A New Era for Protein:

Why U.S. Dairy Delivers in the Crowded Protein Marketplace

Consumers are asking for more information about where their food comes from and how it's made so they can feel good about what they are consuming. As of 2017, 40% of U.S. consumers were looking to foods and beverages to help manage their health holistically.[1] Seventy-eight percent of U.S. consumers also believe that protein contributes to a healthy diet and half of them indicated they want more of it in their diets.[2] Meanwhile, the global population is estimated to grow to over 9.8 billion by 2050 which creates future supply security concerns and the need for sustainable protein ingredients.[3] Rising consumer demand for protein has spurred action by multinational food companies looking to diversify protein sourcing. Additional identification, isolation and characterization of proteins from a variety of sources is resulting in over 300 patent filings on protein functionality and food applications between 2012 and 2017.[4]

Many types of animal, plant and single cell proteins are being marketed for use in foods and beverages. With so many choices, food formulators need to be well informed when formulating food and beverage solutions. Choosing the right protein ingredient is imperative to delivering the consistent appearance, taste, functionality and nutritional attributes that consumers want. All proteins are not created equal. This report will discuss how whey and milk protein ingredients uniquely address formulator needs for sustainably produced, nutritious, functional, tasteful, versatile, consumer appealing, securely sourced ingredients for use in food and beverage products.

DID YOU KNOW

The cow's unique contribution to our global food system delivers vital nutrients to humans while efficiently using inedible feeds and replenishing the soil with fertilizer. Here are the key takeaways from each section of the report:

Sustainably Produced – Through unparalleled cow care and management, the U.S. leads the world in dairy productivity which reduces the carbon footprint while advancing sustainability initiatives.

Processing – Because dairy proteins are naturally soluble in water, they require fewer steps in processing versus other plant/nut-based sources.

Nutrition – Proteins naturally found in milk are unmatched in protein quality and offer benefits across life stages:

- Reducing stunting in vulnerable populations
- Delivering critical nutrition for infant and maternal health
- Supporting weight management
- Enhancing post-exercise recovery
- Assisting in muscle maintenance for healthy aging

Functionality/Sensory – No other protein can provide this breadth of functionality while ensuring a simple ingredient list and neutral flavor profile that consumers desire.

Usage Versatility – There is a dairy ingredient suitable for almost any application.

Supply Security – Year-round U.S. production and rigorous quality assurance supports steady delivery of quality U.S. dairy ingredients.

SUSTAINABLY PRODUCED: COMMITMENT OF U.S. DAIRY FARMERS

For years, U.S. farmers have been using technology and advanced management practices to increase efficiency and reduce their environmental impact. According to the U.S. Environmental Protection Agency (EPA), by 2030, total U.S. livestock production (all animals, both meat and dairy) will account for 14% of greenhouse gas emissions (GHG) as compared to energy production at 31%, transportation at 27% and croplands at 13%.[5]

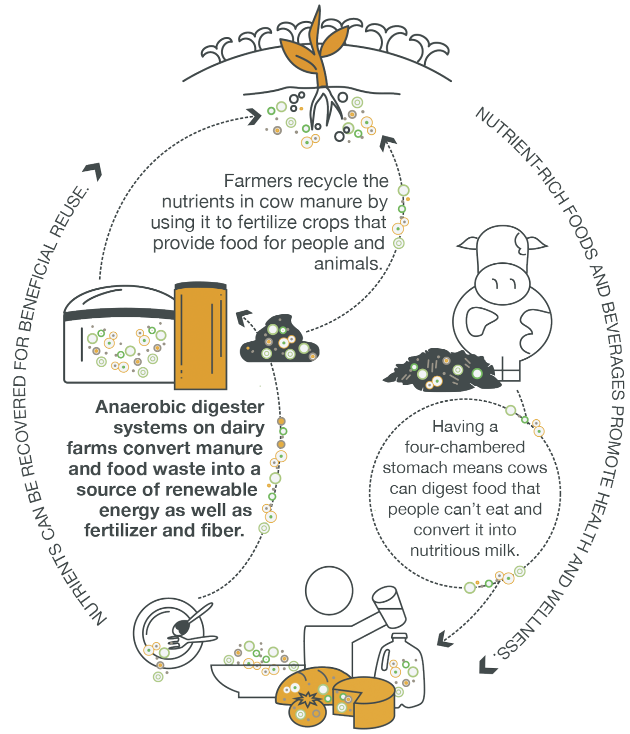
In 2008, U.S. dairy farmers formed the Innovation Center for U.S. Dairy to assess, manage and continuously improve the environmental, social and economic sustainability of U.S. Dairy from farm to table. As a result, life cycle assessments (LCA) were completed to understand environmental impacts of dairy production, processing and transportation. Today, the U.S. dairy industry contributes to only 2% of GHG, 5% of water usage and 9% of land usage.[6] For example, advancements in farming and management practices from 1950 to 2017 have enabled dairy farmers to produce 60% more milk while milking 16 million fewer cows, which accounts for a 66% smaller carbon footprint.[7] Ongoing research will continue to identify new technologies and practices to further reduce these impacts.

U.S. dairy farmers house and feed their cows in harmony with the weather conditions and their regional resources.[8] Over 97% of U.S. dairy farms are family-owned businesses that are often passed down through multiple generations. U.S. dairy farmers work year-round to ensure cow comfort by providing a healthy balanced diet, shelter, fans, water misters, sand/water bedding, etc., to optimize cow comfort because well-tended cows produce more milk, more efficiently.

The dairy cow is a recycler of nutrients. About 80% of what a cow eats cannot be eaten by people—people simply can't digest it. Some examples are cottonseed hulls, citrus pulp and almond shells. It's a win/win—the cows eat the entire corn stalk, the humans eat the corn on the cob, the cow eats the almond hull, the human eats the almond, the cow eats the cottonseed hull, the human wears the T-shirt potentially decreasing the amount of waste going to landfills. Plus, the human benefits from the great nutrition the cow unlocks and turns into nutrient-rich milk via it's unique four-chambered stomach. Although approximately 20% of the cow's diet is made up of what a human could eat (components digestible by humans), only around 2% is made up of what humans would eat (based upon food industry demand or desirable consumption).[9]

To complete the sustainability cycle, the cow produces nutrient-rich manure to be applied back into the soil to keep it fertile for future use. Each day, one U.S. dairy cow produces 64 liters (17 gallons) of manure. That's enough fertilizer to grow 20 kilograms (46 pounds) of corn based upon an average soil content and a lactating dairy cow in Illinois.[10]

FIGURE 1: DAIRY'S CONTRIBUTION TO SUSTAINABILITY



Source: U.S. Dairy Sustainability Commitment. USdairy.com: 2014

PROCESSING: THE ADVANTAGES IN HOW PROTEINS ARE DERIVED FROM MILK

Due to the perishable nature of milk, the conversion of milk into dairy products and ingredients occurs shortly after milking in nearby facilities. Unlike many alternative protein sources, dairy proteins are separated from a soluble liquid and do not require additional milling or chemical additions to keep them in solution. Fewer processing steps and less transportation allows the U.S. dairy industry to consistently deliver safe, high-quality, accessible, nutritious dairy ingredients for use in foods and beverages.

Milk proteins are comprised of a combination of 80% casein and 20% whey protein. Water is used to gently filter the protein, fat and carbohydrate components through membranes based upon their physical size. After separation, the protein components can be concentrated and dried into higher protein ingredients with different ratios of casein and whey protein, such as micellar casein concentrate (MCC), milk protein isolate (MPI), milk protein concentrate (MPC) or milk whey protein (native whey) which have unique functional attributes.[11,12] Whey protein derived from cheesemaking can also be filtered and concentrated into whey protein isolate (WPI) or whey protein concentrate (WPC).[13]

FIGURE 2: PROTEINS DERIVED FROM MILK

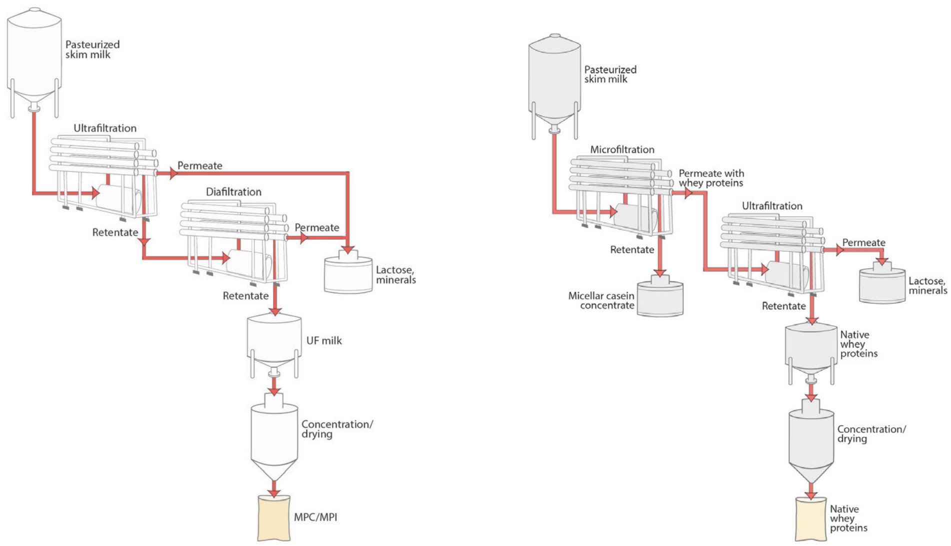
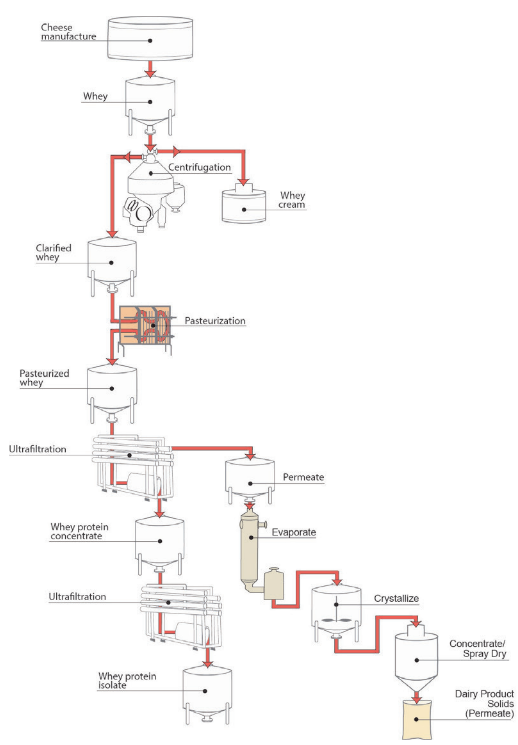


FIGURE 3: PROTEINS DERIVED FROM CHEESE



Source: Smith K. 2017. Dried Dairy Ingredients, 2nd Edition. Wisconsin Center for Dairy Research.

Since this type of filtration uses water and membranes, much of the water removed from the milk can be filtered and recycled for cleaning or further purified for release back into the environment as drinkable water.

NUTRITION: PROTEIN QUALITY MATTERS

Cow's milk has had a long history in nourishing human lives. Since the 1600s, early immigrants to the United States brought cattle with them from Europe to supply milk and meat to sustain their families.[14] By 2016, cow's milk and milk products became the third largest provider of protein and the fifth largest provider of calories, while nourishing over 6 billion people around the world.[15]

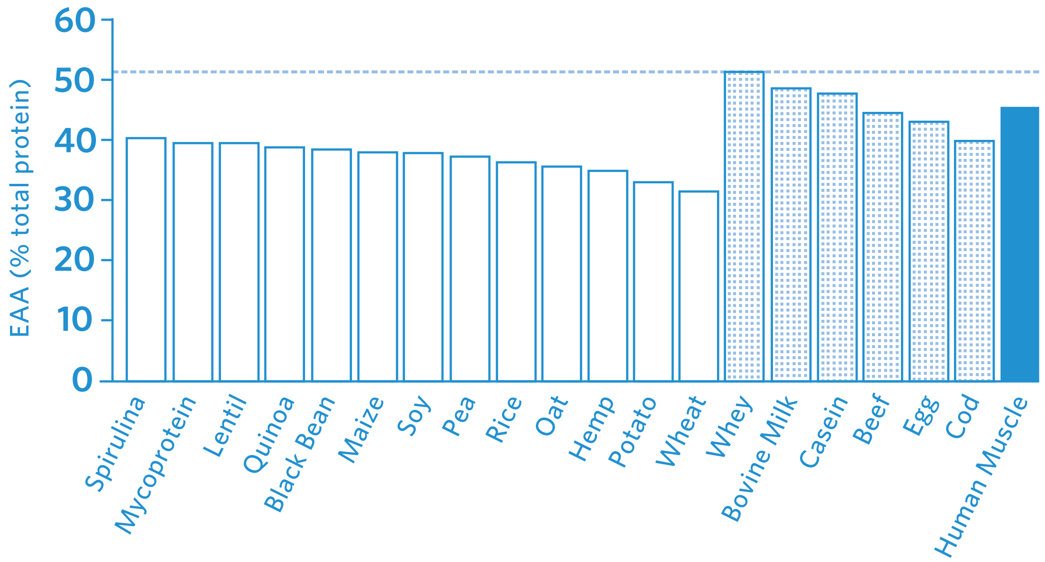
Protein quality is a key consideration when selecting high-protein containing ingredients. Protein plays an integral role in the body's structure, function and regulation of tissues and organs. The body can make the protein it needs only if all the essential amino acids are available from the food that is consumed. While all animal-based and most plant-based foods contain some amount of protein, not all proteins are created equal as they can differ in the amount of essential amino acids they provide, and in their digestibility and bioavailability. The amount required to maximize muscle protein synthesis may vary depending on the individual person and the type (quality) of protein consumed. High-quality protein is defined as a protein that contains all the essential (indispensable) amino acids in the ratios needed by the body while maintaining bioavailability and rapid digestability.[16] Dairy proteins meet these requirements.

TABLE 1: ESSENTIAL AND NONESSENTIAL AMINO ACIDS

Essential	Conditionally Essential	Nonessential
Histidine	Arginine	Alanine
Isoleucine	Cysteine	Aspartic acid
Leucine	Glutamine	Asparagine
Lysine	Glycine	Glutamine acid
Methionine	Proline	Serine
Phenylalanine	Tyrosine	
Threonine		
Tryptophan		
Valine		

Source: Institute of Medicine. 2006. Dietary Reference Intakes: The Essential Guide to Nutrient Requirements.

TABLE 2: ESSENTIAL AMINO ACIDS (EAAs) AS A PERCENT OF TOTAL PROTEIN



Source: van Vilet, S., Burd, N.A. and van Loon, L.JC. 2015. The skeletal muscle anabolic response to plant- versus animal-based protein consumption. J Nutr.

Sources of protein vary in the amount of essential amino acids they contain. Animal sources tend to be higher in essential amino acids as a percentage of total protein compared to plant-based sources with dairy proteins having the highest levels.[17] Scientific evidence shows that the health benefits of higher protein diets seem to be greater if the protein(s) consumed are high-quality, complete proteins.[18,28] The current measure of protein quality in the United States is the Protein Digestibility Corrected Amino Acid Score (PDCAAS).[19]

Proteins differ in their quality based on amino acid (AA) content, digestibility and bioavailability. Animal proteins are high-quality, complete proteins since they contain all the essential AAs. Except for soy protein, plant proteins are typically lower quality and incomplete due to deficiencies in essential AAs in sufficient quantities required by the body. Proteins from cow's milk (whey, casein) have the highest protein quality score, which is 1.0.

TABLE 3: PDCAAS OF COMMON PROTEIN FOODS

Source	PDCAAS
Milk	1.00
Whey	1.00
Egg	1.00
Soy protein isolate	1.00
Casein	1.00
Beef	0.92
Soy	0.91
Pea	0.67
Oat	0.57
Whole wheat	0.45

Source: van Vilet, S., Burd, N.A. and van Loon, L.JC. 2015. The skeletal muscle anabolic response to plant- versus animal-based protein consumption. J Nutr.

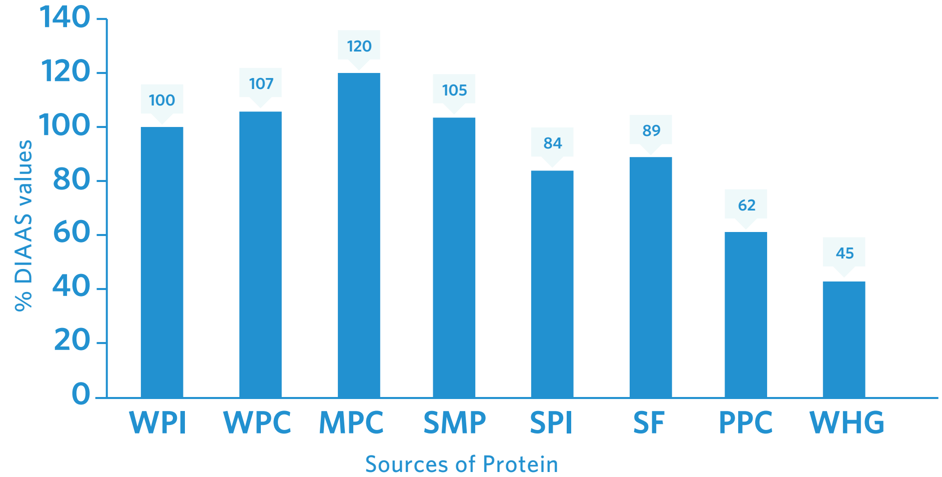
Despite it being the current gold standard method recognized by international authorities such as the The Food and Agriculture Organization of the United Nations (FAO), the PDCAAS is not without limitations. First, values are calculated from the total tract digestibility (fecal digestibility) of crude protein. However, the digestibility of AAs is most correctly determined at the end of the small intestine (ileum) as AAs are only absorbed from the small intestine and hindgut fermentation can affect fecal AAs excretion. Second, the digestibility of crude protein is not representative of the digestibility of all AAs because individual AAs are digested with different efficiencies. Third, scores are truncated at 1.0. Some proteins, particularly the dairy proteins, have non-truncated scores higher than 1, thereby eliminating the possibility of distinguishing the relative high value of high-quality proteins. Fourth, food processing which can sometimes reduce the bioavailability of AAs, is not accounted for. Collectively, these limitations contribute to PDCAAS generally underestimating the value of high-quality proteins and overestimating the value of low-quality proteins.[19,20,21]

Given these limitations in PDCAAS, the FAO convened a panel of experts to address the issue. Their recommendation was to replace PDCAAS with a new method of protein quality scoring called DIAAS or Digestible Indispensable Amino Acid Score (DIAAS).[22] This method would account for some of the noted limitations in the PDCAAS method, including calculating protein quality from true ileal (small intestine) digestibility of AAs (not crude protein scores calculating over the entire intestinal tract), correcting the variations in protein quality due to food processing, and disbanding truncation of scores at 1.0. Additional studies are required to understand the quality of newer alternative protein sources.

DIFFERENCES BETWEEN PDCAAS AND DIAAS NUTRITIONAL SCORING	Protein Digestibility Corrected Amino Acid Score (PDCAAS)	Digestible Indispensable Amino Acid Score (DIAAS)
	Based upon fecal digestibility	Based upon ileal amino acid digestibility which is favorable compared to fecal digestibility as amino acids are only absorbed from the small intestine, and hindgut fermentation via microbiota can affect fecal amino acid excretion
	Based upon the digestibility of crude protein which does not account for the face the individual amino acids are digested with different efficiencies	Based upon individual amino acid digestibility which accounts for differences in digestibility of individual amino acids
	Truncation of scores at 1	No truncation of scores
	Does not allow for distinguishing the relative value of high-quality proteins (non-truncated scores >1.0)	Allows for distinguishing the relative value of high-quality proteins (scores greater than 1.0) thereby giving credit to a protein based on its value as a complementary source of amino acids with other sources of proteins in a mixed diet
	Influence of food processing which may impact bioavailability to specific amino acids is not accounted for	Includes a scoring modification for food processing
	Use of the amino acid requirements of the 1- to 2-year-old child to estimate PDCAAS values for all humans	Utilizes amino acid scoring patterns (requirements) for multiple age groups

Source: Mathai, JK, et al., Br J Nutr 2017 and Rutherfurd, SM, et al., J Nutr 2015.

TABLE 4: QUALITY OF COMMON PROTEIN SOURCES EXPRESSED AS PERCENT DIGESTIBLE INDISPENSABLE AMINO ACID SCORE (DIAAS)

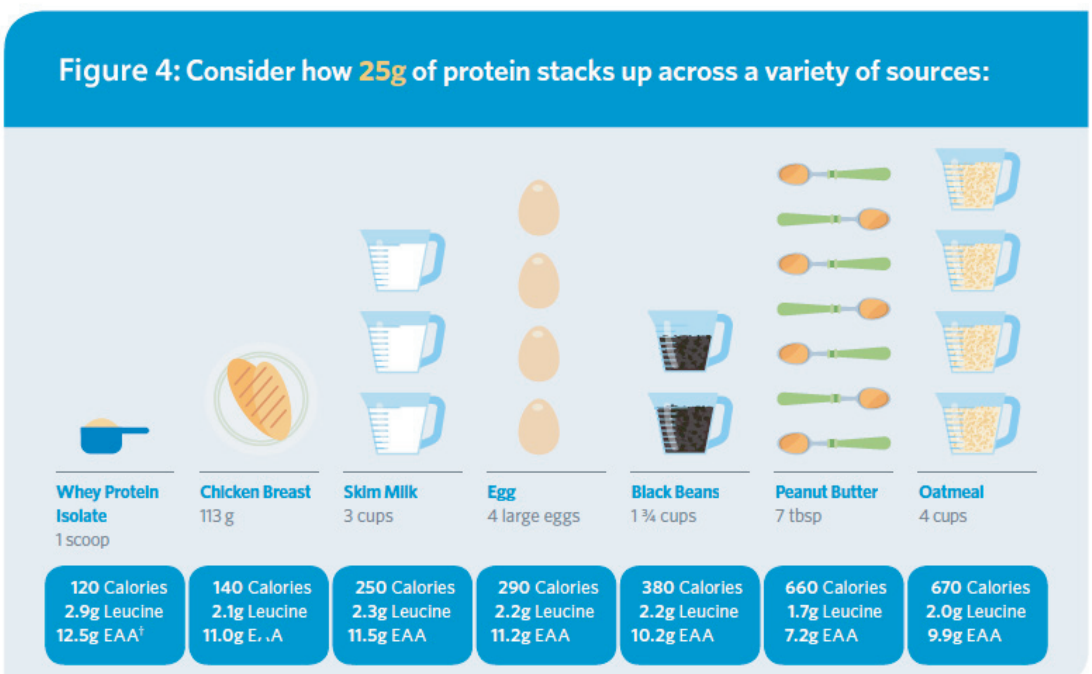


Key: WPI=whey protein isolate; WPC=whey protein concentrate; MPC=milk protein concentrate; SMP=skim milk powder; SPI=soy protein isolate; PPI=pea protein isolate; WHG: whole-grain wheat.

Source: Mathai JK, Liu Y, Stein HH. Brit J Nutr. 2017.

HOW THE HUMAN BODY USES PROTEIN

Upon consumption, the human body digests protein into AAs for further absorption and use. While essential amino acids (EAAs) are critical to the support of muscle protein synthesis (MPS) to build, grow and repair body tissues, branched chain amino acids (BCAAs), leucine, isoleucine and valine have a particularly important role in muscle metabolism. Leucine has been shown to be the key AA stimulating the initiation of MPS. Animal-based protein sources generally contain more leucine than do plant-based proteins. Most plant-based proteins have a leucine content of 6-8%, whereas animal-based protein sources tend to have a leucine content in the range of 8.5-9% and >10% in the case of dairy proteins.[17] Therefore, protein sources that have a high concentration of EAAs, BCAAs and leucine are preferred when looking to optimize (or maximize) MPS to maintain strength and performance.[23,28]



Source: Whey Protein Isolate Nutrition Panel. Available at http://www.gnc.com/whey-protein/GNCProPerfornace100WheyIsolate.html.

USDA National Nutrient Database for Standard Reference, Release 28. 2016. Available at https://ndb.nal.usda.gov/ndb/.

THE DOUBLE BURDEN OF MALNUTRITION

Globally, there are growing concerns over how undernutrition and overnutrition impact humans throughout their life stages. In 2017, over 815 million people went to bed hungry.[24] According to UNICEF, 156 million children under the age of five are stunted (low height-for-age) and 52 million are wasted (low weight-for-height).[25] Additionally, over 462 million adults are under weight and more than 1.9 billion adults are overweight or obese.[26] Since dairy proteins are high-quality proteins, their use in products designed for these population segments may be beneficial as suggested by different published studies. For instance, researchers evaluated the results of six clinical studies with children six months and older to examine the relationship between protein quality, linear growth and the prevention of stunting. Researchers concluded that particularly in malnourished children, dairy proteins were associated with higher growth.[27]

In adults, skeletal muscle mass is the product of continuous and simultaneous processes of MPS and muscle protein breakdown (MPB). The net balance between these two processes determines whether muscle mass increases (positive protein balance), decreases (negative protein balance) or remains constant. The ratio of MPS and MPB may be influenced by several factors including energy deficit, resistance training and aging. Following the consumption of a protein-containing meal, short-term periods of hyperaminoacidemia stimulates MPS and hyperinsulinemia inhibits MPB resulting in a net positive protein balance. The differential MPS response to protein feeding is a function of the quality of the ingested protein.

Scientific evidence indicates that dairy proteins, specifically whey protein, may stimulate the greatest rise in MPS when combined with resistance exercise, thereby optimizing body composition compared to other non-meat protein sources.[23,28] Optimizing muscle mass across the lifespan is crucial to maximizing overall health as the body ages. An additional meta-analysis across 14 clinical trials indicated that the body of evidence supports the use of whey protein supplementation combined with resistance exercise or as part of a weight loss or weight maintenance diet, to improve body composition.[29]

TABLE 5: AMOUNT OF DIETARY PROTEIN TO THEORETICALLY MAXIMIZE POSTPRANDIAL (AFTER A MEAL) MUSCLE PROTEIN SYNTHESIS

Source	Leucine, % total protein	Representative amount of protein to be ingested per meal for ~3g leucine, g	Representative amount of food source to be ingested per meal, g
Maize	12.3	25	264
Spirulina	8.5	36	63
Black bean	8.4	36	167
Rice	8.2	37	500
Soy	8.0	38	104
Lentil	7.9	39	150
Pea	7.8	39	180
Oat	7.7	35	236
Quinoa	7.2	43	302
Hemp	6.9	45	121
Wheat	6.8	45	299
Mycoprotein	6.2	49	447
Potato	5.2	58	2891
Animal source			
Whey	13.6	23	27
Milk	10.9	28	876
Casein	10.2	30	35
Beef	8.8	35	164
Egg	8.5	36	5
Cod	8.1	38	211

Amount of protein source to be ingested to maximize postexercise MPS rates in response to feeding in young subjects. Data are ranked from high to low by leucine content. A higher leucine content suggests that a lower amount of dietary protein from a given source is needed to maximize postprandial MPS rates. The third column (amount of protein to be ingested per meal) represents a theoretical value using whey protein as a standard of reference. The amounts of protein calculated represent the amount needed to match the leucine content found in 23g whey protein (~3g). The representative amounts for whey and casein assume isolated protein sources, whereas all other protein sources are expressed as representative amounts of the intact food source. MPS, muscle protein synthesis. Number of eggs

Source: van Vilet, S., Burd, N.A. and van Loon, L.JC. 2015. The skeletal muscle anabolic response to plant- versus animal-based protein consumption. J Nutr.

As the number of adults aged 60 years and older rises globally from 962 million in 2017 to an estimated 2.1 billion in 2050, the loss of muscle mass associated with aging, known as sarcopenia, may negatively impact the ability for these individuals to perform daily activities.[30] Data from the U.S. National Health and Nutrition Examination Survey (NHANES) has shown that older adults are not consuming adequate amounts of protein, and intakes may be skewed toward the evening meal which can also predispose older adults to energy-protein undernutrition.[31] Consuming protein-containing meals can stimulate MPS; however, older adults are less sensitive to the stimulatory effects of protein on MPS.[32] Higher intakes of high-quality proteins have been shown to preserve muscle mass in older adults.[28] Higher intake of animal-protein foods, alone and especially in combination with physically active lifestyles, has also been associated with preservation of muscle mass and functional performance in older adults.[33]

Some plant-based materials (e.g., soybeans, pea and rice) contain antinutritional factors that require additional processing for removal. This processing may impact the digestibility and availability of leucine as compared to whey protein.[17] As a result, higher amounts of plant proteins may need to be consumed to achieve the same clinical results.[17,34]

FUNCTIONALITY: PERFORMANCE OPTIMIZING PROPERTIES

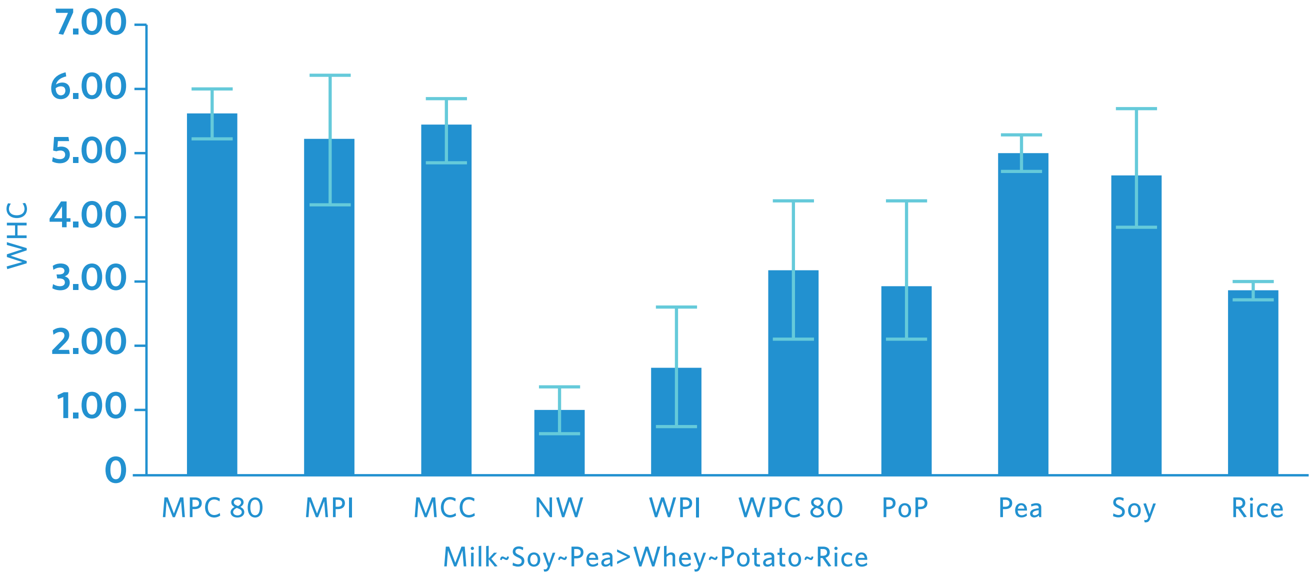
Ingredient selection impacts sensory and functional properties which contributes greatly to product enjoyment. A 2017 study[35] was conducted to characterize, compare and contrast functional and sensory attributes across a variety of commercially available dairy and plant protein sources. A total of 30 commercial protein ingredient samples of MPI, MPC 80%, MCC, milk whey protein (native whey), WPI, WPC 80%, potato protein ranging from 77-89%, pea protein ranging from 70-76%, soy protein ranging from 80-90% and rice protein 83% were evaluated.

Physical appearance, pH (ranging from 5-7), viscosity, emulsion stability, gelation and foaming of proteins varied across milk, whey and plant sources. However, the most interesting differences were in water holding capacity and heat stability.

WATER HOLDING CAPACITY

Water holding capacity (WHC) is the ability of an ingredient to absorb and maintain water or moisture. WHC is a key consideration for beverage, bakery, formed meat, sauce, soup, gravy and frozen dessert applications where the formulator does not want water separation in the finished product.

TABLE 6: WATER HOLDING CAPACITY



Methodology: Neumann et al., 1984.

Key: Milk Protein Isolate=MPI, Milk Protein Concentrate=MPC 80, Micellar Casein Concentrate=MCC, Milk Whey Protein/Native Whey=NW, Whey Protein Isolate=WPI, Whey Protein Concentrate=WPC 80, Potato Protein=PoP, Pea Protein=Pea, Soy Protein=Soy, Rice Protein=Rice

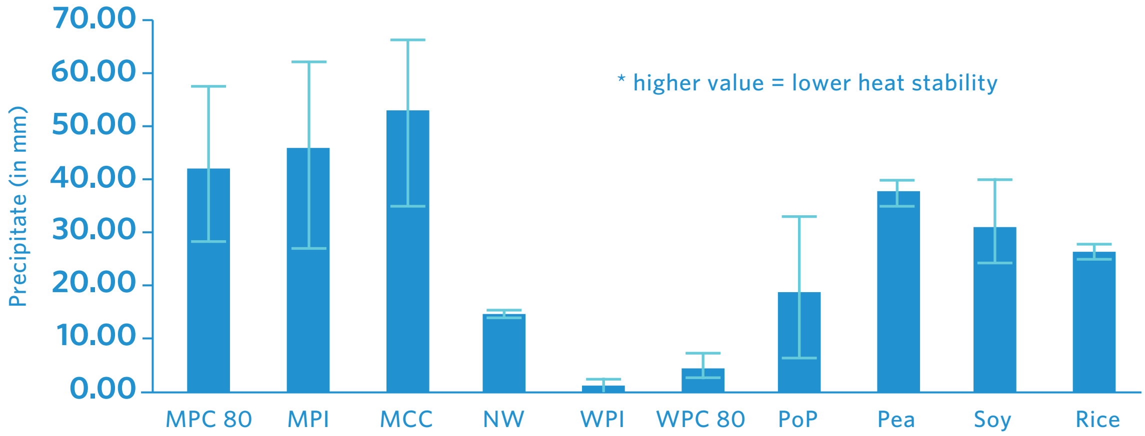
Source: Kapoor, R., Burrington, K.J., Jiang, H., Larson, S., Drake, M.A. 2017. Characterization of functional and sensory properties of select commercial food protein ingredients. 2017 International Whey Conference, Chicago.

Milk, soy and pea proteins exhibited significantly higher WHCs ($p<0.05$) than whey, potato or rice proteins. However, pH and thermal processing prior to packaging may impact the protein's performance in the finished product. These characteristics are especially important when processing ready-to-drink beverages.

HEAT STABILITY

There are four basic types of thermal pasteurization: aseptic, retort, tunnel pasteurization and hot-fill. Aseptic and retort are high-heat treatments with products typically processed at a neutral pH between 4.6 and 7.5. Tunnel pasteurization and hot-fill processing take place at lower temperatures, so product must be held at acidic pH conditions between 2.8 and 4.5 to control pathogen growth.[36] Understanding how proteins function under these different conditions is important for determining which ingredient to use.

TABLE 7: HEAT STABILITY AT pH 3



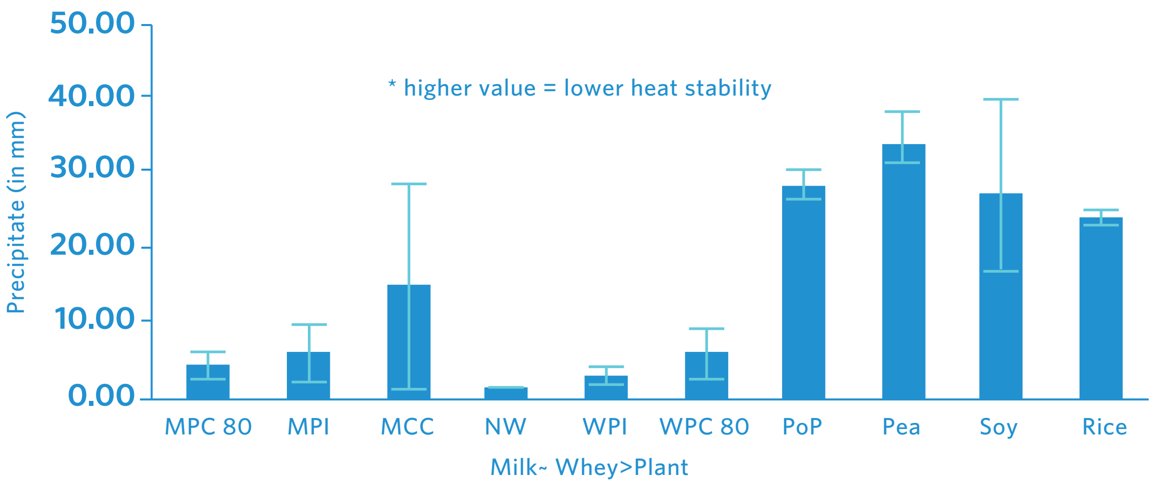
Methodology: Harper and Lee, 1988.

Key: Milk Protein Concentrate=MPC 80, Milk Protein Isolate=MPI, Micellar Casein Concentrate=MCC, Milk Whey Protein/Native Whey=NW, Whey Protein Isolate=WPI, Whey Protein Concentrate=WPC 80, Potato Protein=PoP, Pea Protein=Pea, Soy Protein=Soy, Rice Protein=Rice

Source: Kapoor, R., Burrington, K.J., Jiang, H., Larson, S., Drake, M.A. 2017. Characterization of functional and sensory properties of select commercial food protein ingredients. 2017 International Whey Conference, Chicago.

At pH 3, (See Table 7) whey proteins perform significantly better ($p<0.05$) than plant or milk proteins which means they would be well suited for high acid (low pH) processing conditions.[35] Additionally, WPI solutions remained clear at pH 3 which makes this ingredient ideal for clear, ready-to-drink applications.

TABLE 8: HEAT STABILITY AT pH 7



Methodology: Harper and Lee, 1988.

Key: Milk Protein Isolate=MPI, Milk Protein Concentrate=MPC 80, Micellar Casein Concentrate=MCC, Milk Whey Protein/Native Whey=NW, Whey Protein Isolate=WPI, Whey Protein Concentrate=WPC 80, Potato Protein=PoP, Pea Protein=Pea, Soy Protein=Soy, Rice Protein=Rice

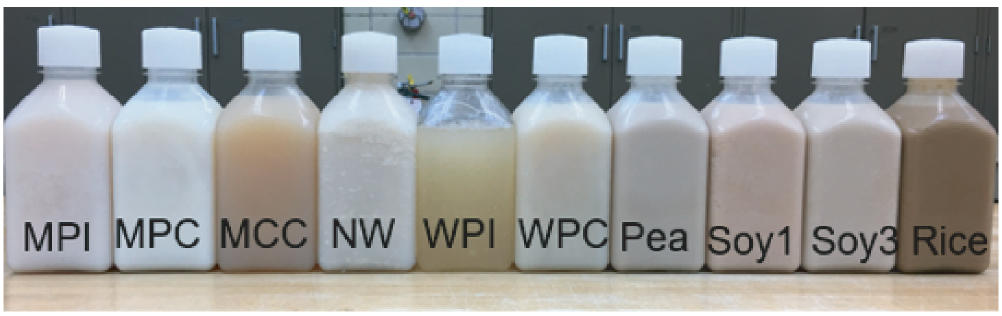
Source: Kapoor, R., Burrington, K.J., Jiang, H., Larson, S., Drake, M.A. 2017. Characterization of functional and sensory properties of select commercial food protein ingredients. 2017 International Whey Conference, Chicago.

At pH 7, (See Table 8) both milk protein and whey protein ingredients were more heat stable ($p<0.05$) than plant protein ingredients.[35] Therefore, milk protein, whey protein or a combination of these would work better for aseptic products. Since retort processing occurs within the package itself, higher temperature/longer hold times are required which result in extended heat exposure. Thermal stability is critical for retort products, so milk proteins which contain higher levels of casein may perform better.[36]

BEVERAGE EVALUATION

To understand how the proteins performed under beverage processing conditions, the best performing proteins from the benchtop heat stability evaluation were used to formulate 5% protein-containing ready-to-drink beverages at both pH 3 and pH 7.[37] The neutral pH beverage used sugar, natural vanilla flavor, dipotassium phosphate and gellan gum to mimic commercially flavored and stabilized beverages. The formulation was then thermally processed to mimic aseptic conditions (140 C/284 F for 6 sec.). The high acid beverage used sugar, natural green mango flavor and 85% phosphoric acid to flavor and acidify to pH 3. The high acid beverage formulations were thermally processed to mimic hot fill conditions (82 C/180 F for 2 min.). Physical appearance and shelf-life stability of thermally processed beverages were assessed after being held at 45 C (113 F) for one month.

FIGURE 5: NEUTRAL pH (pH 7) READY-TO-DRINK BEVERAGE COMPARISONS



Key: Milk Protein Isolate=MPI, Milk Protein Concentrate=MPC, Micellar Casein Concentrate=MCC, Milk Whey Protein/Native Whey=NW, Whey Protein Isolate=WPI, Whey Protein Concentrate=WPC, Pea=Protein, Soy Protein=Soy1 and Soy3, Rice Protein=Rice

Source: Burrington, K.J. 2017. Characterization of Functional and Sensory Properties of Select Commercial Food Protein Ingredients. Presented at the WI Center for Dairy Research, Research Forum, November 14, 2017.

Before thermal processing, one potato protein sample and one pea protein sample separated immediately and were consequently removed from the shelf-life evaluation. Another potato protein sample was thermally processed, but plugged the processing unit, so it was removed from evalution as well. Rice protein was much more viscous than the other protein sources. At neutral pH, color varied by protein source and, if present, bitter notes were accentuated after thermal processing.[37] These are important formulation considerations as color and/or flavor maskers may be required depending on the protein selected.

FIGURE 6: HIGH ACID (PH 3) READY-TO-DRINK BEVERAGE COMPARISONS

Key: Milk Whey Protein/Native Whey=NW, Whey Protein Isolate=WPI4, Whey Protein Concentrate=WPC2, Potato Protein=PoP1, Soy Protein=Soy1, Pea Protein=Pea3, Rice Protein=Rice1

Source: Burrington, K.J. 2017. Characterization of Functional and Sensory Properties of Select Commercial Food Protein Ingredients. Presented at the WI Center for Dairy Research, Research Forum, November 14, 2017.

When formulated into thermally processed high acid, low pH beverages, the rice protein separated immediately and the pea protein separated overnight after Day 0. The other proteins remained in solution. The milk whey protein (native whey), WPI and potato protein exhibited more clarity than other protein sources.[37]

BAR EVALUATION

The commercial protein ingredient samples were evaluated in a standard nutrition bar application which targeted 40% carbohydrate, 30% protein and 30% fat based upon calories.[37] Since the composition of each protein ingredient is unique, individual formulations were developed to accommodate for the differences in protein and caloric content. The liquid fructose (carbohydrate component) was kept constant at 52%. The amount of canola oil (fat component) was adjusted in each formulation to account for the differences between protein ingredients. All ingredients were weighed and mixed in a Kitchen Aid Professional Mixer on Speed 3 for 30 seconds. The mixture was weighed and divided into four (25g) replicates which were packed into 1-ounce (28g) plastic cups. Just like the beverage formulations, variations in color existed between protein ingredient samples.

The cups were then heat sealed into a metalized package and placed under storage conditions. One control sample for each protein ingredient was stored at room temperature for 24 hours prior to undergoing bar hardness analysis utilizing the TA.XT Plus Texture Analyzer from Texture Technologies, Ramona, California, USA. Additional triplicate samples were held for 30 days at 45 C and then analyzed for texture by the same method.

FIGURE 7: COLOR VARIATION

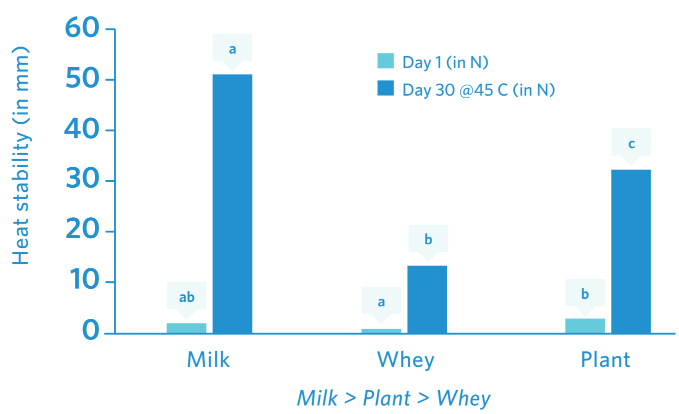
Key: Milk Protein Isolate=MPI1-3, Milk Protein Concentrate=MPC1-3, Micellar Casein Concentrate=MCC1-4, Whey Protein Isolate=WPI1-4, Whey Protein Concentrate= WPC1-3, Milk Whey Protein/Native Whey=NW1, Soy Protein=Soy1-4, Pea Protein=Pea1-4, Potato Protein=PoP1-3, Rice Protein=Rice1

Source: Burrington, K.J. 2017. Characterization of Functional and Sensory Properties of Select Commercial Food Protein Ingredients. Presented at the WI Center for Dairy Research, Research Forum, November 14, 2017.

TEXTURAL ANALYSIS OF NUTRITION BARS

After accelerated shelf-life testing, significant differences ($p<0.001$) were noted between sources of protein.[37] Milk and plant proteins developed greater degrees of hardness compared to whey proteins which remained softer. Variation existed between sources of soy and potato proteins, so diligence must be used when sourcing proteins.

TABLE 9: BAR HARDNESS



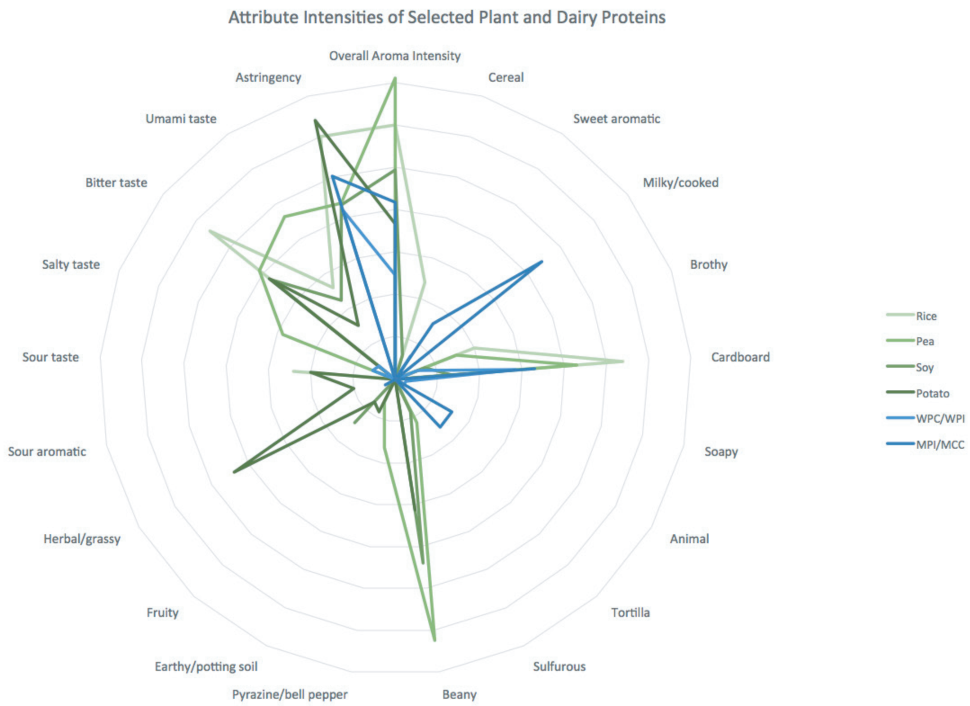
Means with different letters were significant (p<o.oo1)

Source: Burrington, K.J. 2017. Characterization of Functional and Sensory Properties of Select Commercial Food Protein Ingredients. Presented at the Wisconsin Center for Dairy Research, Research Forum, November 14, 2017.

SENSORY: EVALUATION

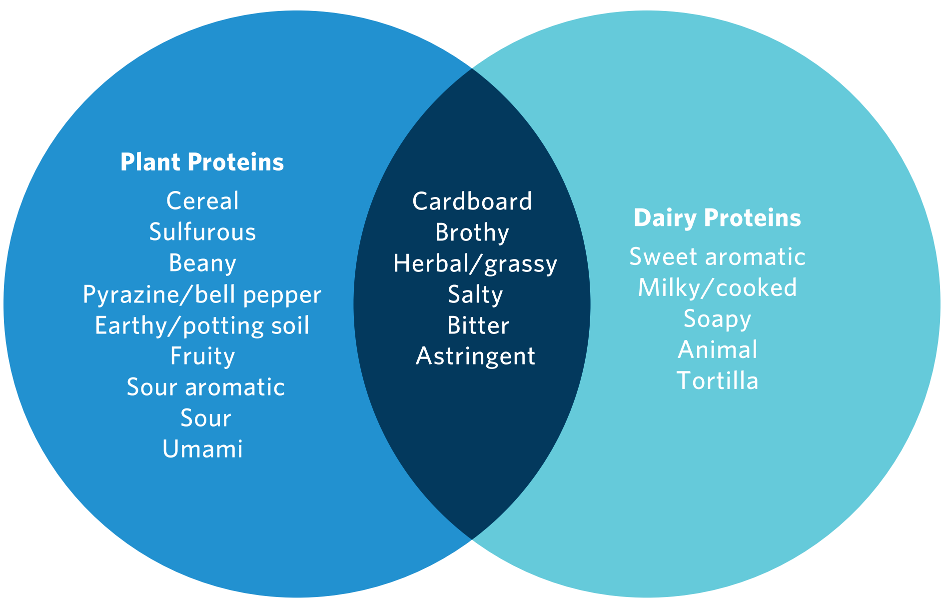
Consumer enjoyment is imperative for successful new food and beverage products. Initially, the proteins evaluated were rehydrated to 10% solids and evaluated in duplicate at 21 C (70 F) by a trained sensory panel to document flavor properties.

FIGURE 8: FLAVOR INTENSITIES OF PLANT AND DAIRY PROTEINS



Source: Kapoor, R., Burrington, K.J., Jiang, H., Larson, S., Drake, M.A. 2017. Characterization of functional and sensory properties of select commercial food protein ingredients.

FIGURE 9: FLAVOR DIFFERENCES BETWEEN PLANT AND DAIRY PROTEINS



Source: Kapoor, R., Burrington, K.J., Jiang, H., Larson, S., Drake, M.A. 2017. Characterization of functional and sensory properties of select commercial food protein ingredients.

Dairy proteins exhibited sweet aromatic and cooked/milky attributes versus plant sources which exhibited beany, earthy, sulfurous and sour notes. The potato protein was more astringent than all the other protein sources. Additionally, dairy proteins exhibited significant lower ($p<0.05$) intensities of cardboard, brothy, herbal/grassy, bitter taste and astringency than plant protein sources.[35] These differences in sensory perception allow dairy proteins to offer a superior sensory experience.

An additional consumer sensory assessment (n=105 consumers) of four commercially available vanilla ready-to-mix protein beverages also showed that plant protein beverages were less well-liked than dairy protein ready-to-mix protein beverages ($p<0.05$) for overall, appearance, flavor and texture/mouthfeel attributes.[35]

Depending on the application and targeted flavor profile, plant-based sources may require the addition of flavors, stabilizers and masking agents to achieve consumer acceptance which may increase cost and/or negatively impact ingredient statements. Working with individual suppliers remains important to maximize performance because variability between protein ingredients within the same type of protein still exist.

USAGE VERSATILITY: WIDE-RANGING APPLICATION POTENTIAL WITH CONSUMER APPEAL

Global launches of food and beverage products claiming, “added protein” or “high” in protein have more than doubled from 2013 to 2017, creating the opportunity for a wide range of new protein applications. In food and beverage products for human use, plant proteins have been positioned most often in meat, beverage and bakery products, while dairy proteins have been more widely used in beverage, frozen dessert and nutrition bar applications. Yet, across all protein types, taste is still the number one attribute claimed for new product launches.[38] Due to milk’s unique composition of protein, fat, carbohydrate and minerals, dairy ingredients can inherently provide nutrition, function and flavor to a variety of applications. Dairy protein ingredients can be concentrated, isolated or hydrolyzed to enhance the ability to whip, emulsify, gel, bind water or remain soluble under a variety of conditions.[39]

Cafe Mocha

FOOD AND BEVERAGE DRY MIXES

Dairy protein ingredients may be used in dry mix formulations to enhance protein level and provide an economical source of minerals to a formulation. If a thicker, more viscous mouthfeel is desired, milk proteins would be selected because they bind more water than whey proteins. Whey proteins would be a better selection for a thinner consistency upon rehydration or if the final mix has added acidulants because the protein remains soluble below pH 4.6.

Milk & Honey Bedtime Beverage

READY-TO-DRINK LOW-ACID BEVERAGES

Ready-to-drink beverages can be pasteurized, hot filled, ultra-high temperature (UHT) pasteurized and/or retorted to ensure their safety. Milk proteins contain higher levels of casein which are heat-stable if the beverage is above pH 6. Consequently, milk proteins, like MPC, MPI or MCC, are commonly used in low-acid beverages that are UHT pasteurized or retort processed. Whey proteins may also be formulated in these types of beverages in combination (minimum of 50%) with milk proteins to ensure heat stability. When using milk protein powder in higher-protein containing ready-to-drink beverages, adequate mixing and hydration time (approximately 60 minutes at 50 C, 122 F) prior to processing are important to ensure that the protein is completely in solution prior to heat treatment.[40]

Clear, Mango-Flavored Green Tea

HIGH-ACID BEVERAGES

For high-acid beverages (pH <4.6), whey proteins such as WPC, WPI or milk whey protein (native whey) are the best choice because they remain soluble at lower pH ranges. Once again, proper hydration of the protein (approximately 30 minutes) is important prior to hot fill processing for shelf stability.[40] If the beverage is below pH 3.5, WPI may be the best choice because it contains the lowest levels of fat, and the protein molecules have a higher positive charge which inhibits electrostatic interactions and allows the beverage to remain clear.


Soft Protein Pretzel

BAKERY APPLICATIONS

In bakery applications, dairy proteins provide multiple functionalities, such as water binding, egg/fat replacement, nutritional enhancement and shelf-life extension. Higher protein ingredients, such as WPC, have been shown to improve gluten structure and water binding characteristics in breads and frozen dough products while at the same time contributing protein to the nutritional label.[41]


Yogurt Dipped Peach Snack Bar

NUTRITION BARS

In protein bar applications, WPC and WPI have been used in bar mixes, compound coatings and extruded crisps to provide texture, flavor and enhanced nutrition to bar/snack food formulations. Whey proteins that have been hydrolyzed have also been shown to reduce bar hardening over time.[42]


Frozen Matcha Bar

FROZEN DESSERT APPLICATIONS

Milk and cream have traditionally been used in ice cream and frozen desserts. As consumer interest in higher protein treats has grown, so has the interest in higher protein dairy ingredients for inclusion in ice cream and frozen desserts. Both MPC and WPC have been used to increase protein content from 4.9% to 7.2% in ice cream without negative effects on sensory or storage stability. WPC has also been used for fat replacement in ice cream formulations.[43]


Lentil Power Soup

SOUP AND SAUCE APPLICATIONS

Milk, cheese and cream have been used to add flavor to soups and sauces for years. Dairy proteins contribute water binding and mouthfeel which makes them an ideal match for high-protein meal solutions. Milk proteins and whey proteins can both be used in soup or sauce formulations to provide a nutritional enhancement with a neutral flavor and smooth texture. However, if the soup or sauce will be retorted or UHT processed for shelf stability, milk proteins, like MPC, MPI or MCC, may be a better choice because the casein is more heat stable and binds more water to maintain a consistent viscosity and appearance.[44]

Dairy proteins are not only functional and nutritious, but versatile enough to bring creative and tasteful food solutions that consumers desire. Go to ThinkUSAdairy.org for more information about these types of applications and in-depth technical reports on how dairy proteins are made and function.

SUPPLY SECURITY: EXPANDING, HIGH QUALITY RISING CAPACITY FOR FUTURE INNOVATION NEEDS

Protein comes from many food sources. Traditional sources would include milk, meat/collagen, egg, soybean and wheat. Yet, the marketplace has seen an expanding array of commercially available protein sources for food use including pea, lentil, bean, pulse, rice, potato and oat. Newer entrants such as canola, insect, hemp, micro algae and single cell proteins are being harvested, characterized and commercialized. For use in foods and beverages in the United States, protein must undergo rigorous testing and approvals such as Generally Recognized as Safe (GRAS) status, allergenicity testing, nutritional analysis, functional characterization and consumer acceptance testing, so formulators should be sure to check the status of ingredients prior to selection.

Consistent supply availability is a key consideration for buyers and manufacturers when selecting and sourcing ingredients. As the world's largest single-country producer of cow's milk, the source for whey and milk protein ingredients, the U.S. dairy industry is well equipped to reliably deliver safe, high-quality, nutritious dairy ingredients for food formulations around the globe. The scale of plant-based protein production, in contrast, remains limited with the exception of soy. Comparing production numbers reinforces this considerable supply gap. As of 2017, the total volume of dairy proteins (whey and milk protein concentrates and isolates) produced just in the United States alone was 336,000 MT.[45] This was about the same as the total global production volume of the emerging proteins pea, rice, wheat and potato combined (330,000 MT in 2016).[46] Blessed with a growing cheese industry, an abundance of land, continuous investments in research and development and an expanding export focus, U.S dairy protein production is anticipated to further expand in the years ahead, ensuring secure supply and ample choice of a wide range of dairy protein ingredients, tailored to customer and consumer needs.

SUMMARY

All proteins are not created equal. Whether formulating protein into products intended for vulnerable undernourished populations, sports nutrition, weight management or healthy aging, it is important to choose a high-quality, complete protein. Dairy proteins consistently deliver this important level of nutrition.

Flavor, appearance, performance and nutrition all play a role in product enjoyment, but these attributes are balanced with cost and lifestyle considerations. In this new era of increased focus on protein, more fortified food options exist than ever before. Finding proteins that consistently deliver on multiple attributes is key.

Proteins from U.S. milk are undeniably and uniquely able to deliver multiple, desirable attributes to help people thrive at every life stage. For more information on formulating products with U.S. dairy ingredients or locating suppliers, visit ***ThinkUSAdairy.org***.

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INDEX

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