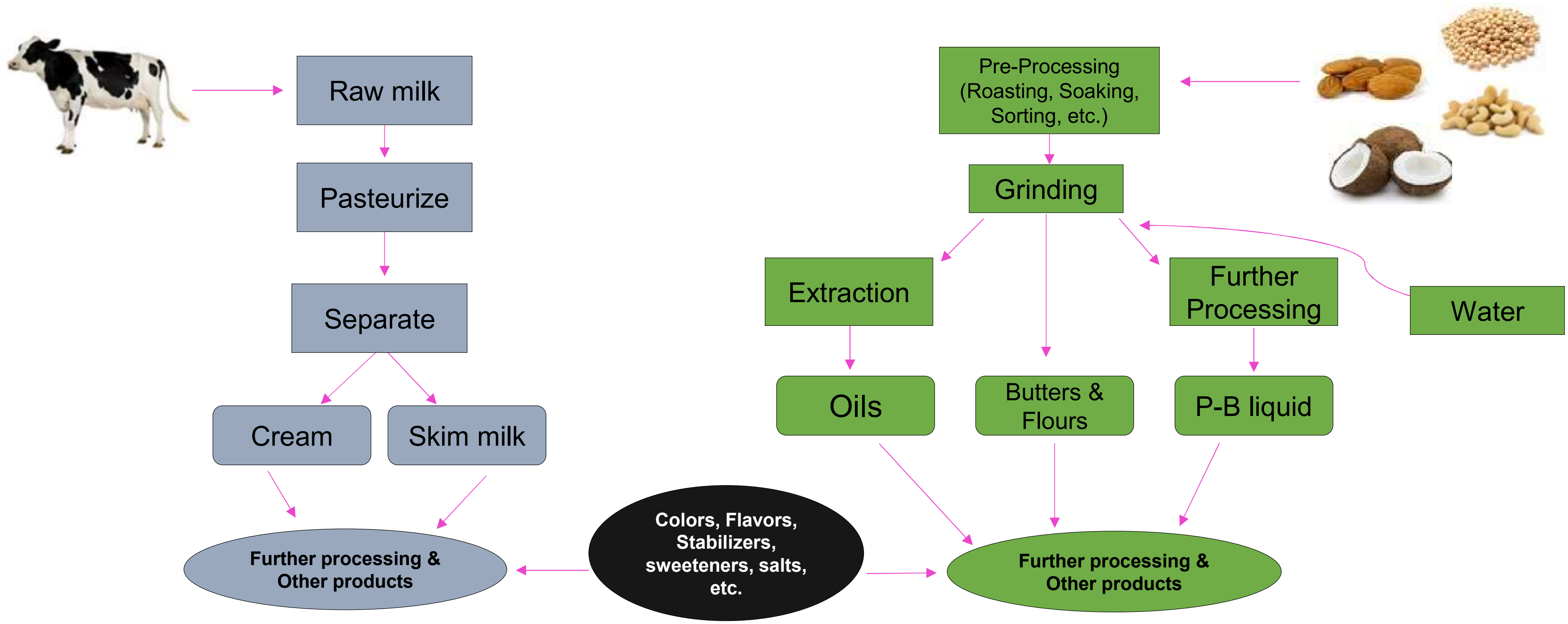
Dairy vs. Plant "Milk" Processing

Processing Liquids

Processing Solid Pieces



Complex source considerations



Process Comparison Summary Statements

- Unlike typical dairy milk processing when plant, bean, nut milks are made there are often some portions of the original nonfat solids that are separated out and thus creating two product streams (i.e. soymilk processing typically creates a second product stream called Okara). <u>This fact changes the composition of the nonfat-nonprotein solids that are often used to make frozen desserts or some plant milks.</u>

- The typical assumption of dairy milk processing mentioned above gets violated when high protein – special dietary frozen desserts get made as these formulas typically use some sort of protein concentrate (i.e. milk protein isolate, whey protein isolate, caseinate) that has significant amounts of the lactose and minerals removed by filtration or precipitation processes. Not our focus in this presentation.

Formula Approach: Dairy vs. Plant Based

- **Dairy vs. Plant Based comparison is helpful**
  - ***Use knowledge of dairy ice cream as a foundation; adjust formulas to accommodate plant ingredient variation (i.e. fat and protein containing ingredients are the key to building a suitable emulsion for freezing)***
  - **What's different ?**

Dairy
- ***Milkfat or Butterfat Level***
- ***MSNF Level***
- Sweetener(s) Level
- Stabilizer/Emulsifier Level

Plant Based
- ***Oil Level***
- ***PSNF Level***
- Sweetener(s) Level
- Stabilizer/Emulsifier Level

Total Solids (TS)
- ***Dairy – TMS = Total Milk Solids***
- ***Plant – TPS = Total [Plant] Solids (ex. Total Soy Solids)***

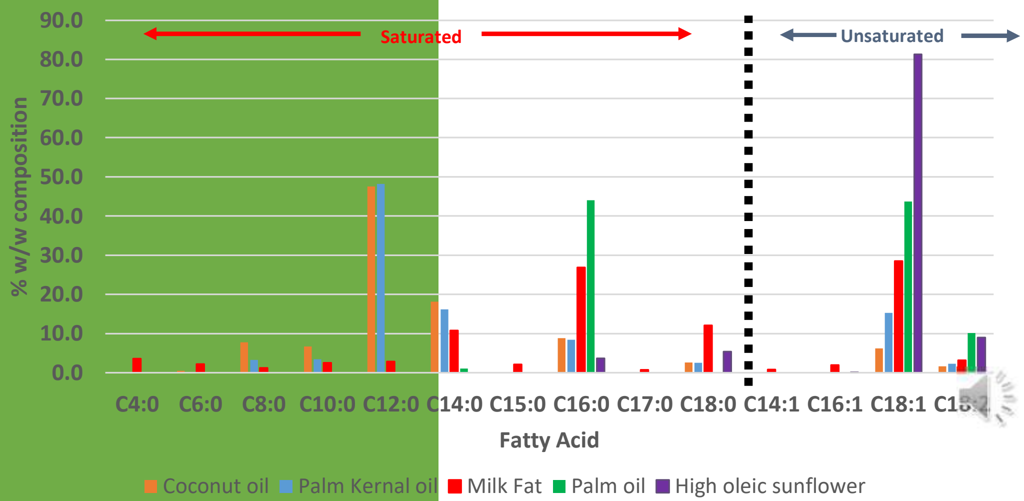
Solids-Not-Fat (SNF)
- ***Dairy – MSNF or NMS = Milk Solids-Not-Fat***
- ***Plant – PSNF or NPS = [Plant] Solids-Not-Fat (ex. Soy Solids Not Fat)***

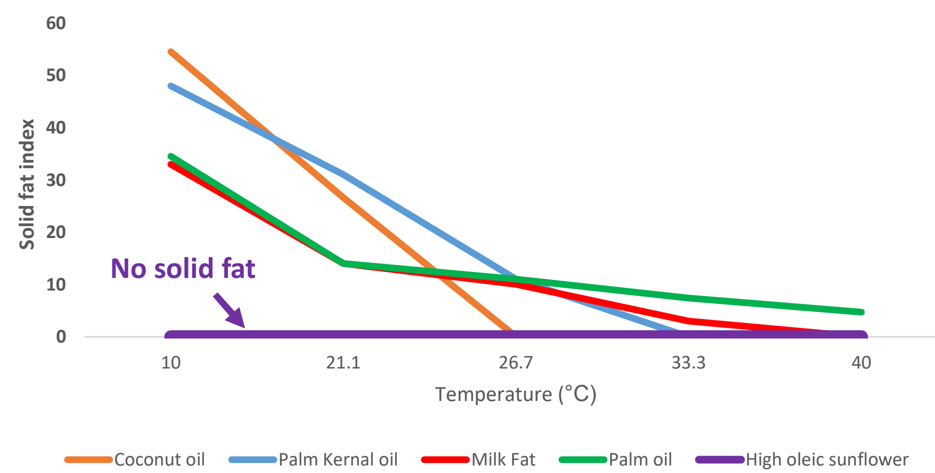
Ingredient categories
Fats and oils

- Dairy – **Milk fat solids**
    - ***Sources***: *Cow milk*
    - ***Emulsions** - Cream, milk, condensed milk, butter, etc.*
    - ***Dry –** Dried cream, whole milk solids, buttermilk solids, etc.*
    - ***Fats** - AMF*

- Plant – **Plant fat & oil solids**
    - ***Sources**: legumes, grains, kernels, seeds, nuts, and fruits (ex. Soy, Peanut, Palm, Palm kernel, Corn, Sunflower, Safflower, Canola, Flax, Coconut, Cocoa butter, Avocado, Almond, Cashew)*
    - ***Emulsions**- Coconut "milk" & cream, margarine, etc.*
    - ***Dry** – Flour, meal (may have oil partially expressed)*
    - ***Butters** – ground nuts and seeds (raw or roasted)*
    - ***Fats** – solid at room temp (saturated fats). Refined, bleached, deodorized (RBD) or virgin*
    - ***Oils** – liquid at room temp (unsaturated fats). Refined, bleached, deodorized (RBD) or virgin*

Fat considerations cont.





High temperature
Less saturated

Low — Solid fat index — High

Low temperature
More saturated

Diverse fatty acids
Less saturated

Broad — Melt profile — Sharp

Uniform fatty acids
More saturated

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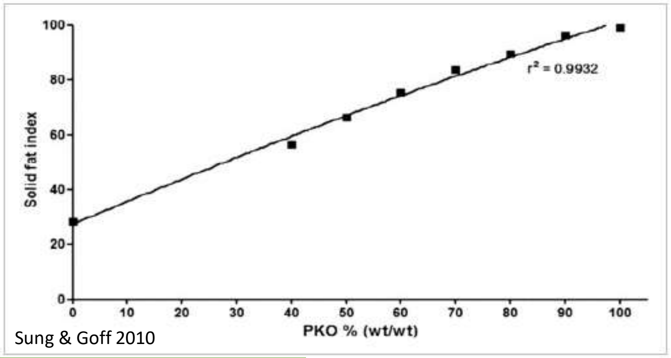
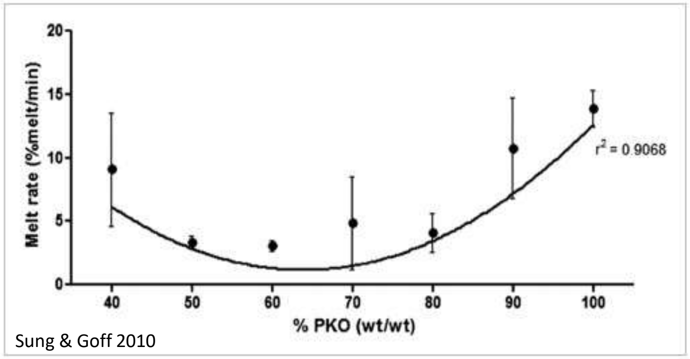
Figures adapted from: 1. Fats & Oils, 3rd Ed, R Obrien, CRC Press, 2009

Fat composition considerations





Typical Data	Avg. Iodine value (degree of unsaturation)	Avg. Solid fat index @10C°	Crystallization Onset Temperature (°C)
Coconut Oil	**10** [5]	**54.5** [5]	**15.0** [10]
Palm Kernel Oil	**17.8** [5]	**67.6** [5]	**7.0** [9]
Milkfat	**34** [5]	**33** [5]	**16-17** [6]
Palm oil	**53** [5]	**34.5** [5]	10.2 [9]
High Oleic Sunflower Oil	**83** [5]	-	**-45.8** [8]
Canola Oil	**115** [5]	-	**-17.1** [9]
Soybean Oil	**131** [5]	-	**-10.2** [9]

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2.) Sung & Goff (2010)
1.) Fats & Oils, 3rd Ed, R Obrien, CRC Press, 2009
3.) Tomaszewska-Gras (2013)
4.) Howell et al (2003)
5. Mettler Toledo (unknown)
6.) Applewhite (1994)
7.) Gordon & Rahman (1991)

Ingredient categories
Solids non-fat

- **Dairy –Milk solids-non-fat (MSNF)**
  - > ***Sources***: *Cow milk*
  - > ***Fluid –*** *Skim, Condensed milk, whey, retentate, etc.*
  - > ***Dry –*** *NFDM, whey solids, MPI, permeate, Buttermilk, etc.*
- **Plant –Plant solids-non-fat (PSNF)**
  - > ***Sources:*** *legumes, seeds, nuts, grains, roots/tubers, fruits and marine (ex. Soy, Pea, Hemp, Potato, Canola, Chia, Flax, Peanut, Faba, Coconut, Cocoa, Almond, Cashew, Oats, Algae, Avocado)*
  - > ***Dry*** *- Flour, defatted flour, meal, concentrates, isolates, hydrolysates*
  - > ***Butter*** *– ground nuts and seeds (raw or roasted)*
  - > ***Fluid*** *– suspensions (aka: "milks") such as almond, oat, and cashew*

Ingredient categories
Other

- **Sweeteners & bulking agents**
    - Similar sources in both dairy and plant formulation
        - CRITICAL EXCEPTION- lactose in dairy
- **Flavors**
    - Similar sources in both dairy and plant formulation
- **Stabilizers/ emulsifiers**
    - Similar sources in both dairy and plant formulation

Critical ingredient differences
5 examples

		PLANT			DAIRY	
COMPOSITION	Units	Defatted Soy Flour	Cashew Butter	Pea Protein Isolate	NFDM	MPC 50
Protein	g/100 g	50	19	80	34	50
Total Fat	g/100 g	1	50	1	1	1
Total Carbohydrates	g/100 g	34	28	3	51	37
Dietary Fiber	g/100 g	19	3	2	0	0
Lactose	%	0	0	0	51	37
Sugars	g/100 g	*15	3	0	*51	37
Total Solids	%	92	95	95	96	96
Solids Not Fat	%	91	45	94	95	94
Relative Sweetness	g/100 g	7	6	0	7	5
Sucrose Equivalence	g/100 g	*28	6	2	*52	36
Ash	%	7	3	6	10	8
Sugar/Ash Ratio		2	1	0	5.1	4.6

*Plant solids contain a variety of sugars, starches, fibers, fats, minerals and proteins that can influence functional ingredient properties with more variability than is typically seen with dairy solids. Note: * comparison*

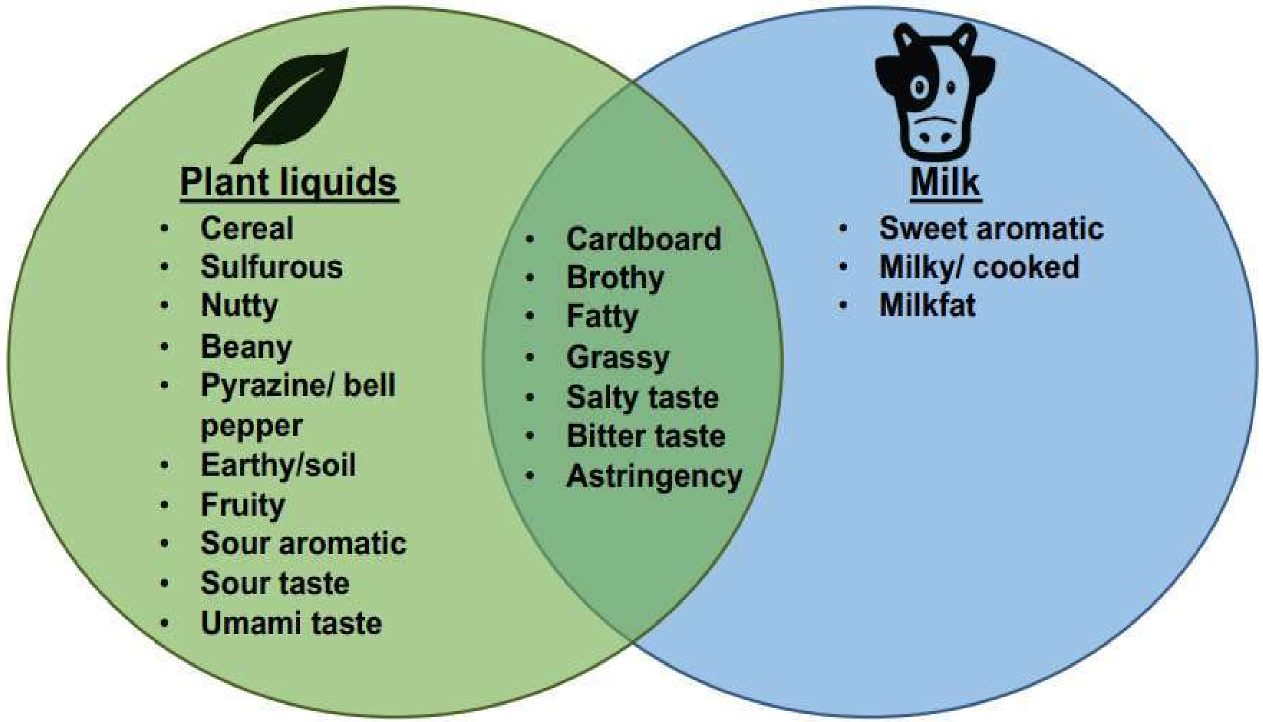
Impact of ingredients on sensory

Relative sweetness of soy flour example

Specific sugar	% of soy flour sugars	% of total soy flour	Relative Sweetness	Total Sweetness Contribution
rhamnose	2.76	0.40	40	0.16
fucose	0.46	0.07	90	0.06
ribose	0.46	0.07	10	0.01
arabinose	11.06	1.60	58	0.93
xylose	4.61	0.67	50	0.33
pinitol	4.15	0.60	10	0.06
mannose	4.15	0.60	37	0.22
galactose	35.02	5.08	30	1.52
glucose	37.33	5.41	74	4.01
total	100.00	14.50		7.30

Plant ingredient sensory characteristics

P-B ingredients have more flavor-variability relative to dairy; many ingredients have off-notes that must be masked or complemented.



Courtesy of Mary Anne Drake, North Carolina State University

P-B protein characterization (i.e. possible viable sources)

Sensory descriptors

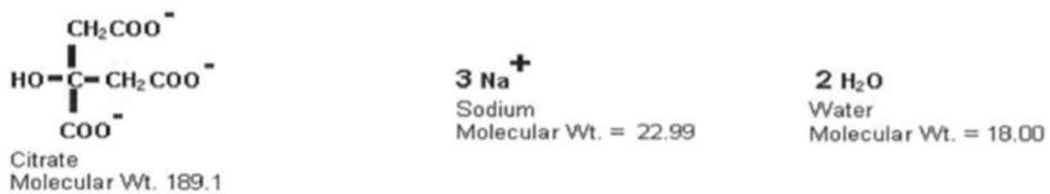
Protein Type	Flavor & Mouthfeel
Rice protein	Slightly sweet, slightly nutty, very gritty
Faba protein #1	Clean, slightly beany, slightly grassy, viscous
Faba protein #2	Clean, slight cereal, slight mouthcoating
Soy protein	Very clean, slightly nutty, fruity, viscous
Pea protein #1	Slight cereal, nutty, earthy, viscous and mouthcoating
Pea protein #2	Nutty, cereal, beany, brothy, mouthcoating and gritty
Cornerstone® Faba-pea protein	Slight cereal, slightly nutty, viscous and mouthcoating
Whey protein (reference #1)	Slightly milky, slightly barny, astringent
Milk protein (reference #2)	Slightly milky, slight cardboard, mouthcoating

PSNF Ingredient Characterization

Impact of composition on FPD

Freezing point depression (FPD)

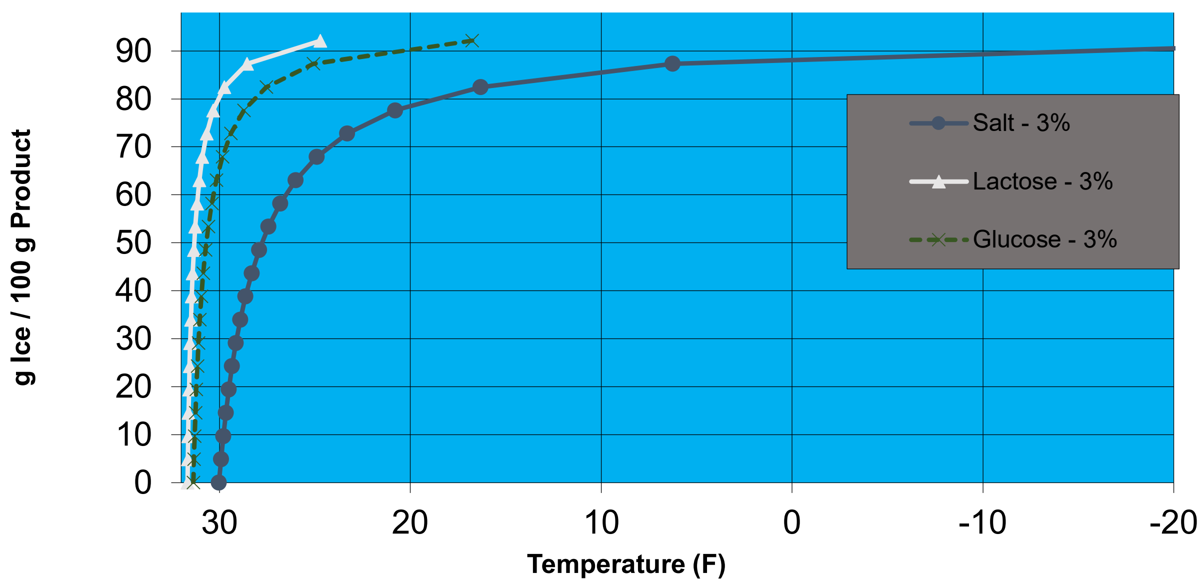
- P-B ingredients contain highly variable amounts of sugars, minerals, and buffering salts from processing (may not be labeled!)
- Sugars, minerals, and buffering salts contribute to **Sucrose Equivalence (SE)** and thus **freezing point depression (FPD)**
  - **Non-ionic species**: SE = (Sucrose molecular weight / molecular weight species)*100g
  - **Ionic species**: SETOT= SE1+SE2+… = (%Ion 1 * SE Ion1)*100+(%Ion 2 * SE Ion 2)*100…..
- Example: **Trisodium citrate**
  - 100g sodium citrate is equivalent to 466g sucrose in its ability to depress the freezing point



Example courtesy of Owl Software

Impact of ingredients on FPD (i.e. freezing point depression)
Sugars & minerals calculation example

Techwizard Formula Simulation	Salt - 3% Solution	Lactose - 3% Solution	Glucose - 3% Solution
Sucrose Equiv (%)	*17.7*	*3.0*	*5.8*
Total Solids (%)	*3.0*	*3.0*	*3.0*
Freezing Point (F)	*30.0*	*31.7*	*31.4*
Difference	*Reference*	*-1.6*	*-1.3*
Freezer Exit Temperature (F)	*25.0*		
% Product Frozen	*67.5*	*91.9*	*87.4*
Difference (%)	*Reference*	*36.2*	*29.5*



Techwizard Freezing Curve Simulation

Impact of ingredients on FPD continued
Soy flour sugars examples

Specific sugar	% of soy flour sugars	% of total soy flour	molecular weight	Specific Sucrose eq. (per 100g sucrose)	Total SE contribution
rhamnose	2.76	0.40	164	208	0.83
fucose	0.46	0.07	164	208	0.14
ribose	0.46	0.07	150	228	0.15
arabinose	11.06	1.60	150	228	3.65
xylose	4.61	0.67	150	228	1.52
pinitol	4.15	0.60	194	176	1.06
mannose	4.15	0.60	180	190	1.14
galactose	35.02	5.08	180	190	9.64
glucose	37.33	5.41	180	190	10.28
TOTAL	100.00	14.50			28.42

Impact of composition on FPD continued

Soy formula examples

Generic Soy Frozen Dessert –
Bakigen® Soy Flour

	%
Defatted Soy Flour	4.0
Safflower Oil	8.9
Sweetener (sugar, corn syrup)	22.6
Bulk Ingredients (tapioca solids)	3.3
Stabilizer/emulsifier	0.4
Water	60.8

note: 2% protein

Generic Soy Frozen Dessert –
Soymilk

	%
Soymilk Powder	4.4
Safflower Oil	8.0
Sweetener (sugar, corn syrup)	22.6
Bulk Ingredients (tapioca solids)	3.3
Stabilizer/emulsifier	0.4
Water	61.2

note: 2% protein

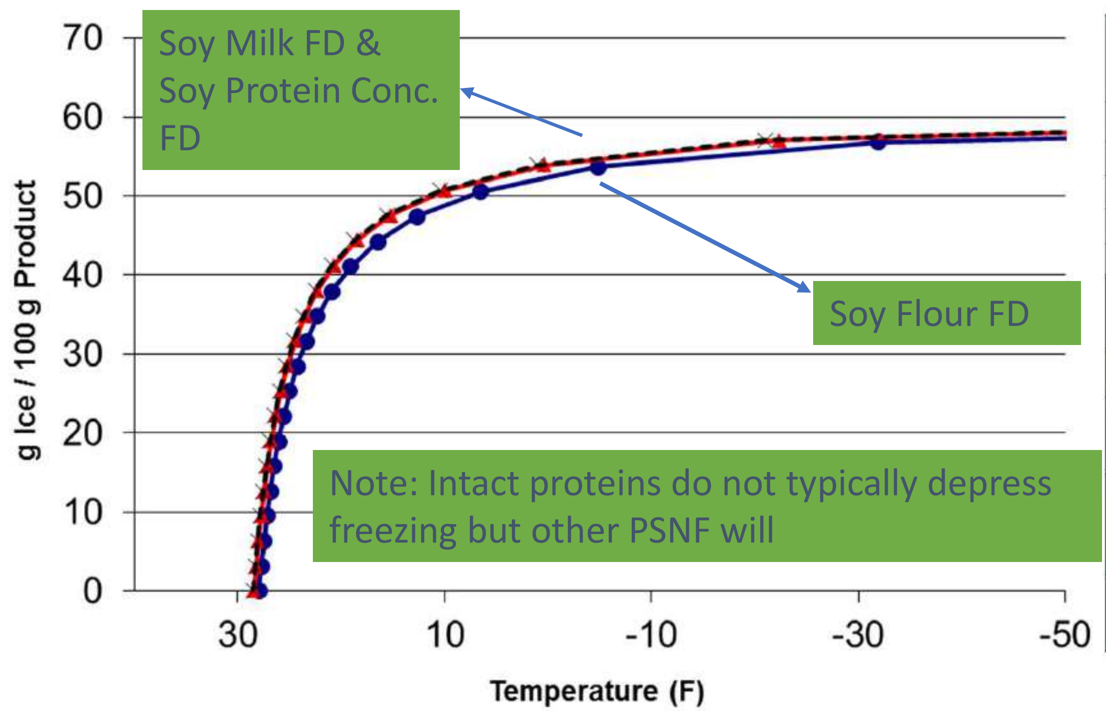
Generic Soy Frozen Dessert –
Cornerstone® Soy Protein

	%
Soy Protein Concentrate	2.6
Safflower Oil	9.0
Sweetener (sugar, corn syrup)	22.6
Bulk Ingredients (tapioca solids)	4.2
Stabilizer/emulsifier	0.4
Water	61.2

note: 2% protein

Impact of composition on FPD continued

Soy formula calculation example



Formula Name:	Soy Frozen Dessert - Soy Flour	Soy Frozen Dessert - Soymilk	Soy Frozen Dessert - Soy Concentrate
Soy Solids Not Fat (SSNF) (%)	3.6	3.3	2.4
Sucrose Equiv (%)	22.8	20.4	20.0
Fat (%)	9.1	9.1	9.2
Total Solids (%)	36.8	36.6	36.6
Mix Density(Lb/gal)	9.2	9.2	9.2
Freezing Point (F)	28.0	28.4	28.5
Difference	Reference	-0.50	-0.54
Freezer Exit Temperature (F)	22.0		
% Product Frozen	35.5	38.7	39.1
Difference (%)	Reference	9.0	10.2
Dipping Temperature (F)	10.0		
% Product Frozen	49.0	50.7	50.9
Difference (%)	Reference	3.6	4.0

A small change in SE translates into a big difference in the amount of product frozen at draw!

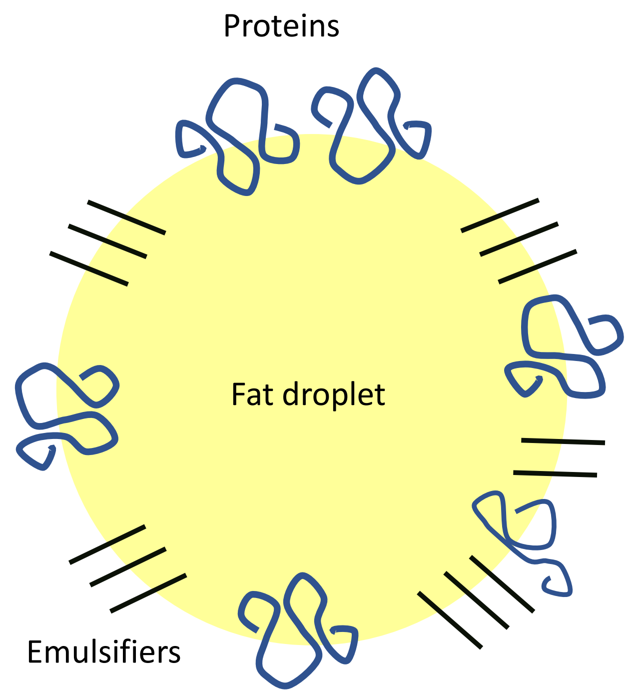
Techwizard Freezing Curve Simulation

Key points
Impact of ingredient composition on FPD

- **Know your ingredient composition**
  - Calculate the ingredient SE
  - Understand the impact of ingredient sugars, minerals, and buffering salts on FPD
  - Know that plant-based ingredient processing aids may not be disclosed
- Graphing your **calculated SE** can be a helpful visual aid to understanding **mix FPD**

Protein characterization focus

- **Protein:fat** interaction is key in finished product characteristics like **melt rate, shelf stability, and textural quality** (8,9,10)
- **P-B fats/oils** seem easier; not difficult to characterize good sources for a given project.
- **P-B protein/ PSNF** ingredients are unpredictable; more effort put in to characterize and screen



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8.) Daw & Hartel (2015)
9.) Amador et al. (2017)
10.) Goff, H.D. (1997)

P-B protein characterization

Sources tested

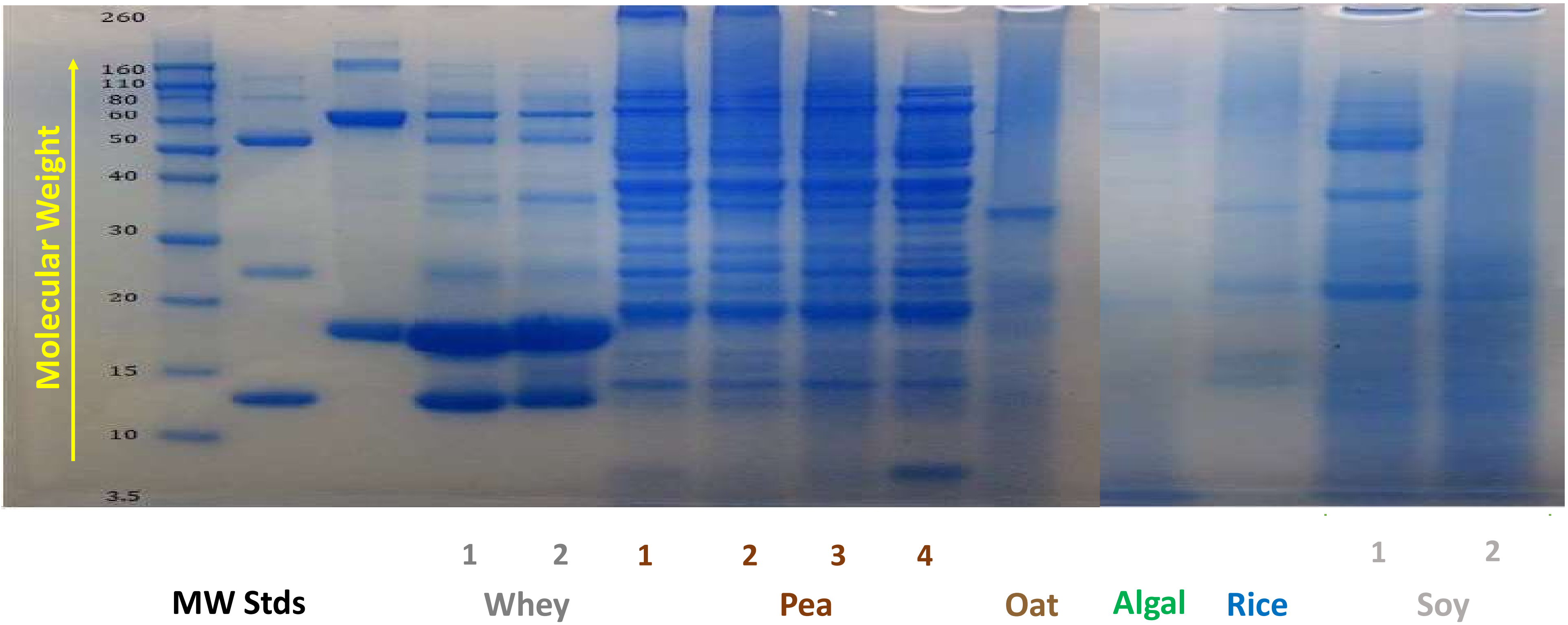
Whey (Reference)

Algal	**Pea #1**	**Soy #1**
Canola	**Pea #2**	**Soy #2**
Oat	**Pea #3**	
Rice	**Pea #4**	



P-B protein characterization

SDS-PAGE (gel electrophoresis)



P-B protein characterization
Solubility & zeta potential

- Solubility – Reflects variation in ingredient processing
- Zeta potential - Surface charge has a direct impact on emulsion characteristics [6]; larger magnitude = more surface charge, usually negative for proteins neutral pH
- Isoelectric point –pH where protein precipitates and usually is least functional

11.) Li,X., et al. 2017. *F Chem 239*, 75–85.

Protein Type	% Solubility Index [a]	Zeta Potential @ pH=7 (mV)	Approx. Isoelectric pH (Zeta mV= 0)
Whey *(Reference)*	***102***	***-17***	***4.43***
Algal	***69***	***-14***	***3.24***
Canola	***99***	***N/A***	***N/A***
Oat	***14***	***-8***	***3.80***
Pea #1	***13***	***-23***	***4.14***
Pea #2	***54***	***-8***	***4.71***
Pea #3	***63***	***-18***	***4.26***
Pea #4	***10***	***-21***	***4.30***
Rice	***2***	***-21***	***4.66***
Soy #1	***52***	***-24***	***4.33***
Soy #2	***62***	***-21***	***4.35***

a Adapted from AACC Internationl method 46-23.01 for Nitrogen solubility index

P-B protein characterization I continued

Heat stability

Comparing viscosity measurements taken pre/post heating are a simple way to predict heat stability during processing

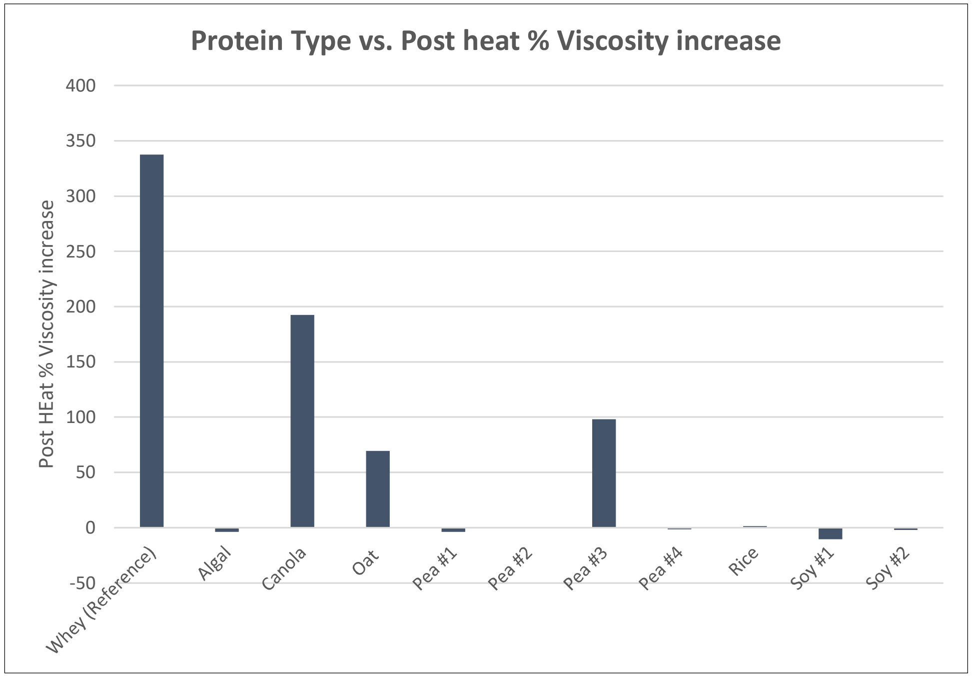
Protein Type	Post heat % viscosity increase[a]
Rice protein	**1.00**
Faba protein #1	**325**
Soy protein	**-23.0**
Pea protein #1	**24.3**
Pea protein #2	**1.50**
Cornerstone® Faba-pea protein	**240**
Whey protein (reference #1)	**2550**
Milk protein (reference #2)	**-25.0**

a Measured on an RVA, 160 RPM, 30 min hydration @ 40° C, 10 min hold @ 90 C. Based on an 6.8% protein as-is, no pH adjustment

P-B protein characterization II
Post heating viscosity

- Viscosity measurements after heating are a way to look at water-protein and protein-protein interactions

Protein Type	Post heat % viscosity increase b
Whey *(Reference)*	*338*
Algal	*-4*
Canola	*192*
Oat	*69*
Pea #1	*-4*
Pea #2	*0*
Pea #3	*98*
Pea #4	*-2*
Rice	*1*
Soy #1	*-11*
Soy #2	*-2*



b Measured on an RVA, 320 RPM, 10 min hold @ 90 C. Based on an approximately 6.8% protein as-is, pH = 6.5 adjusted solution

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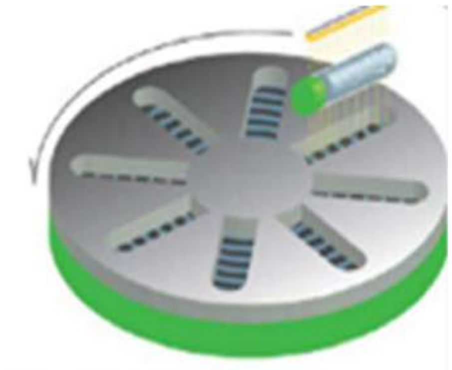
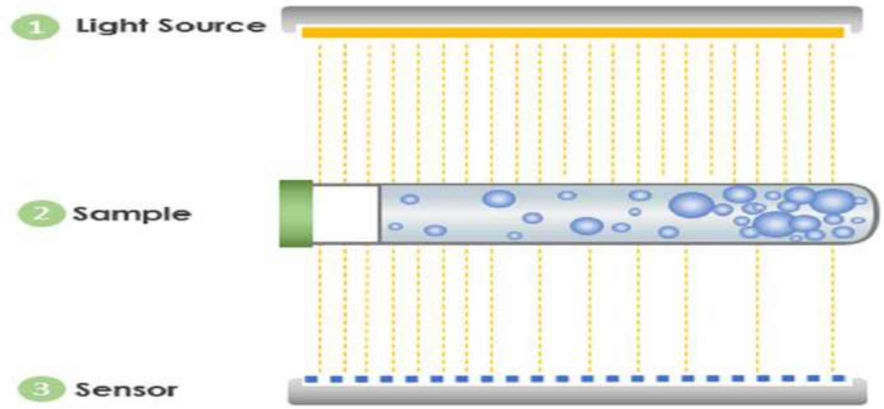
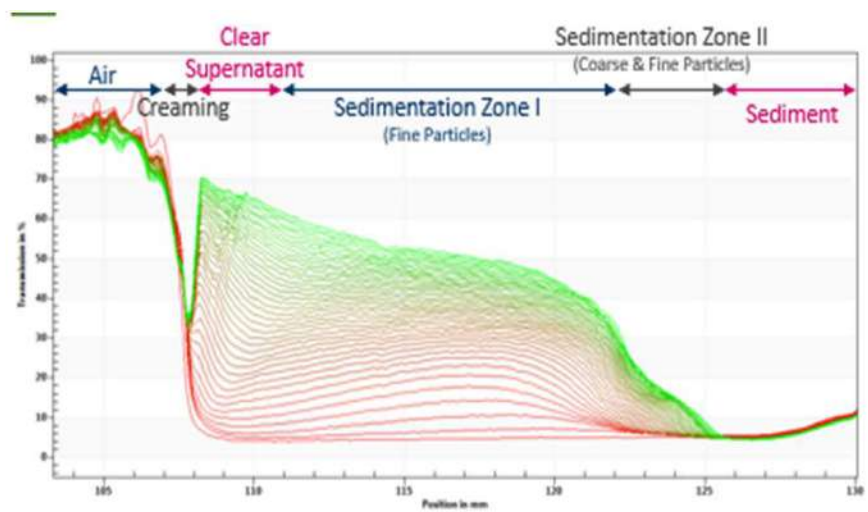
Separation Testing of Emulsion (i.e. LumiSizer)

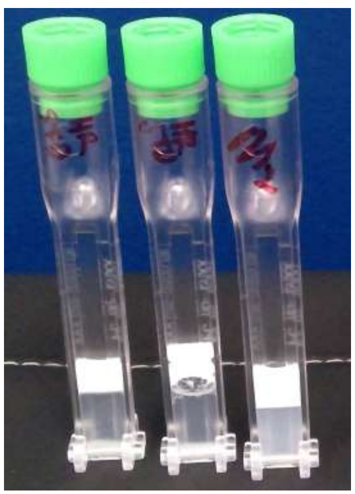




Test Parameters

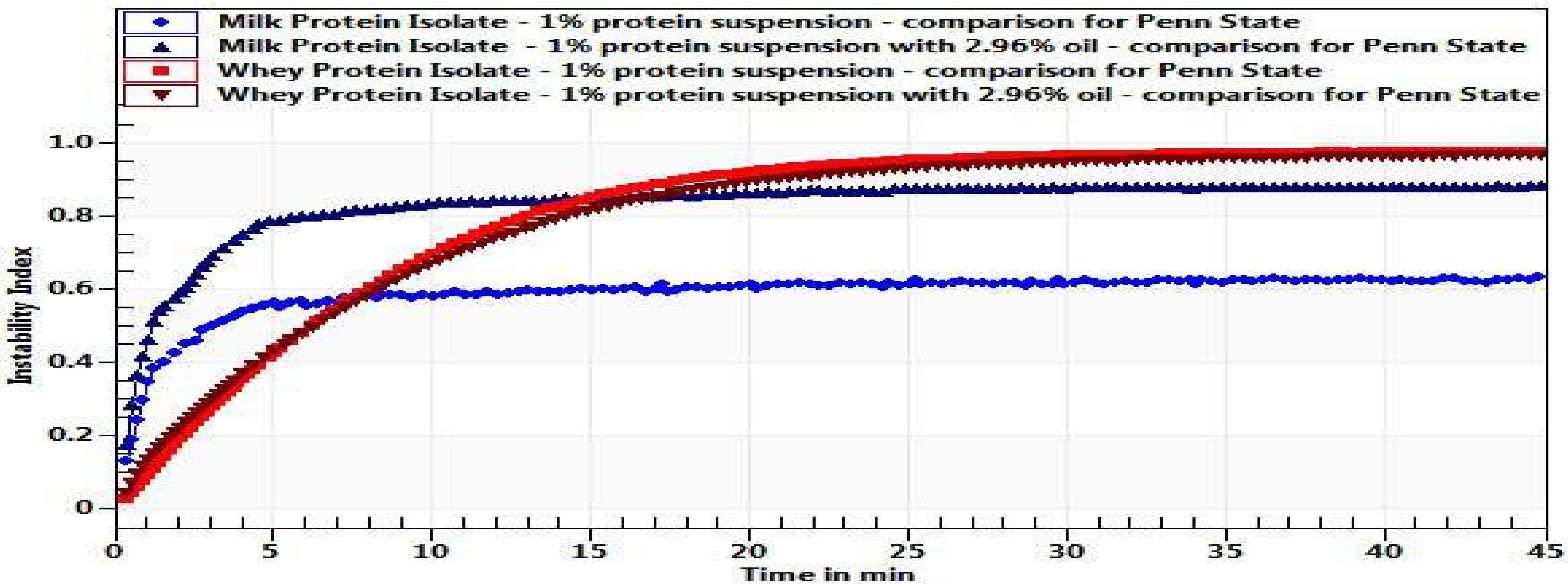
- Interval: 10s
- Speed: 4,000 RPM
- Temperature: 25.0°C





Finished Separated Samples

Milk Protein Solubility vs. Milk Protein Emulsion Strength - Centrifugal Separation Curves



Note: - test solutions standardized to 1% protein with 2.96% corn oil - HTST processed, unhomogenized - 5° C overnite – 4000 RPM at 5°C – 45 minutes

- *Sedimentation veloclity – relative indication of suspendibility and solubility*
- *Creaming velocity – relative indication of two phase, liquid mix emulsion strength*

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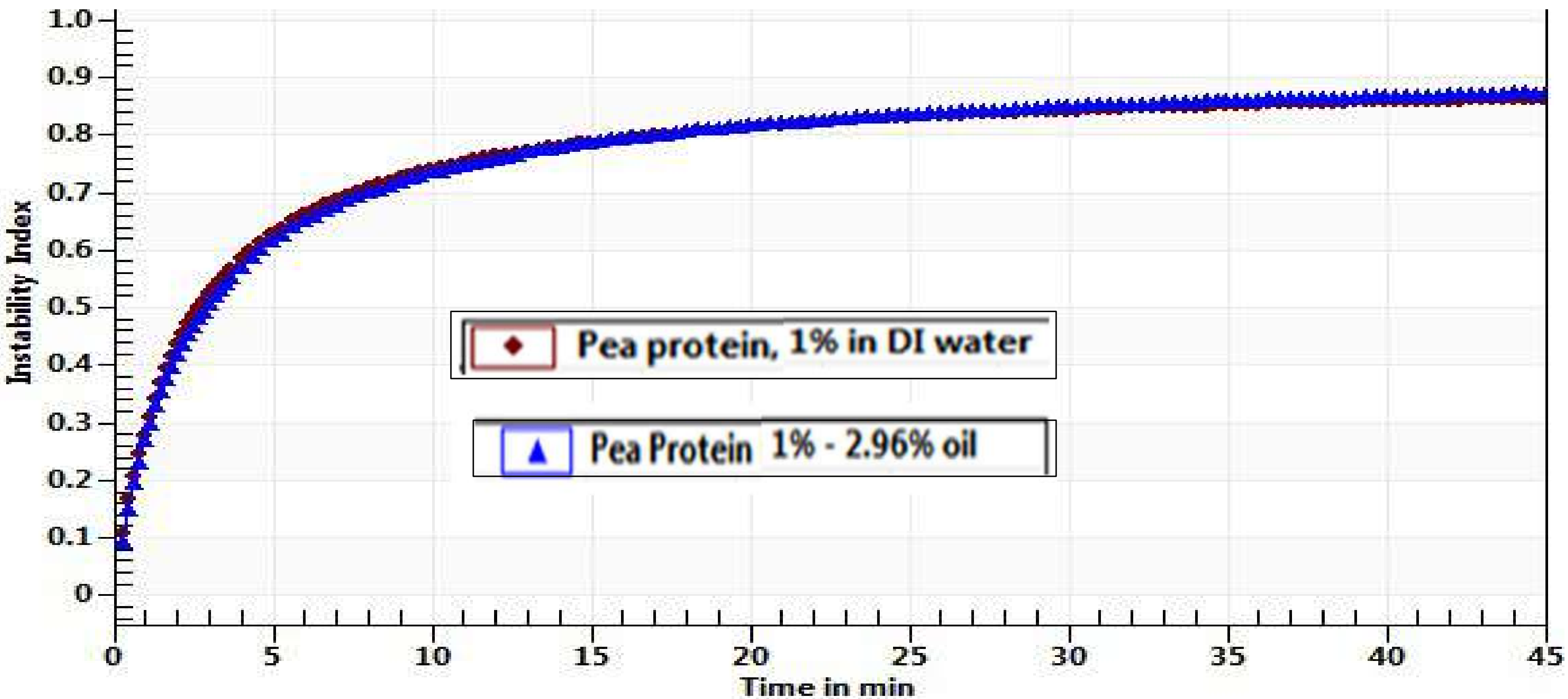
Pea Protein Solubility vs. Pea Protein Emulsion Strength – Centrifugal Separation Curve



Note: - test solutions standardized to 1% protein with 2.96% corn oil - HTST processed, unhomogenized - 5° C overnite – 4000 RPM at 5°C – 45 minutes

- *Sedimentation veloclity – relative indication of suspendibility and solubility*
- *Creaming velocity – relative indication of two phase, liquid mix emulsion strength*

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P-B protein characterization Suspension & emulsion separation resistance

Suspension/ Emulsion Separation Rate– the smaller the number, the more resistant the suspension or emulsion is to separation

Protein Type	*P-B protein solution only* Suspension Separation Rate [a,1]	*P-B protein + Oil Emulsion* Emulsion Separation Rate [b,1]
Pea #1	***23***	***33***
Pea #2	***41***	***51***
Pea #3	***85***	***89***
Canola	***161***	***177***
Soy #2	***52***	***40***
Milk protein*(Reference)*	***6***	***23***
Whey *(Reference)*	***7***	***16***

[a] 1% Protein in water
[b] 1% Protein + 2.96% oil in water
[1] Measured via Analytical centrifuge (LumiSizer)

Key point: Smaller Numbers → More resistance to separation

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Effect of a Processing Aid/Additive on Protein Ingredient Performance

Sample I.D.	Sedimentation Velocity (harmonic mean)	Creaming Velocity (harmonic mean)
Pea Protein I	1512	3535
	1860	3527
	1419	2618
	1306	2902
Average	1524.25	3145.5
Standard Deviation	239.157375	460.0003623
Pea Protein 55%	7169	12453
	7275	11545
	7561	12916
	7557	12600
Average	7390.5	12378.5
Standard Deviation	199.3280378	588.2859282
Pea Protein - Pea Protein 80 - SF Lecithin	1886	4299
	1850	3539
	2282	4294
	2065	3710
Average	2020.75	3960.5
Standard Deviation	197.9248595	394.2152542

Note: - test solutions standardized to 1% protein with 2.96% corn oil - HTST processed, unhomogenized - 5° C overnite – 4000 RPM at 5°C – 45 minutes

- *Sedimentation veloclity – relative indication of suspendibility and solubility*
- *Creaming velocity – relative indication of two phase, liquid mix emulsion strength*

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Sample I.D.	Sedimentation Velocity (harmonic mean)	Creaming Velocity (harmonic mean)
Hemp Protein I	11292	5055
	10762	4996
	9868	5142
Average	10640.66667	5064.333333
Standard Deviation	719.7119794	73.44612538
Hemp Protein 50%	5247	4895
	5402	4758
	4684	4226
	5460	4626
Average	5198.25	4626.25
Standard Deviation	354.4275902	288.5508332
WPC 34% Food Grade - FDA - ST (special testing), item# 108087 - c	1448	4506
	1502	5011
	1444	4156
Average	1464.666667	4557.666667
Standard Deviation	32.39341497	429.8352398
NFDM, low heat, CROPP Organic COOP, Item#52191	1688	2523
	1804	2889
	1819	2483
	1699	2261
Average	1752.5	2539
Standard Deviation	68.54925237	260.240914

Note: - test solutions standardized to 1% protein with 2.96% corn oil - HTST processed, unhomogenized - 5° C overnite – 4000 RPM at 5°C – 45 minutes

- ***Sedimentation veloclity – relative indication of suspendibility and solubility***
- ***Creaming velocity – relative indication of two phase, liquid mix emulsion strength***

Sample I.D.	Sedimentation Velocity (harmonic mean)	Creaming Velocity (harmonic mean)
Sunflower Protein 55%	1712	5923
	1511	5486
	1595	5984
	1629	6333
Average	1611.75	5931.5
Standard Deviation	83.22409507	347.611373
Sunflower Protein 80%	4030	18210
	3694	20729
	3630	19370
Average	3784.666667	19436.33333
Standard Deviation	214.8611955	1260.809396
WPC 34% Food Grade - FDA - ST (special testing), item# 108087 - c	1448	4506
	1502	5011
	1444	4156
Average	1464.666667	4557.666667
Standard Deviation	32.39341497	429.8352398
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- *Sedimentation veloclity – relative indication of suspendibility and solubility*
- *Creaming velocity – relative indication of two phase, liquid mix emulsion strength*

Tests for Protein Screening (i.e. key points)

- Why Protein Focus?
  - Fat-Protein interaction is key in finished product characteristics like melt rate, shelf stability, and sensory quality [8,9,10] . *Protein is the backbone of a frozen dessert!*

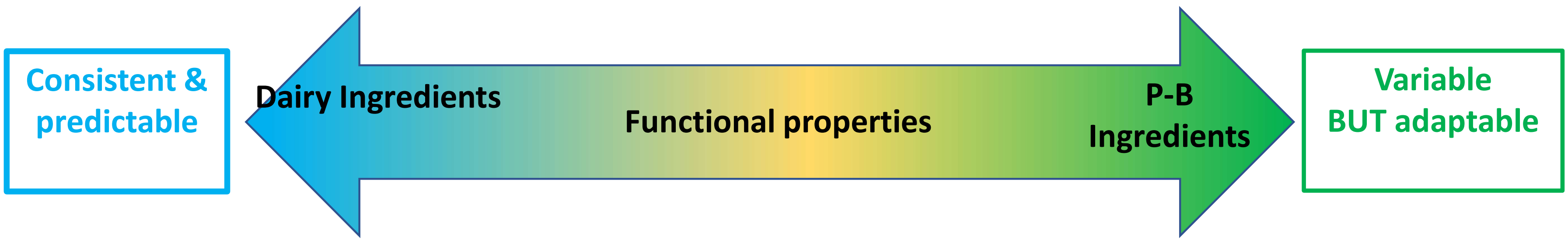
- Tests used to compare protein sources
  - Sensory (Can I flavor with it?)
  - Solubility (Will it go into solution & function?)
  - Zeta potential (Surface Charge)
  - Viscosity (Water binding)
  - Separation Stability (Sedimentation resistance & Emulsion Capacity)
  - SDS- PAGE (Molecular size)

8.) Daw, E., and Hartel, R.W. (2015). Fat destabilization and melt-down of ice creams with increased protein content. *International Dairy Journal 43*, 33–41
9.) Amador, J., Hartel, R., and Rankin, S. (2017). The Effects of Fat Structures and Ice Cream Mix Viscosity on Physical and Sensory Properties of Ice Cream. *Journal of Food Science 82*, 1851–1860.
10.) Goff, H.D. (1997). Review Colloidal Aspects of Ice Cream-A Review. *International Dairy Journal 7*, 363–373.

Critical ingredient differences continued

Key functional properties

- ✓ Freezing point depression (sucrose equivalence)
- ✓ Buffering capacity (resistance to pH change)
- ✓ Emulsification performance
- ✓ Viscosity contribution to the mix formulation
- ✓ fatty-acid composition (texturizing & stability considerations)

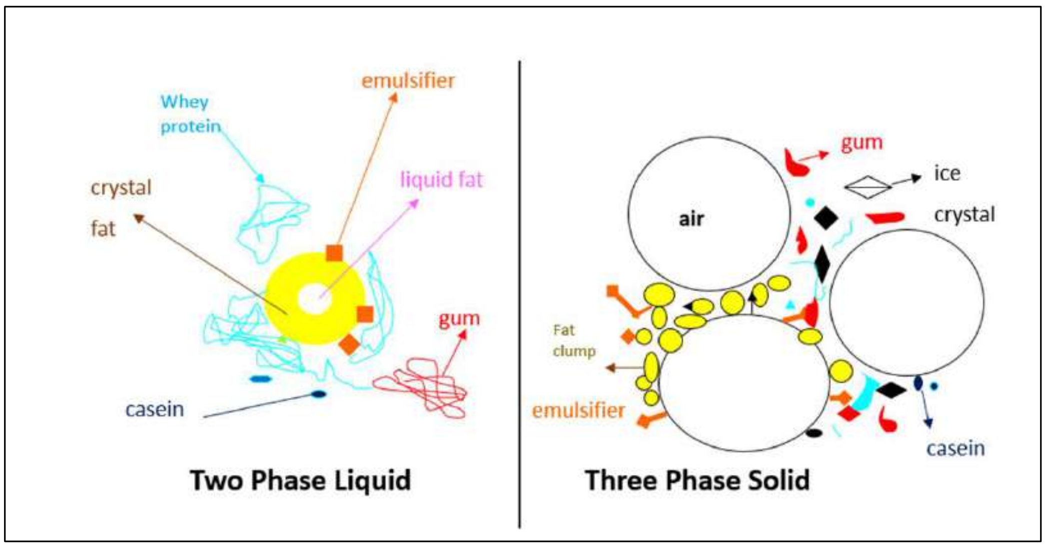


Key functional properties in P-B ingredients will be harder to predict due to their variable composition and processing

Product development Examples (Impact of differences on frozen dessert mix performance)

Fundamentals of Frozen Dessert Freezing and Aeration

- **For a dairy ice cream mix the emulsifier partially destabilizes the two phase (oil in water) mix such that freezing and agitation partially coalesces the fat with protein around the air cells.**
- ***Plant based FD changes protein and fat composition and possibly removes emulsifier; so a new balance of forces on the mix emulsion has to be found.***



Armfield Continuous Pilot Plant Freezer

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Approach to applications testing
Considerations

- Little information is published on 100% P-B frozen desserts
  - Relevant publications to P-B applications testing:
    - ***Formulation of a true plant protein/ fat formula*** *(12)*
    - ***Hybrid non-dairy fats with dairy proteins*** *(2,13)*
    - ***Hybrid protein formulas (dairy and soy)*** *(14)*
- No standards of identity exist for P-B frozen desserts, so formulation options seem unlimited

2.) Sung & Goff (2010)
12.) Chan & Pereira (1992)
13.) Nadeem et al. (2010)
14.) Cheng et al. (2016)

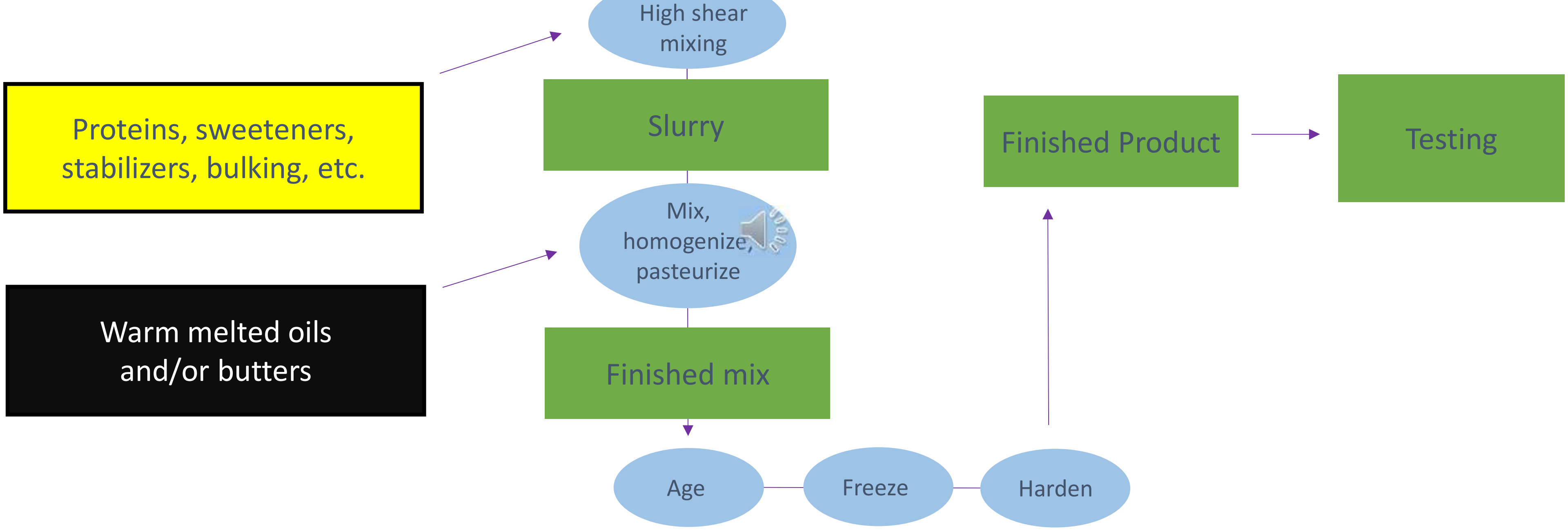
Approach to applications testing
Define parameters

- Start with what is known: ice cream/P-B hybrid formulas
  - *Select a formula composition – Often defined in project scope*
    - Fat level **8-10% fat is typical [14]**
    - Solid fat content **(60%-70% solid fat deemed optimal in** Mellorine **[2])**
    - Protein **few guidelines for P-B ingredients**
    - Total solids **36% is low-average [1]**
    - Stabilizer/emulsifier **Same stabilizers as dairy (guar, locust, carrageenan, etc.). Emulsifier selection changes with label requirements and actual need.**
  - *Testing* based on established dairy applications testing
  - *Processing* based on established dairy processing

2.) Sung & Goff (2010)
14.) Goff & Hartel (2013)

Basic Processing

Agropur's pilot plant equipment



Possible applications tests to perform

The basics

- Viscosity
- pH
- Mix Separation
- Overrun
- Meltdown Rate
- Sensory
- Accelerated Shelf life
- Microbiological verification

Advanced

- Mechanical Hardness
- Fat Destabilization
- Adsorbed protein
- Others

Example Study 1

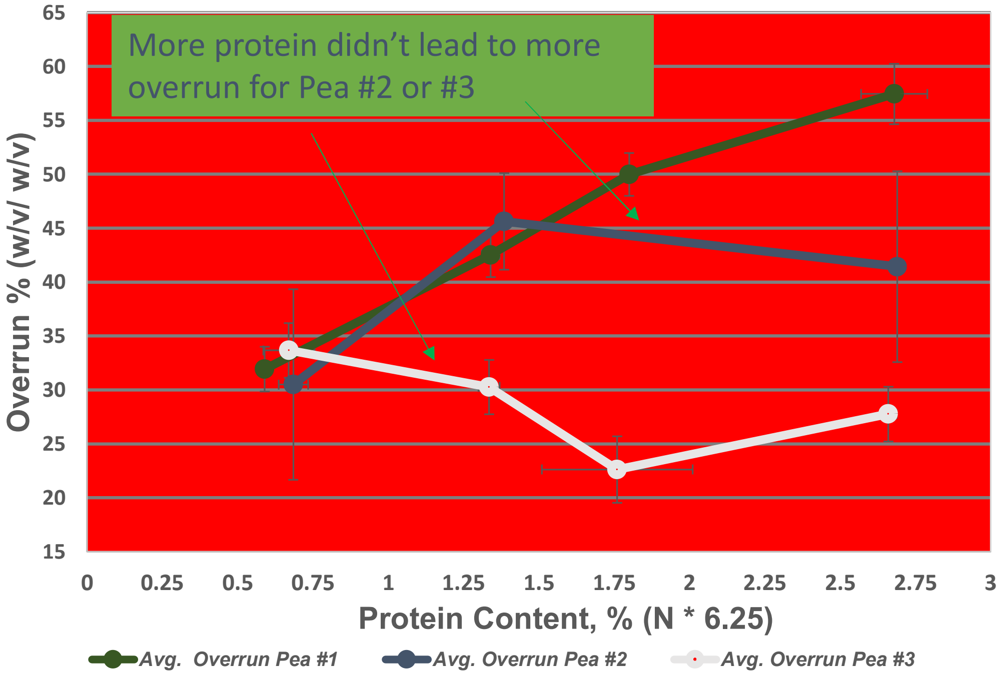
Protein source and inclusion rate

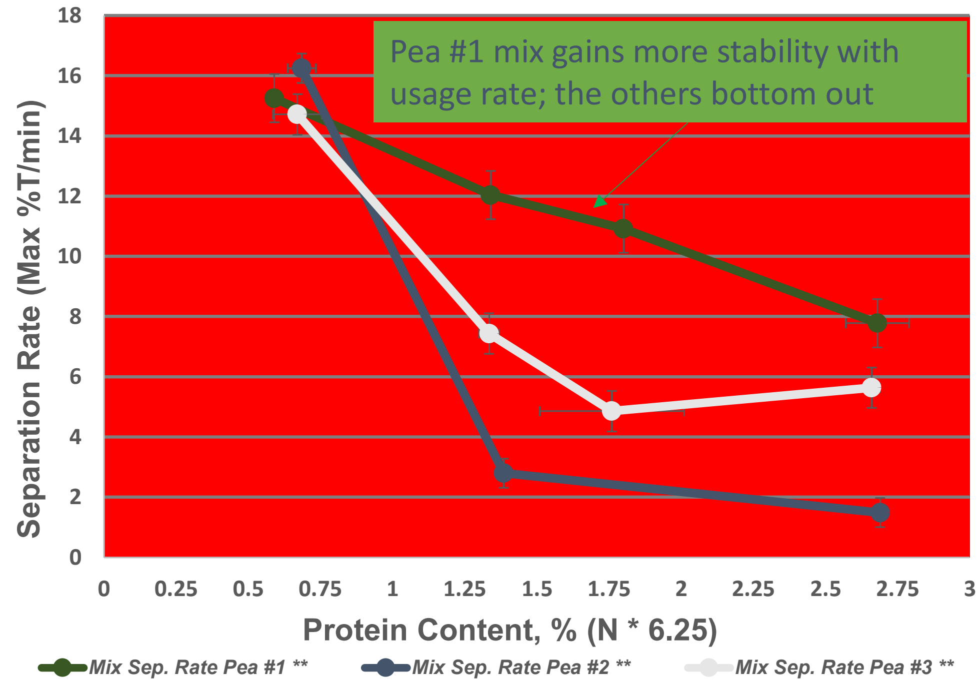
- **Objective** – Evaluate the variability between different pea protein sources on formula performance.
- **Standardize formulations for:**
  - ***36% Total solids***
  - ***10% total fat from 65:35, Fractionated palm kernel: High Oleic Sunflower Oils***
  - ***Sucrose equivalence @22***
  - ***Stabilizer: Guar, LBG, mono & diglycerides, Poly 80***
- **Variables**
  - ***3 pea protein sources***
  - ***Protein inclusion @ 0.5%, 1.25%, 1.75%, 2.5%***

Example study 1: pea protein variable

Results

-Pea protein #1 at a use rate of 1.75% - 2.5% gave the best results in this system





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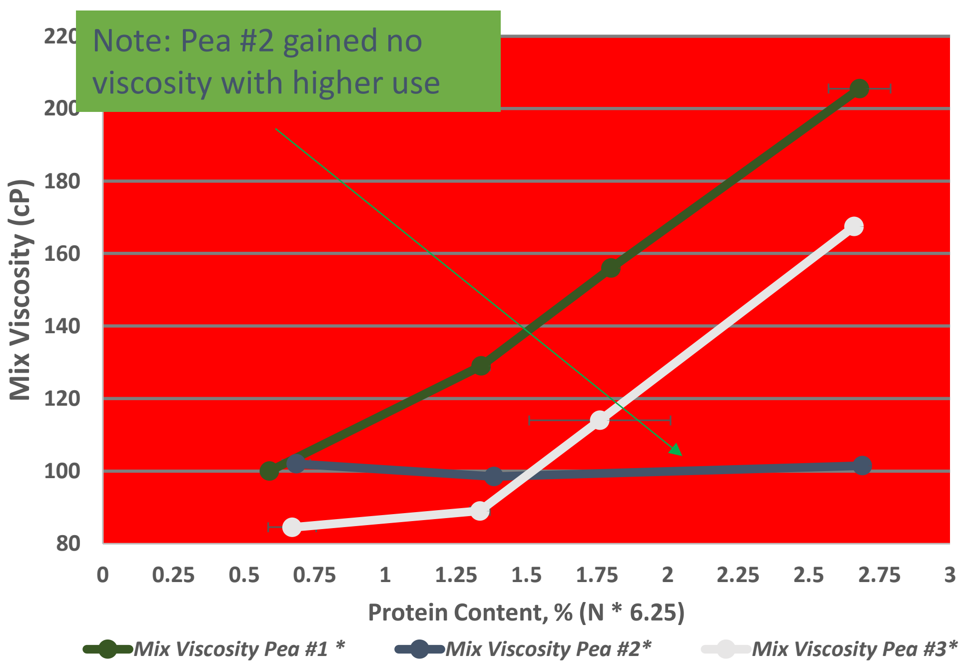
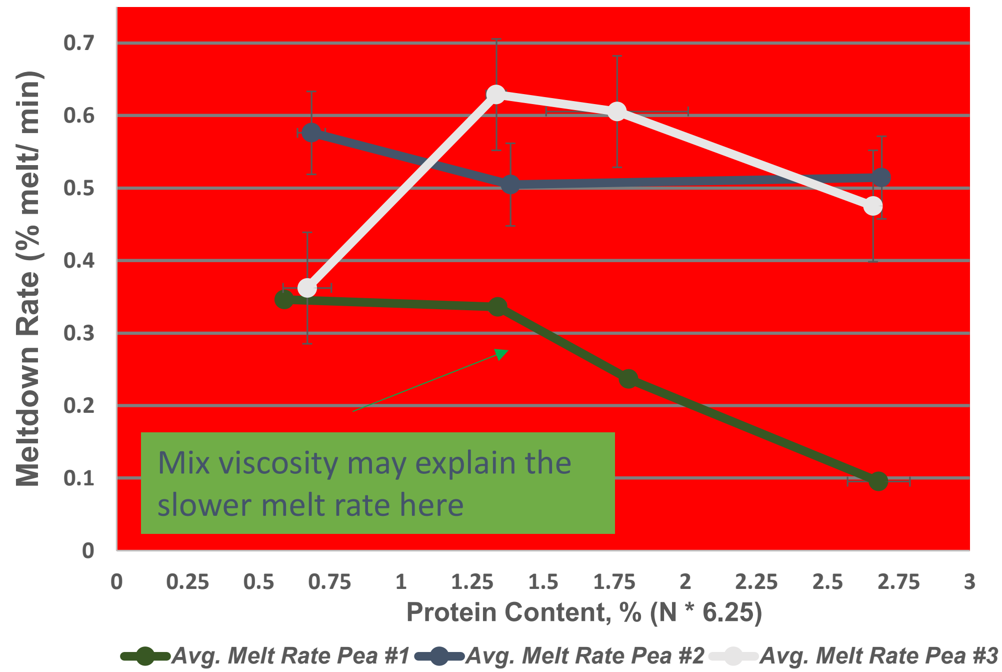
Vertical Error bars are 95% Confidence intervals

Example study 1: pea protein variable

Results continued





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Vertical Error bars are 95% Confidence intervals

Example study 1: pea protein variable

Conclusions

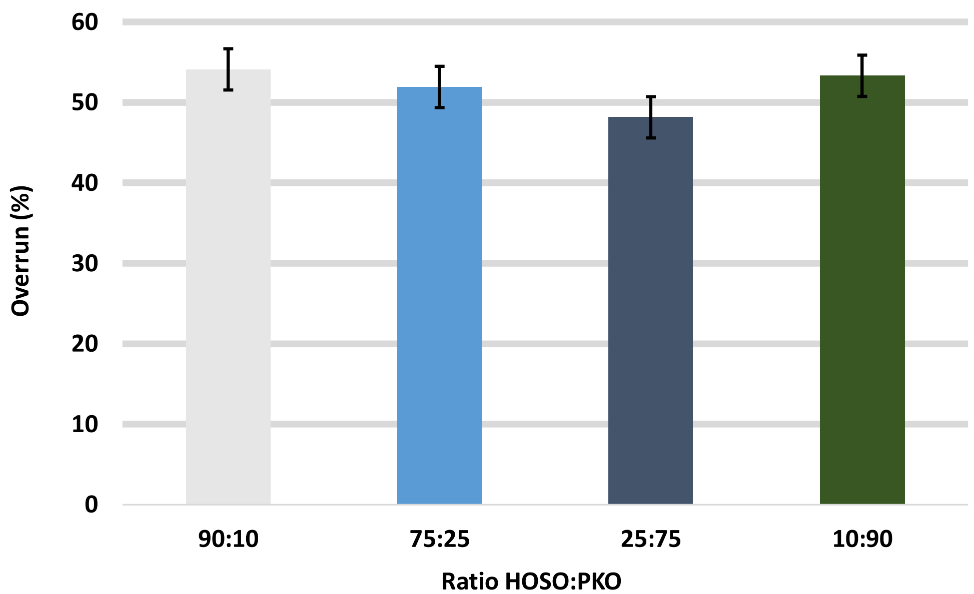
- Protein source & use level appear to impact key product characteristics
- By running defined applications tests, optimal combinations become evident
  - ***Pea #1 @ 2.5% looks best***
- Pre-screening sources for sensory characteristics is advised – helps shorten number of pilot runs.

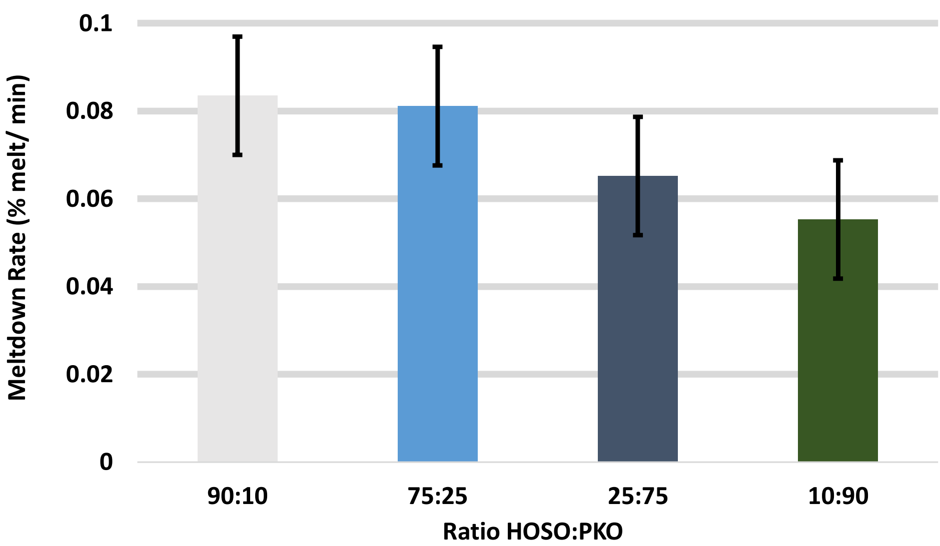
Example Study 2
Solid fat content

- **Objective** –***Evaluate solid/liquid fat ratios to find the optimum for a formula.***
- ***Standardize formulation for:***
  - **36% Total solids**
  - **10% fat**
    - **High-Oleic Sunflower Oil (HOSO) = liquid fat**
    - **Fractionated Palm-Kernel Oil (PKO) = solid fat**
  - **2.5% Pea protein**
  - **Sucrose equivalence @ 22**
  - **Stabilizer: Guar, LBG, Gum Acacia**
- Variables
  - **Blended fats at ratios of HOSO:PKO @ 90:10, 75:25, 25:75, and 10:90**

Example study 2: fat/oil ratio evaluation

Results





Vertical Error bars are 95% Confidence intervals

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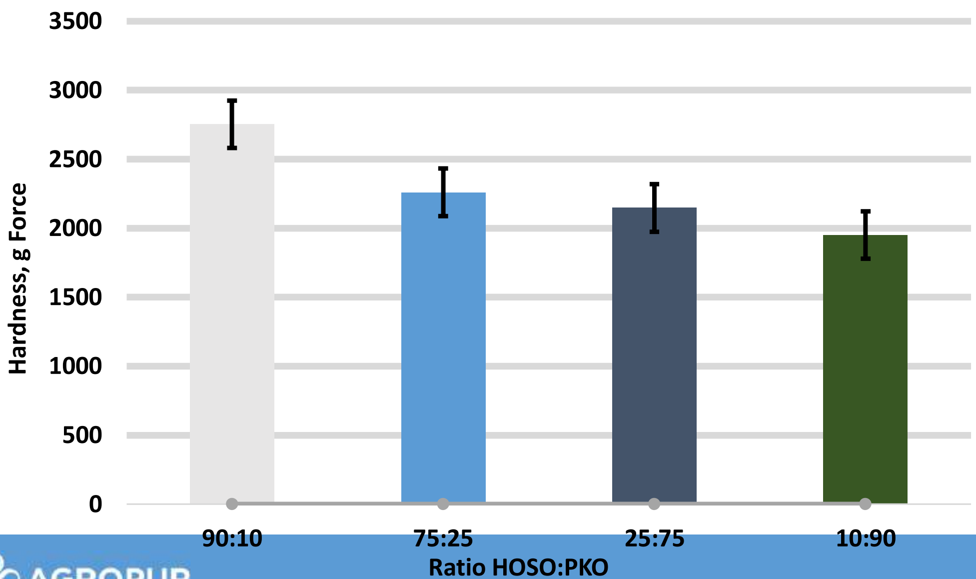
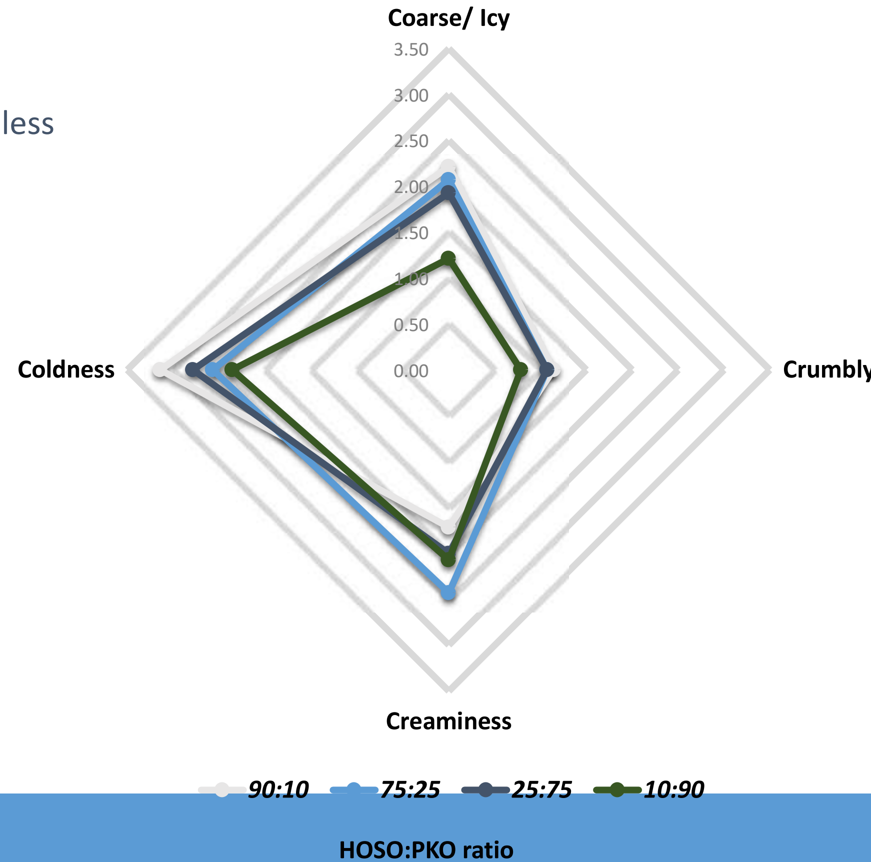
Example study 2: fat/oil ratio evaluation
Results continued

– Trend shows that a higher ratio of solid fat results in a softer product
– Sensory implies that more solid fat may make desserts that are less cold, less icy, and less crumbly.





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Vertical Error bars are 95% Confidence intervals. Sensory results are non-statistical

Example study 2: fat/oil ratio evaluation **Conclusions**

- Decreasing liquid/fat ratios affects texture and eating characteristics
  - Overrun was not significantly changed by oil/fat ratio
  - Firmness and meltdown rate negatively correlated with solid fat ratio
  - Decreased iciness and cold sensation associated with increasing solid fat

Development Tips and Strategies : Plant Based Frozen Desserts

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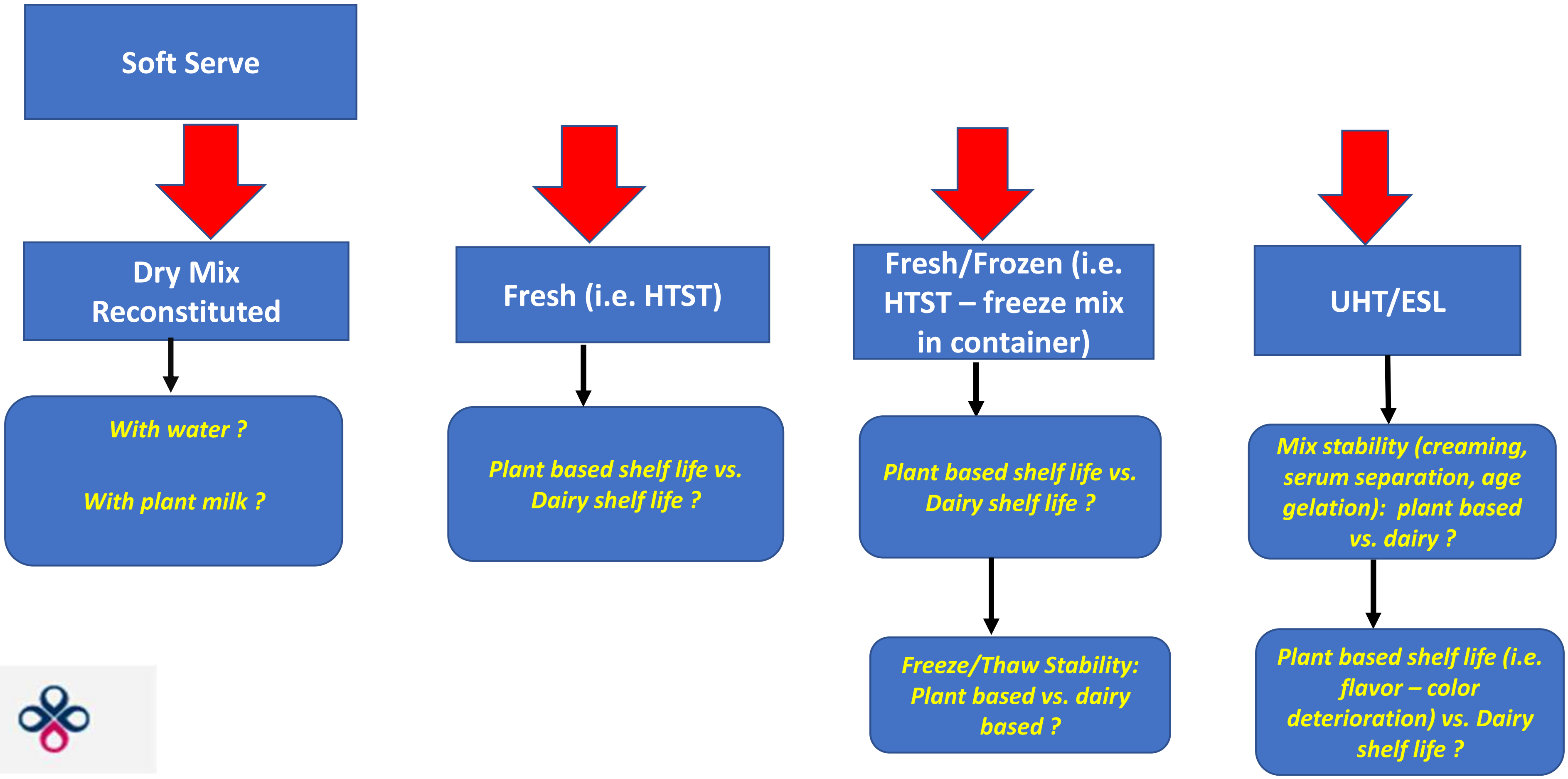
Where to start: establish target audience

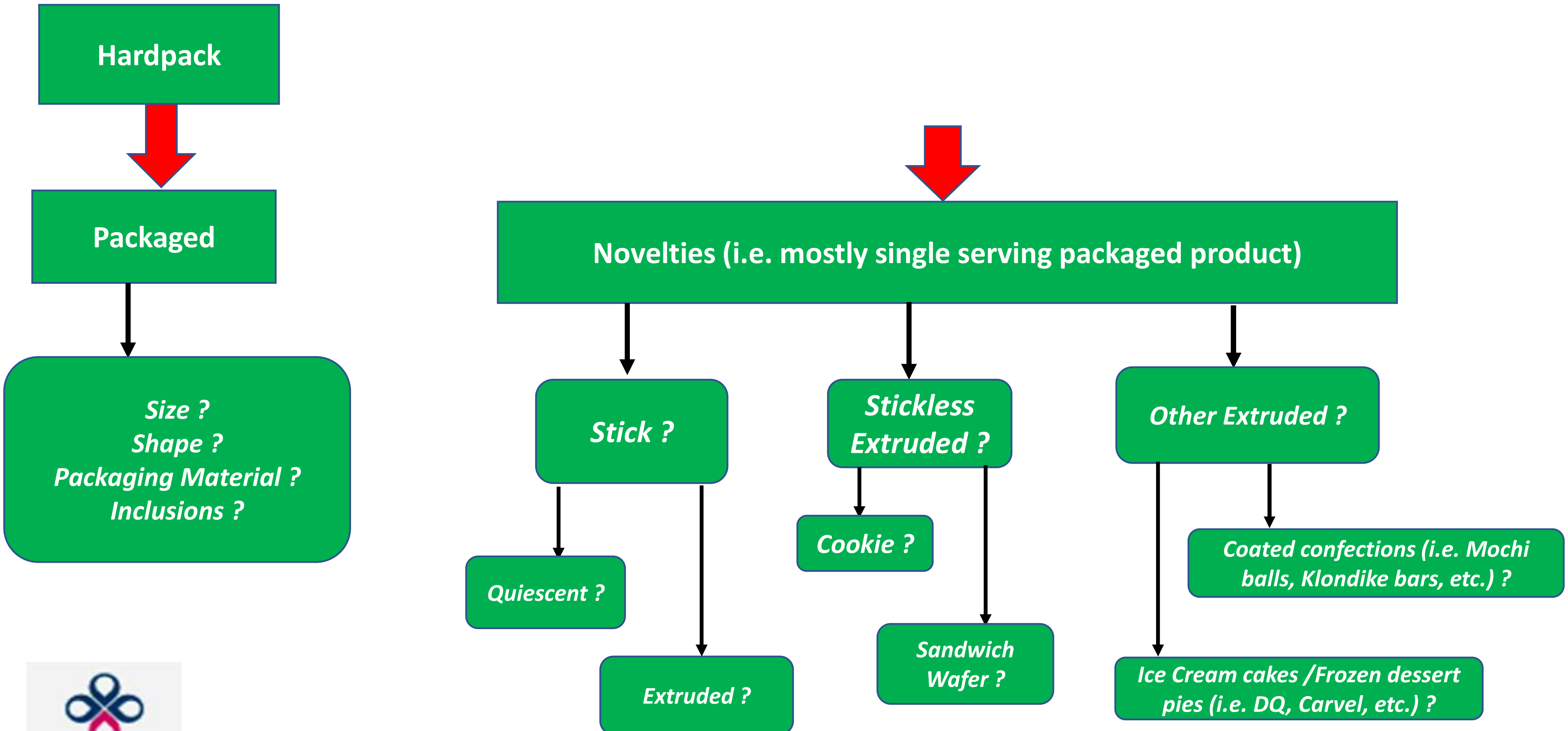
Narrowing the options

PSNF Sources	Clean label/ natural / non-GMO available ?	Good supply ? (multiple vendors)	Bland Flavor?	"Good" emulsification?	Soluble sources available?	Allergen-Free available?
Algal	Y	?	Y	?	Y	Y
Canola	Y	?	?	?	Y	Y
Oat	Y	?	Y	Y	Y	?
Rice	Y	Y	Y	?	?	Y
Pea	Y	Y	?	Y	Y	Y
Soy	?	Y	Y	Y	Y	?
Hemp	Y	Y	?	?	?	Y
Non-Pea Pulses *(Lentil, chickpea, Faba)*	Y	?	?	Y	Y	?

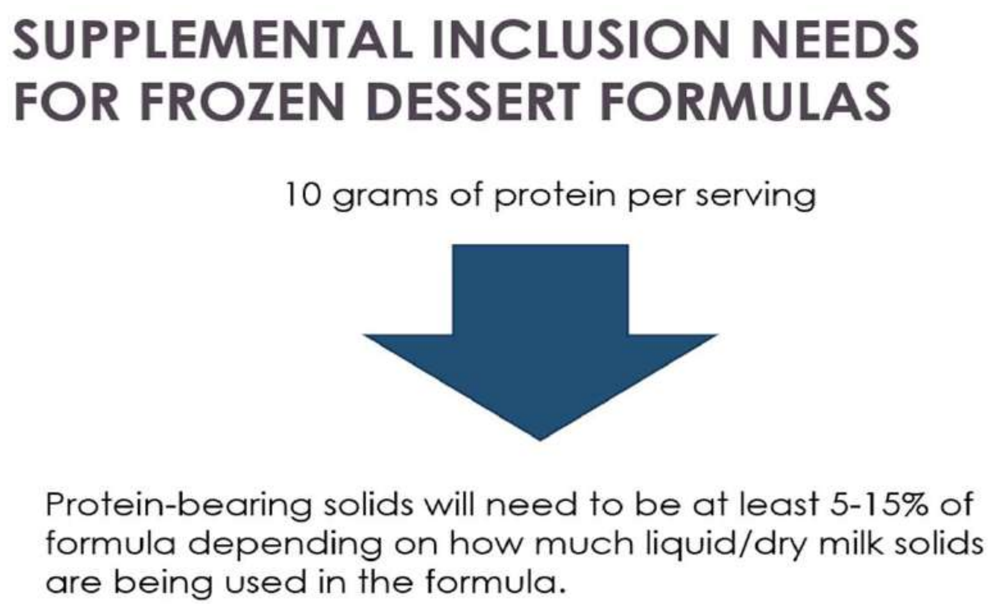
Competitor Comparisons – Parameters to consider when developing a new soft serve product



Competitor Comparisons – Parameters to consider when developing a new hardpack product

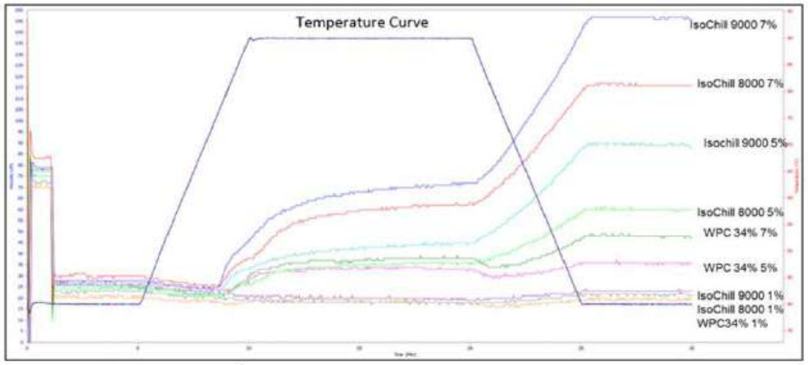


Alternative Product Idea: Potential Flexitarian Formula for process-friendly, cost efficient high protein delivery example:



How do we approach 10% protein in a mix without exploding the viscosity ?

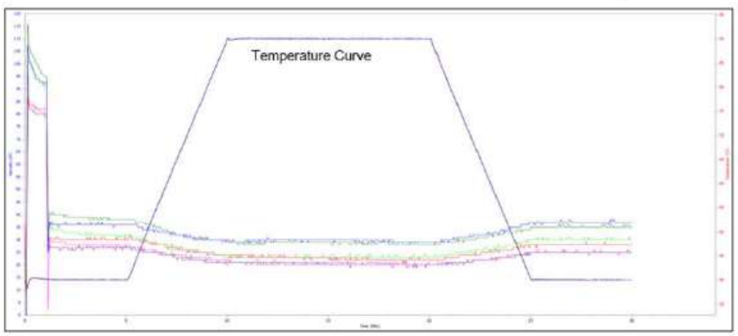
RVA of WPI & WPC



Test	End Viscosity (cP)
Isochill 9000 7%	146
Isochill 8000 7%	116
WPC 34% 7%	47

Temperature Profile – 25 C -> 90 C (10 minutes) -> 40 C

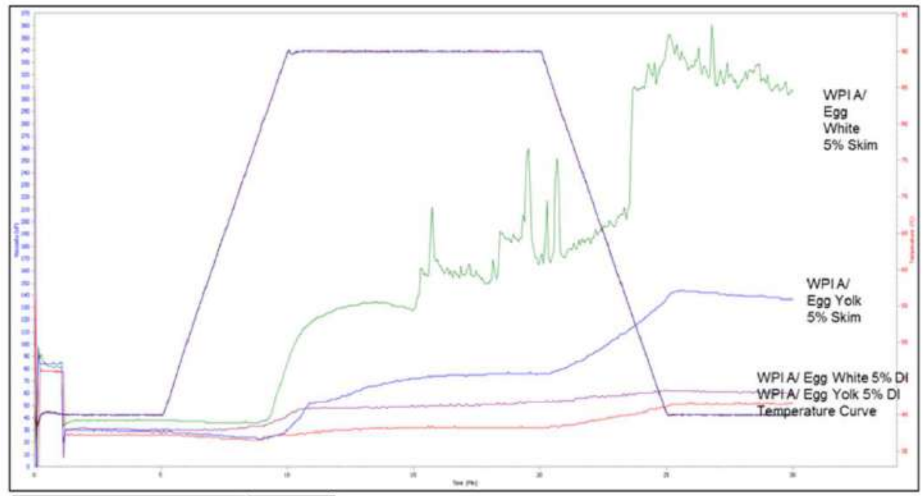
RVA of SOY PROTEIN ISOLATE/MPC



Test	Final Visc
Soy Protein Isolate/MPC 75/25-10%	37
Soy Protein Isolate/MPC 75/25-5%	28

Temperature Profile – 25 C -> 90 C (10 minutes) -> 40 C

RVA OF WHEY PROTEIN ISOLATE WITH EGG SOLIDS



Test	Final Visc
WPI A/Egg White 5% Skim	307
WPI A/Egg White 5% DI	60
WPI A/Egg Yolk 5% Skim	137
WPI A/Egg Yolk 5% DI	52

Temperature Profile – 25 C -> 90 C (10 minutes) -> 40 C

Note: presence of casein with different proteins appears to create more viscosity

Testing Considerations

<u>Factors affecting emulsion stability and suitability for freezing/aeration step:</u>

- ***- oil/fat droplet concentration** (fat level, total solids)*
- ***- water phase viscosity** (amount and type of stabilizer)*
- ***- oil/fat droplet size** (homogenizer pressures and stages)*
- ***- fat density difference with water** (amount and type of emulsifier)*
- ***- solid fat content of the oil/fat used** (preheat temperatures)*
- ***- presence of surface tension reducing/emulsifying ingredients***

Generic Mix Procedure Notes:

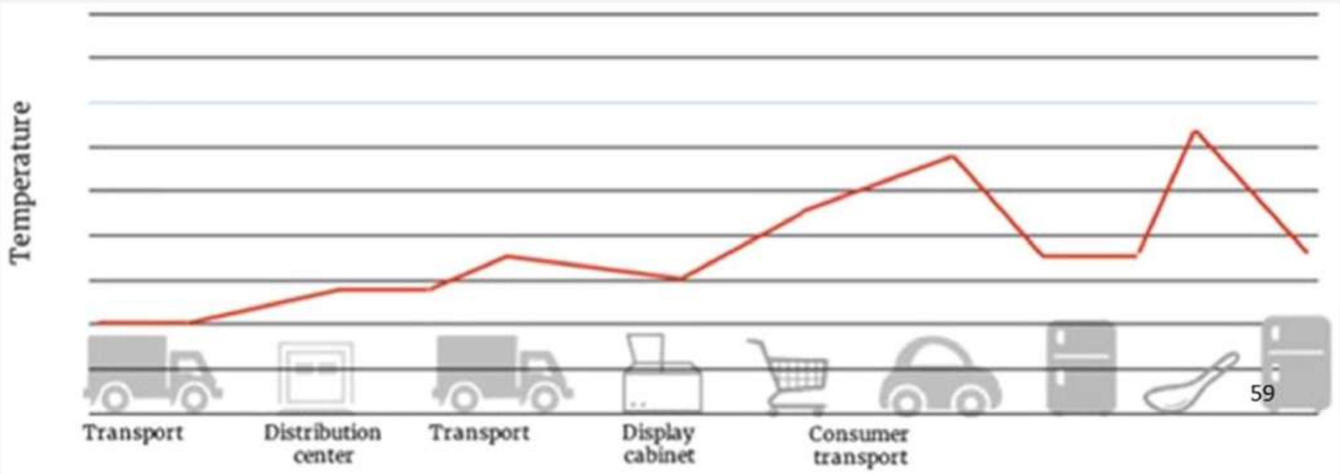
- ***O/W emulsion - moderate refrigerated stability (i.e. susceptible to partial coalescence in freezer)***
- ***Ensure some fat crystallization (i.e. aging) for higher overrun products (i.e. ≥ 50% overrun)***
- ***Plant based – Mixed Source introduces hardfats (i.e. raw mix preheating) and liquid oils that are mostly unemulsified (i.e. homogenization changes).***
- ***Many small batches for screening purposes***

Agropur Pilot Plant Pasteurizer/Homogenizer

Agropur Pilot Plant Freezer

Helpful Tip: If it is pinholing out of the freezer, reformulate

Accelerated shelf life testing (heat shock)



- ***Identify best and worst case scenarios for storage and distribution to set parameters for accelerated shelf life testing.***
- ***Generally follow up accelerated testing with sensory analysis. Check for defects such as excess shrinkage, iciness, and gumminess.***

Some typical accelerated heat shock methods:

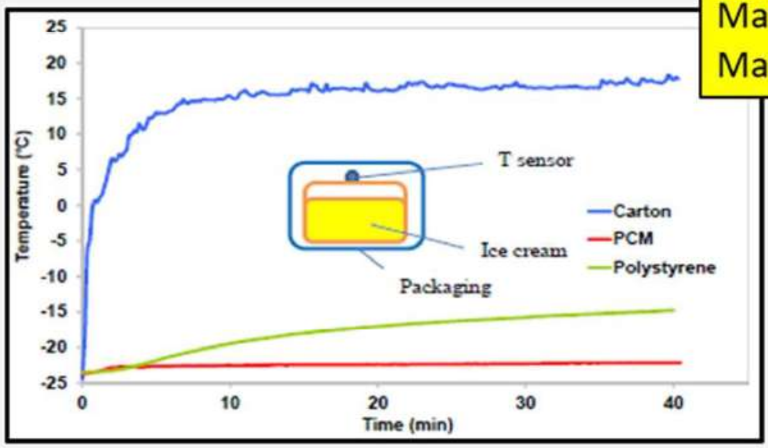
- *Programmable freezer cycles - 0°F to 20°F two times in 24 hours*
- *5 days - 10-20 minute daily exposure - room temperature (22-25°C)*
- *12 cycles of 0°F- 20°F for 10 days*

Potential possibilities are endless. There is no standard method.

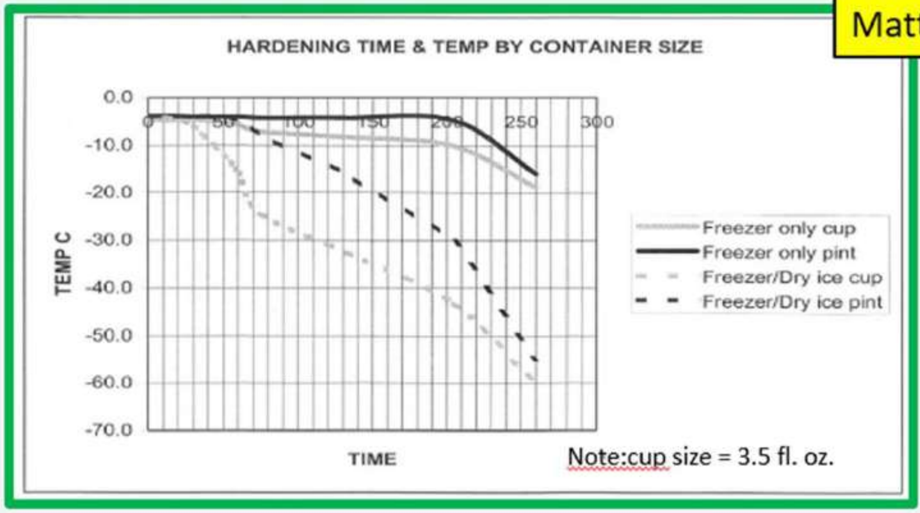
Additional Considerations for Shelf Life Testing

MicroClimate® 3 Compact Environmental Chambers

Package Material Matters



Size Matters



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Possible Ingredient Sources at Agropur Ingredients:

- **Cornerstone®** –functional plant, dairy, and animal proteins
- **Keystone®** – hydrocolloids and emulsifying ingredients
- **Darigen®** – Custom, complete formula bases
- **ISO Chill®** – low-temperature microfiltered whey protein isolate & concentrates
- **BiPRO®** – ion exchange whey protein isolates

COR DAR

BiPRO KEY

ISO Chill

SUPERIOR INGREDIENTS.
INNOVATIVE SOLUTIONS.

Slide 62

PR1 Phil Rakes, 10/7/2020


Better Dairy.
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