U.S. WHEY PRODUCTS AND SPORTS NUTRITION

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Recently U.S. whey products have become very popular ingredients in sports nutrition. The past decade has seen increasing popular interest in healthy lifestyles based on regular exercise. This increase in the number of muscle and fitness enthusiasts has prompted a growing consumer demand for protein sports beverages, specialized nutritional drinks, nutritional snack bars and other products designed to optimize athletic performance. A growing body of scientific evidence indicates whey proteins deliver important physiological benefits for consumers seeking superior physical performance and recovery.

SPECIALTY SUITED PROTEINS FOR SPORT PRODUCTS

Whey proteins are both easily digested and have excellent metabolic efficiency, giving the protein a high biological value. They also contain the highest concentration of branched chain amino acids (BCAAs) available from any natural food protein source. During exercise, whole body protein synthesis is decreased, and proteins are mobilized into free amino acids. Skeletal muscles take up BCAAs from the blood and break them down into glucose for energy. Therefore BCAAs are unique among amino acids in their ability to provide an energy source during endurance exercise. Whey proteins are specially suited to sports drink and bar formulations. Isolates provide a high concentration of BCAAs (26g per 100g protein) high quality pure protein and excellent bioavailable calcium.

The use of whey products as ingredients in sports foods has been increasing steadily with improvements in the technological capabilities of the industry to produce commercially attractive whey protein concentrates (WPCs), whey protein isolates (WPIs) and enriched whey protein fractions. Whey protein concentrates are available in various protein concentration levels such as 34% (WPC34), 50% (WPC50) or 80% (WPC80). Whey protein isolates contain more than 80% protein (typically 90%). The key whey products used in sports nutrition bars and drinks are sweet dried whey, WPCs, WPIs, hydrolyzed whey products, whey peptides, lactoferrin and other fractions.

PROTEIN POWER AND SPORTS CONNECTION

WHEY, ENERGY AND SPORT

The main source of energy in short and medium term exercise is carbohydrate as glycogen. This is gradually replaced by lipid, as the exercise period becomes longer. Proteins can also be used as a source of energy particularly during prolonged exercise. The oxidation of amino acids, mainly branched-chain amino-acids, can provide 10–15% of the total energy required during exercise.

Several studies using leucine turnover measurements show an increase of up to 20% in protein turnover during aerobic exercise. The case for increased protein needs during exercise is also supported by studies showing increased excretion of 3-methyl histidine, increased urea nitrogen losses, and depression of protein synthesis.

Studies show an increased utilization of primarily the BCAAs, leucine, isoleucine, and valine, during exercise. The BCAAs are degraded by active skeletal muscles to release nitrogen, which is combined with pyruvate in muscles to form alanine. The liver removes nitrogen from alanine to form glucose as a source of energy. However, turnover rates for other amino acids, such as lysine, are unaffected by exercise.

SPECIAL PROTEIN REQUIREMENTS AND SPORTS

To maintain fitness and overall health, the U.S. Recommended Daily Allowance (RDA) for protein is 0.8 gram per kg body weight. However, an individual's protein requirements also depend on lifestyle, physical condition, overall health, age, gender, carbohydrate status, previous level of protein intake, training level, and type, duration and intensity of exercise.

In general, the RDA is sufficient for a sedentary lifestyle, but exercise increases the need for protein. The American Diet Association (ADA) and other nutritionists associations have reported that 1.5 g protein per kg body weight, which is considered an adequate amount for athletes, is required for maximum protein deposition (97 to 105 g of protein per day for a 70 kg individual). These protein intakes are recommended for keeping the body in nitrogen balance, or to give a positive balance with increased muscle mass for certain athletes or other individuals requiring more muscle mass.

Nutritional considerations of strength/power athletes participating in bodybuilding, weightlifting, wrestling, and self-defense are different than other sport groups. Nitrogen balance studies indicate levels of protein up to 2.0 g per kg body weight per day may be required for endurance and strength/power athletes to remain in positive balance. Body builders are known to take in large quantities of whey proteins.

Some consume higher than 2.0 g protein per kg of body weight. They recognize that increasing lean muscle mass requires additional protein intake and demanding bouts of exercise.

It does not take much extra protein to supply amino acids for enlarging muscles. However, no protein is 100% utilized. The loss of efficiency in high-quality protein utilization is about 30%, and in poorer-quality protein, it is about 60%. Ingestion of very high amounts of protein increases metabolic stress to organs. It is clearly much more desirable to eat proteins with the best biological value, such as whey proteins.

Benefits of Whey Proteins in Sports Nutrition

- Easily digestible high quality protein—provides additional energy, spares endogenous protein
- Contains high levels of BCAAs: leucine, isoleucine, and valine
- Good source of sulfur-containing amino acids such as cysteine and methionine—maintains antioxidant levels in the body, and are thought to stabilize DNA during cell division
- Contains high levels of arginine and lysine—may stimulate growth hormone release, and thus stimulates an increase in muscle mass and a decline in body fat
- Contains glutamine—helps muscle glycogen replenishment and prevents decline in immune function from overtraining
- Excellent source of bioavailable calcium—reduces stress fractures during exercise and prevents bone loss in hypoestrogenic female athletes

U.S. WHEY PROTEINS DELIVER SUPERIOR VALUE

Proteins are all good, but some are better than others. The ideal sports protein should meet these criteria:

- A good balance of essential and nonessential amino acids
- An abundant supply of BCAAs
- Low in fat, and cholesterol

A PDCAAS measures protein quality based on the amino acid requirements of humans. Criteria needed for PCAAS are approximate nitrogen composition, essential amino acid profile, and true digestibility.

According to this method, the PDCAAS of an ideal protein that meets all the essential amino acid requirements of the human body has a value of 1.00. Whey proteins have a PDCCAS of 1.14, a score that exceeds the 1.00 for soy protein.

PDCAAS of Key Proteins

Protein Source	PDCAAS
Whey protein	1.14
Casein	1.00
Milk protein isolate	1.00
Soy protein isolate	1.00
Egg white powder	1.00
Ground beef	1.00
Canned lentils	0.52
Peanut meal	0.52
Wheat gluten	0.25

"Whey has an excess of essential amino acids," according to a key U.S. whey protein supplier. Essential amino acids make up over 60% of whey's total protein content. As a result, there are no limiting essential amino acids in whey proteins, as is the case with some vegetable proteins, to detract from protein quality.

Nutritive Value of Key Proteins

Protein Source	BV	PER	NPU
WPC	104	3.2	92
Soy Protein	74	2.1	61
Whole Egg	100	3.8	94
Cow's Milk	91	3.1	82
Casein	77	2.9	76
Beef	80	2.9	73

Essential Amino Acid Profile of Key Proteins (mg/g protein)

Amino Acid	WPC 80	Soy	Egg	Wheat
Leucine	105	85	86	68
Lysine	93	63	70	27
Phenylalanine + Tyrosine	32	97	93	78
Methionine + Cysteine	21	24	57	39
Isoleucine	63	47	54	33
Valine	58	49	66	43
Threonine	69	38	47	29
Tryptophan	18	11	17	11
Histidine	17	—	22	—

Whey protein isolates (WPIs) *provide the excellent balance needed for a sports nutrition product.* WPIs *are extremely low in lactose, less than 1%. In addition, their bland flavor allows their formulation with products not normally associated with dairy products, like a fruit-bar or fruit-juice application.*

In sports drinks and bars WPIs *are used:*

- *To provide quick energy*
- *To increase muscle weight 'gain'*
- *To repair muscle tissue*

U.S. WHEY PROTEINS: A RICH SOURCE OF BRANCHED CHAIN AMINO ACIDS

Whey proteins contain a high level of BCAAs (~26%) that are taken up directly by skeletal muscles during extensive exercise, rather than first being metabolized through the liver like other amino acids. Since the body's demand for these amino acids increases during exercise, athletes who want to preserve muscle mass may benefit by increasing their consumption.

Whey has 10 g leucine, 6.5 g isoleucine and 5.5 g valine per 100 g of protein. There are some variations in amino acid composition depending on the origin and the processing of the protein. Different processes produce whey proteins with different BCAA contents. For example, an ion exchange process and microfiltration produce a profile with more β-lactoglobulin richer in BCAAs. In the US, dairy companies produce whey proteins with enhanced levels of BCAAs specifically tailored for sports beverages and sports bar applications.

BCAA Content of Key Proteins

Protein Source	BCAAs g/100 g Protein
WPI	26
Egg White Powder	22
Milk Protein Isolate	20
Soy Protein Isolate	17

BCAAs *Aid Recovery*

- BCAAs are thought to decrease muscle protein degradation during exercise and allow athletes to train more intensively for longer periods of time. There is evidence they can help revive athletes after intense exercise and aid recovery, and these areas have become active areas for sports medicine research. The current theory is that during prolonged exercise, BCAAs are oxidized by skeletal muscle, the carbon part is used as fuel and the nitrogen part is used to make the amino acid alanine, which then goes to the liver where it is turned into glucose for energy. For athletes who want to protect their existing mass, the idea is to take whey protein fortified products naturally rich in BCAAs before and after the exercise. Exercise can be considered to be a "metabolic stress" like injury or trauma. Under these conditions, muscle tissue is progressively catabolized to provide the liver with precursors for glucose. Therefore BCAAs can be extremely beneficial in the diet of athletes as aid to recovery.

BCAAs *Delay Fatigue*

- Marathoners talk of 'hitting the wall' and cyclists speak of 'bonking.' Both groups experience fatigue in intense events lasting longer than an hour. It has been proposed that ingestion of BCAAs might delay fatigue during prolonged aerobic exercise by delaying central fatigue. Central fatigue hypothesis suggests increased concentrations of brain Serotonin 5-HT can impair central nervous system function during exercise. Increased brain 5-HT can occur because of increased levels of the amino acid precursor tryptophan. Transportation of free tryptophan (f-TRP) across the blood barrier is shared with the BCAA. Thus, brain 5-HT concentration increases as the ratio of plasma f-TRP/BCAA ratio increases.

  It is proposed that decreasing the f-TRP/BCAA ratio can reduce central fatigue. One way to change this ratio is to increase the amount of BCAAs in the blood. In theory, the greater the circulating levels of BCAAs, the smaller the amount of tryptophan to cross the blood-brain barrier. Several field studies using BCAA supplementation with runners, soccer players, and cross-country skiers have shown beneficial effects on performance.

U.S. WHEY PROTEINS, MUSCLE GROWTH AND FATIGUE PREVENTION

Whey proteins are rich in arginine and lysine. Arginine and lysine are among the amino acids thought to possibly stimulate growth hormone, a potentially beneficial response for bodybuilders. Proteins may stimulate release of growth hormone, which is an anabolic hormone or stimulator of muscle growth. Since the use of anabolic drugs was banned from competition, strength/power athletes have sought legal, natural substances to help build bigger muscles. Whey proteins offer natural alternatives to anabolic-androgenic steroids for bodybuilders.

Whey contains glutamine, a conditionally essential amino acid. Glutamine has been studied for its role in preventing fatigue and over-training in athletes. It is conditionally essential because in certain situations, it may be needed in the diet. It acts as a fuel for dividing cells. It makes up 60% of the amino acid pool in skeletal muscle, so athletes are cautious not to allow any shortage in the belief its absence would reduce muscle growth and increase muscle breakdown. Glutamine plays an important role in binding ammonia, which is a molecule produced by muscles in exhaustive conditions. Supplementing with whey proteins may increase the need to have more glutamine in the formula since nitrogen from BCAA's may be incorporated into ammonia. While under stress, the body's glutamine requirements can increase considerably. Adding glutamine provides opportunities for whey product line extensions. Glutamine can also be used in sports drinks, bars and instant drink mixes. Formulators may enhance their formulas by adding glutamine into products.

U.S. *Lactoferrin and Sport*

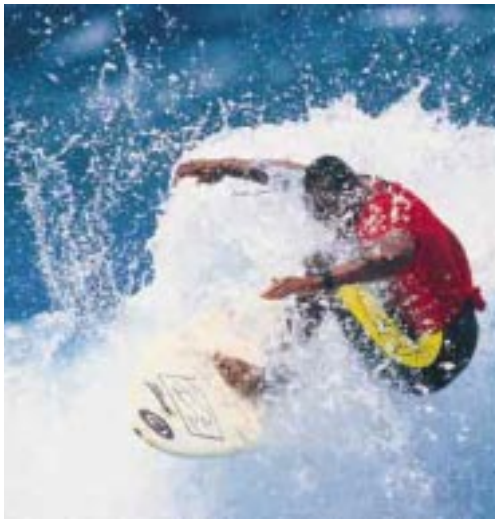
Lactoferrin occurs naturally in whey and is an iron binding protein of the transferrin family. Transferrins are necessary to bind iron in blood to the cells, particularly the production of energy and the regulation of red cells and hemoglobin. The iron status of athletes is important. Most sports draw on the aerobic pathway, which requires oxygen. The transportation and diffusibility of oxygen are limiting factors in aerobic performance. Iron is an important element in cell metabolism and in the transportation of oxygen. It constitutes the acceptor at the core of hemoglobin. A deficiency of iron can impair red cell production by bone marrow. Under these circumstances, a shortage of iron can impair the aerobic performance of athletes. Athletes who take iron supplements by direct injection to boost oxygenation can risk having hemosiderosis, an iron related sickness. Also, taking oral iron supplements often leads to adverse intestinal problems. Lactoferrin can be added to the sports formula as an iron supplement to boost the oxygenation without side effects.

Lactoferrin works as an antioxidant by binding iron and preventing it from participating in free radical formation. Free radicals are increasingly identified as the cause of muscle injuries in athletes, which reduces performance. Lactoferrin plays a significant physiological role in combating free radicals.

Lactoferrin also plays a role in the cellular defense system, most likely by regulating the macrophage activity and stimulating the proliferation of lymphocytes. The immuno-modulatory potential of lactoferrin may be useful for athletes subject to critical stress during periods of intense training.

Glycomacropeptides and Sport

Glycomacropeptides are formed during the cheese making process from the reaction of chymosin with κ-casein. These proteins are strictly kappa casein-derived peptides that are collected and concentrated during ultrafiltration of whey. Whey proteins contain about 15–20% glycomacropeptides (GMPs). Glycomacropeptides are biologically active proteins with a positive effect on the digestive system. 'Digestion regulators' are considered important in sports nutrition. Glycomacropeptides have been shown to stimulate the synthesis and release of cholesystokinin in the body. Choesystokinin plays a role in the regulation of digestive functions as an appetite suppressant. Other functions linked with GMPs include growth factors for bifidus bacteria in the intestine, antiviral activity, modulating digestion, improved calcium absorption, antibacterial properties and improvement of the immune system.



SPORTS NUTRITION PRODUCTS AND FORMULATIONS WITH U.S. WHEY PROTEINS

There are numerous commercial sports nutrition products available in the US today that use whey proteins as a protein source. The categories that incorporate whey proteins as a part of their nutritional profile are in general very high protein products (about 20 to 50 grams of protein per serving): meal replacements, weight-gain products, and pre-workout drinks. Each category is designed for specific benefits to an athlete or bodybuilder, such as providing quick energy for a workout, adding calories for weight and muscle gain, or for recovery and muscle repair after a workout.

Whey proteins are also used as a protein base for homemade sports products such as cookies and/or drinks. Sports nutritionists sometimes recommend homemade sports products as low-cost alternatives to commercial products, particularly for recreational athletes.

Benefits of WPI in Sports Formulations

Properties	Benefits
Excellent protein value	PER, BV and PDCAA
Clean and bland flavor	Allows formulation with dairy and nondairy products such as citrus and fruit flavored drinks
Clarity	Esthetic appearance
Hydration and solvation	Processing advantage—Ease of wettability of powders
Good dispersion and dissociation	Processing advantage—Ease of dispersibility and solubility of powders
Instant option	End-use advantage—Instant stirrability of powders
Acid and heat stability	No sediment, long shelf-life
Low viscosity	Easy to drink
High protein concentration (>90%)	Economic usage
Low fat	Non-fat label claim; benefits low calorie image
Low cholesterol	No-cholesterol label claim; benefits non-atherogenic image
Low lactose	Lactose-free label claim; important for lactose intolerance
High β-lactoglobulin content	Rich in BCAAs, suitable for muscle growth formulations and replenishes BCAAs after exercise

Vanilla Flavored Protein Drink

Ingredient	Percent
WPC80	14.79
Crystalline fructose	2.00
Vanilla Flavor	1.00
Salt	0.20
Artificial sweetener	0.01
Water	82.00
Total	100.00

Data courtesy Salient Inc.

Procedure

- Blend all dry ingredients.
- Add dry ingredients to water.
- Mix thoroughly by hand or blender.

Benefit

- Provides over 34 g of high quality whey protein per serving in an easily dispersible form ideal for dry nutritional beverages.

Protein Bar Formulas with WPC 80

Ingredient	A	B	C	D
Corn Syrup 63 DE	60.00	60.00	60.00	60.00
Vanilla	2.00	2.00	2.00	2.00
WPC80	25.00	12.50	12.50	8.33
Total Milk Protein	0.00	12.50	0.00	8.33
Calcium Caseinate	0.00	0.00	12.50	8.33
Cocoa	5.00	5.00	5.00	5.00
Maltodextrin 10 DE	5.00	5.00	5.00	5.00
Vegetable Oil	3.00	3.00	3.00	3.00
Total	100.00	100.00	100.00	100.00
% Protein in Bar	20.7	22.0	22.0	22.6

Data courtesy Salient Inc.

Procedure

- Blend cocoa, sugar, protein powders, and maltodextrin.
- Add oil to blend mix.
- Add vanilla to corn syrup warmed at 42°C.
- Add vanilla-syrup mixture to powder blend and mix at low speed in a blender for 1–1.5 minutes until all powders are incorporated into syrup mixture, then mix at medium speed for 1 minute.
- Roll mixture into a 5/16 inch sheet on a lightly oiled surface and store in a sealed plastic bag in the dark at room temperature.
- At 24 hours, cut into squares to evaluate firmness and adhesion.
- Double bag samples and store at room temperature.

Benefit:

- WPC80 provides a clean flavored source of protein.
- WPC80 gives initially softer products than other protein sources, but significant firming may be expected upon aging.

U.S. Whey Proteins Used for Body Building Formulations

Product	Protein %	Lactose %
Dried sweet whey	13	75–80
WPC-low protein	34	50
WPC-medium protein	50–75	15–35
WPC-high protein	80	6
WPI-ion exchange treated	90–95	2
WPI-cross flow micro/ultra filtered	98–100	Lactose-free
Hydrolyzed WPC	80–88	5
Tailored whey peptides	83–89	3

Recommended Sports Nutrition Products with Whey Proteins

Products	End-users
Sports drinks as meal supplements	Aerobics, runners, recreational athletes, sedentary workers,etc.
Protein bars, cookies, brownies as meal replacement and/or meal supplements	Cyclists, mountain climbers, skiers, etc.
Protein powders and weight-gain supplements as meal replacements and/or meal supplements	Bodybuilders, weight lifters, wrestlers, rowers, etc.

REFERENCES

Anon. 2000. "Nutritional Bars." *Nutritional Outlook*. 3:35-31.

Anon. 1999. "Proteins and Sport." *Vital News*. Spring, 1-5.

AMPC. 1999, *Applications Review*. AMPC, Ames, Iowa, USA.

Berning, J.R. and Steen, S.N. 1998. *Nutrition for Sport and Exercise*. Aspen Publishers, Inc.

Blomstrand, E., Hassmen, P., Ekblom, B., Newsholme, E. 1991. "Administration of branched amino acids during sustained exercise and effects on performance and plasma concentration of some amino acids." European Journal of Applied Physiology. 83:83-88.

Blomstrand, E., Hassmen, P., Ekblom, B., Newsholme, E. 1991. "Effect of branched amino acid supplementation on mental performance." *Acta Physiologica Scandinavica*. 136:473-481.

Bronner, F. 1999. "Calcium in exercise and sport." *In Macroelements, water, and electrolytes*. Eds. Driskell, J.A., and Wolinsky, J.A. CRC Press. 17-27.

Nutrition Applied to Injury Rehabilitation and Sports Medicine. 1995. Ed. Bucci, L.R. CRC Press.

Burns, J. H. and Berning, J.R. 1999. "Sports beverages." *In Macroelements, water, and electrolytes*. Eds. Driskell, J.A., and Wolinsky, J.A. CRC Press. 212-226.

Burrington, K.J. 1999. "Dairy ingredients for health." *Food Product Design*. October:39-62.

Cantor, S. 1997. "Health beverages for all ages." *Food Product Design*. 7:41-69.

Davis, J.M. 1995. "Carbohydrates, branched amino acids, and endurance: the central fatigue hypothesis." *International Sport Nutrition*. 5:29-38.

Durham, R.J., Hourigan, J.A., Slight, R.W., and Johnson, R.L. 1997. *Whey fractionation: wheying up the consequences*. 49:460-465.

Duxbury, D.D. 1992. "Advanced process for whey protein concentrate increases yield." *Food Processing*. 53:82-83.

Handbook of Dairy Foods and Nutrition. 2000. Eds. Miller, G.D., Jarvis, J. K. and McBean, L.D. CRC Press.

Hugunin, A. 1999. "A protein for all seasons." *Dairy Industries International*. September:19-22.

Jackson, C.G.R. 1995. "Nutritional concerns of recreational strength athletes. *In Nutrition for the Recreational Athlete*. CRC Press. 56-62.

Knapik, J., Meredith, C., Jones, B., Fielding, R., Young, V., and Evans, W. 1991. "Leucine metabolism during fasting and exercise." *Journal of Applied Physiology*. 70:43-47.

Kreider, R., Miriel V., and Bertun, E. 1993. "Amino acid supplementation and exercise performance." *Sports Medicine*. 16:190-209.

Lemon, P., Tarnopolsky, M., MacDougall, J., and Atkinson, S. 1992. "Protein requirements and muscle mass/strength changes during intensive training in novice bodybuilders." *Journal of Applied Physiology*. 73:767-775.

Lemon, W.P. 1998. "Effects of exercise on dietary protein requirements." *International Journal of Sports Nutrition*. 8:426-447.

Mazza, G. 1998. "Functional milk and dairy products." *In Functional Foods Biochemical and Processing Aspects*. Technomic Publishing Company. 356-380.

Morr, C.V. and Ha, E.Y.W. 1993. "Whey protein concentrates and isolates: processing and functional properties." *Critical Reviews in Food Science and Nutrition*. 33:431-476.

Nettl, F. 1995. "The shocking truth about whey protein." *Muscle Media* 2000. November:72-77.

O'Caroll, P. 1998. "A sporting whey." *The World of Ingredients*. October: 54-58.

O'Donnell, C. 1991. "Milk it for all it's worth." *Prepared Foods*. 160:67-68.

Potjewijd, R. 1999. "Lactoferrin, those extra benefits." *The World of Ingredients*. March/April: 58-59.

Pszczola, D.E. 1995. "Drinks for everyone." *Food Technology*. 49:30.

Regester, G.O, McIntosh, G.M, Lee, V.W.K. and Smithers. "Whey proteins as nutritional and functional food ingredients." *Food Australia*. 48:123-127.

Shangold, M.M. and Mirkin, G. 1994. "Nutrition for sports." In *Women and Exercise: Physiology and Sports Medicine*. F.A Davis Company 102-125.

Tarnopolsky M., Atkinson, S., MacDougall, J., Chesley, A., Phillips, S., and Schwarcz, H. 1992. "Evaluation of strength athletes." *Journal of Applied Physiology*. 1992. 73:1986-1995.

Van Hall, G., Saris, W.H.M., Van De Schoor, P.A.I., and Wagenmakers, A.J.M. 2000. "The effects of free glutamine and peptide ingestion on the rate of muscle glycogen resynthesis in man". *International Journal of Sports Medicine*. 21:25-30.

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