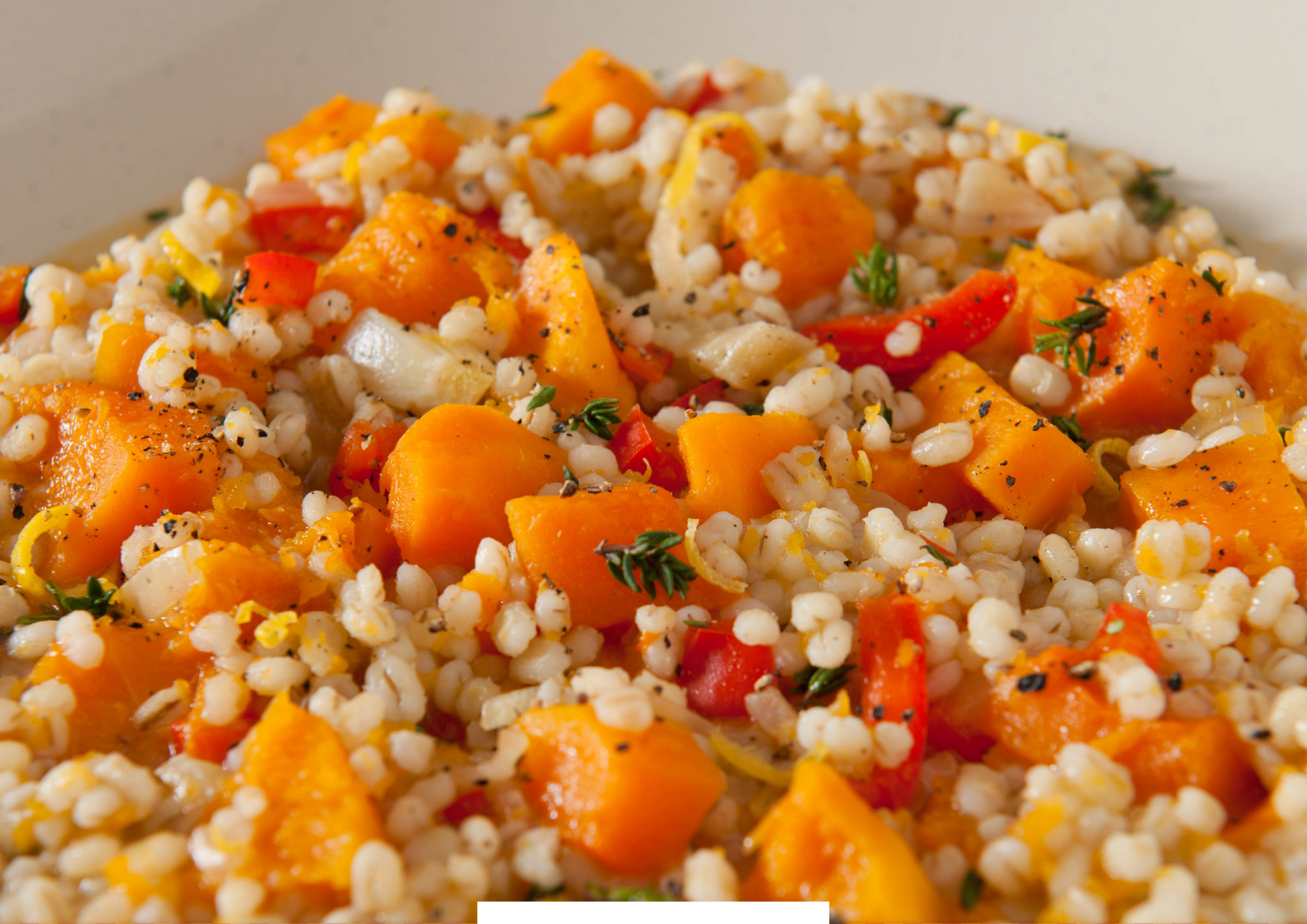

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Barley—A Healthy Protein Source

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Barley—A Healthy Protein Source

The use of plant-based protein is a significant trend in the healthy food sector. Protein-rich foods are important to consumers who are seeking health benefits relevant to the whole family.[1] In the Shopping for Health 2014 survey, 33 per cent of U.S. shoppers indicated that protein content is an essential criterion when purchasing foods.[2] When making decisions about buying packaged food or beverages, 57 per cent of Americans surveyed by the International Food Information Council (IFIC) stated that consuming more protein was an important characteristic in food choice.[3] The primary reasons included: "protein is an important component for a balanced diet" (76 per cent); "to gain energy" (62 per cent); "to build or maintain muscle strength" (56 per cent); and "for satiety" (51 per cent).

As a result of consumer demands, there has been a shift in the food industry away from animal-based proteins toward the use of plant-derived sources that offer similar or superior functional properties. Some of the possible reasons for this shift are:

- Health benefits associated with plant-based diets[4]
- Concerns about animal welfare in food production systems[5]

The Importance of Protein

Protein is an essential nutrient required for growth and development, as well as the maintenance of cellular structures, organs and muscle mass. Proteins are large organic compounds made of one or more chains of amino acids (AA). The AA sequence of a protein determines its three-dimensional structure. Proteins are essential components of all living organisms and are intimately involved in most cellular functions.

There are nine essential amino acids: isoleucine, leucine, lysine, threonine, tryptophan, methionine, histidine, valine and phenylalanine. Non-essential amino acids are those that the body can manufacture and include: glutamic acid, alanine, aspartic acid, asparagine, glutamine, arginine, proline, serine, tyrosine, cysteine, and glycine.[6]

Proteins can be synthesized when there are sufficient quantities of all necessary AA available. If essential amino acids (EAA) are lacking, the body will be unable to make proteins and will have to break down muscle proteins to meet requirements.

Proteins from animal sources (such as meat, poultry, fish, eggs, milk, cheese and yogurt) provide all nine EAA and are referred to as "complete" or "high-quality" proteins. Plant proteins (from grains, pulses, nuts, seeds and vegetables) are low in one or more specific EAA6 and are therefore considered to be "incomplete" proteins. By combining various plant proteins from different sources it is possible to improve the overall EAA profile thereby achieving "complete" or "high quality" proteins. For example, barley can be combined with pulses to achieve a complete protein. EAA requirements can be met exclusively by plant proteins if a variety of plant sources are consumed to meet energy needs.[7]

Protein Requirements

The Recommended Dietary Allowance (RDA) of high-quality protein (i.e., complete and/or complementary proteins) for both men and women is 0.80 grams per kilogram body weight per day.[6] The Acceptable Macronutrient Distribution Range (AMDR) is "the range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients."[6] For protein, the AMDR is 10 to 35 per cent.[6]

Emerging research suggests that protein requirements may be somewhat higher than the levels established by the Institute of Medicine,[8] although this evidence has not yet prompted a revision of the recommendations.

A dietary plan that includes 25 to 30 grams of high-quality protein per meal may help to maximize muscle protein synthesis. Dividing protein intake evenly throughout the day may be a particularly important consideration for elderly populations who are at increased risk for sarcopenia—the degenerative loss of skeletal muscle mass that occurs with aging.[9]

Nutritional Profile of Barley

Barley is an ancient grain that has been cultivated for thousands of years. In North America, barley is a major crop used for animal feed and for malting by the brewing industry. But it is also grown for the food industry, and is increasing in popularity as people focus on consuming more local, healthy foods.

Barley is an important source of dietary fibre, resistant starch, trace minerals, vitamins, phytoestrogens and antioxidants, which are associated with disease prevention. Barley is one of the richest sources of the soluble fibre β-glucan, a non-starch polysaccharide found primarily in the cell walls of the endosperm and aleurone layer of the grain. The health benefits of β-glucan are the most extensively reported of all fibres. β-glucan delays gastric emptying, lowers serum cholesterol and attenuates the postprandial glycemic response.[10] β-glucan has also been reported to possess anti-cancer properties.[10]

Barley has the highest fibre content of the cereal grains.[11] Dietary fibre intake is inversely associated with the risk of chronic disease, including: coronary heart disease, stroke, hypertension, diabetes, obesity and metabolic syndrome.[12] High-fibre foods are recommended for a number of digestive disorders, including: gastroesophageal reflux disease, duodenal ulcers, inflammatory bowel syndrome, diverticular disease, constipation and hemorrhoids.[12] As the largest immune system organ in the human body, the gastrointestinal tract is key to overall health and high fibre intake may enhance immunity.[12]

Barley as a Dietary Protein Source

The amino acid profile of barley is similar to that of other grains (Table 1).[13] Although the protein in grains may not stand out as a key nutritional attribute, they can make an important contribution to overall protein intake, particularly for vegetarians or people trying to consume fewer animal products. In a world that is striving to feed a rapidly expanding population, choosing more plant-based foods is becoming an increasingly popular strategy among health- and environmentally-conscious consumers seeking more sustainable diets.

Table 1. Protein and amino acid content of select grains[11]

	Wheat, hard red spring g/100 g	Barley, pearled g/100 g	Oats g/100 g	Corn, yellow g/100 g	Rice, brown, long grain g/100 g
Protein	13.68	9.91	16.89	9.42	7.94
Tryptophan*	0.195	0.165	0.234	0.067	0.101
Threonine*	0.433	0.337	0.575	0.354	0.291
Isoleucine*	0.541	0.362	0.694	0.337	0.336
Leucine*	1.038	0.673	1.284	1.155	0.657
Lysine*	0.404	0.369	0.701	0.265	0.303
Methionine*	0.230	0.190	0.312	0.197	0.179
Cysteine	0.404	0.219	0.408	0.170	0.096
Phenylalanine*	0.724	0.556	0.895	0.463	0.410
Tyrosine	0.441	0.284	0.573	0.383	0.298
Valine*	0.679	0.486	0.937	0.477	0.466
Arginine	0.702	0.496	1.192	0.470	0.602
Histidine*	0.330	0.223	0.405	0.287	0.202
Alanine	0.555	0.386	0.881	0.705	0.463
Aspartic acid	0.808	0.619	1.448	0.655	0.743
Glutamic acid	4.946	2.588	3.712	1.768	1.618
Glycine	0.621	0.359	0.841	0.386	0.391
Proline	1.680	1.178	0.934	0.822	0.372
Serine	0.663	0.418	0.750	0.447	0.411

*Essential amino acids

Considering the quality of a protein is vital in determining the nutritional benefits that it can provide. A number of methods are used to assess protein quality in foods, which are discussed in detail in Appendix A. As an example, the amino acid score (AAS) is a measure of protein quality calculated using the actual amount of individual amino acids in a food relative to human amino acid requirements. A score ≥1.0 for an amino acid indicates that the amino acid is not limiting relative to requirements.

Animal sources have the highest protein quality scores due to their content of EAA. The most common way to improve the protein quality score for plant-based proteins is to combine them with animal proteins. However, many food products developed with plant-based proteins are meant for applications in which people are avoiding animal proteins. Instead, barley, like all plant-based proteins, can be combined with other protein sources in order to yield a product that is considered a "complete" protein. These complementary proteins can be consumed over the course of the day to provide all EAA.[7] As shown in table 2, lysine is the limiting amino acid in pearled, hulled and flour barley products.

Table 2. Amino acid scores (AAS) for barley products[11, 14]

Amino Acid	Reference mg/g	Pearled mg/g	AAS	Hulled* mg/g	AAS	Flour† mg/g	AAS
Histidine	20	22.3	1.12	28.1	1.41	23.6	1.18
Isoleucine	32	36.2	1.13	45.6	1.43	38.3	1.20
Leucine	66	67.3	1.02	84.8	1.28	71.3	1.08
Lysine	57	36.9	**0.65**	46.5	**0.82**	39.1	**0.69**
Methionine — Cysteine	27	40.9	1.51	51.6	1.91	43.4	1.61
Phenylalanine — Tyrosine	52	84	1.62	105.8	2.03	89	1.71
Threonine	31	33.7	1.09	42.4	1.37	35.6	1.15
Tryptophan	8.5	16.5	1.94	20.8	2.45	17.5	2.06
Valine	43	48.6	1.13	61.2	1.42	51.5	1.20

*Minimally processed to remove the hull

†Made from pearled barley

Barley can be combined with other plant proteins to yield an AAS >1.0. Barley is deficient in lysine and low in either threonine or tryptophan, while pulses are low in the sulfur-containing amino acids methionine and cysteine.[15] This complementarity is exhibited in Table 3.

Table 3. Combining barley flour (25 per cent) and pea flour (75 per cent) results in an Amino Acid Score >1.01[4]

Amino Acids	Reference (mg/g)	25 per cent Barley flour (mg/g)	75 per cent Pea flour (mg/g)	Total (mg/g)	Amino Acid Score
Histidine	20	5.90	17.25	23.15	1.16
Isoleucine	32	9.58	24.75	34.33	1.07
Leucine	66	17.83	48.75	66.58	1.01
Lysine	57	9.78	47.25	57.03	1.00
Methionine — Cysteine	27	10.85	17.25	28.1	1.04
Phenylalanine — Tyrosine	52	22.25	54.75	77	1.48
Threonine	31	8.90	33	41.9	1.35
Tryptophan	8.5	4.38	6	10.38	1.22
Valine	43	12.88	30	42.88	1.00

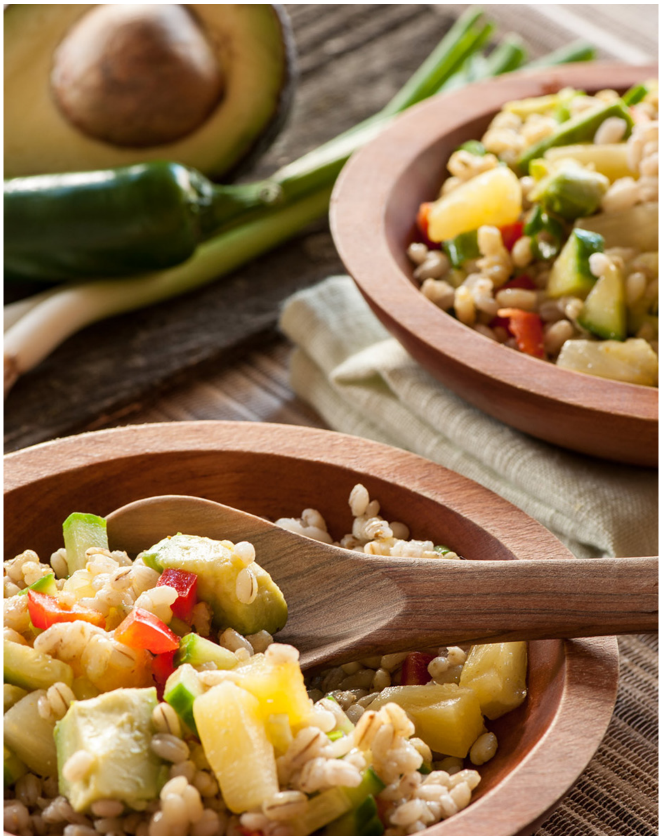
Barley flour can be incorporated into a variety of foods (e.g. bread, pita bread, tortillas, crackers, pasta) to meet the cholesterol-lowering health claims for barley in Canada and the U.S.[16] Research has also shown that fortification of wheat flour with 15 per cent barley protein isolate resulted in pita bread with superior chemical composition, functional properties and content of EAA, compared to pitas made only with wheat flour.[17]

The Health Benefits of Plant-Based Proteins

The Academy of Nutrition and Dietetics states that "appropriately planned vegetarian diets, including total vegetarian or vegan diets, are healthful, nutritionally adequate, and may provide health benefits in the prevention and treatment of certain diseases. Well-planned vegetarian diets are appropriate for individuals during all stages of the lifecycle—including pregnancy, lactation, infancy, childhood and adolescence—and for athletes."[7] Vegetarian diets tend to be lower in saturated fat and cholesterol, and higher in dietary fibre, magnesium, potassium, vitamin C, vitamin E, folate, carotenoids, flavonoids and other phytochemicals.[7] Nutrients that are at greater risk of being inadequate in vegetarian diets include vitamin B12, calcium, vitamin D, zinc, and long-chain omega-3 fatty acids (EPA and DHA).[7]

Cardiovascular Disease

Cardiovascular disease (CVD) has been the number one killer worldwide during the past decade.[18] Barley has been recognized in Canada and the United States as a cardioprotective food. In 2006, the United States Food and Drug Administration indicated that foods containing barley providing at least 0.75 grams of soluble fibre per serving are permitted to claim on the food label that they may help to reduce the risk of coronary heart disease.[19] Health Canada followed in 2012 by permitting the claim that barley-containing foods are a source of fibre shown to help lower cholesterol.[20]



In addition to a fibre content that lowers cholesterol, barley may provide heart health as a plant-based protein source. Research over the past five decades has demonstrated that plant proteins produce cholesterol-lowering effects in animals in comparison to animal proteins, which, in general, can be more cholesterolemic and atherogenic. Plant protein intake appears to be inversely associated with cardiovascular disease mortality.[21] Several factors have been suggested to explain these results. The ratio of amino acids in plant versus animal protein may be one reason.[22] Animal protein may also exert hypercholesterolemic effect through an increased absorption and decreased turnover of cholesterol.[22]

Vegetarian diets are associated with a number of cardiovascular benefits, including lower blood cholesterol, blood pressure and body mass index as well as decreased risk of type 2 diabetes.[7] The Academy of Nutrition and Dietetics reported that vegetarian diets are linked to a lower risk of death from ischemic heart disease.[7]

In one study, a large cohort of postmenopausal women (29,017) was followed prospectively for 15 years to determine cancer incidence and mortality from coronary heart disease, cancer and all causes.[23] Among women in the highest intake quintile, coronary heart disease mortality decreased by 30 per cent with an isoenergetic substitution of vegetable protein for carbohydrate, and plant protein for animal protein. Vegetable protein sources were derived from dried beans, tofu, nuts and peanut butter. Increased coronary heart disease mortality was associated with red meats and dairy products when these were substituted for carbohydrate foods.[23]

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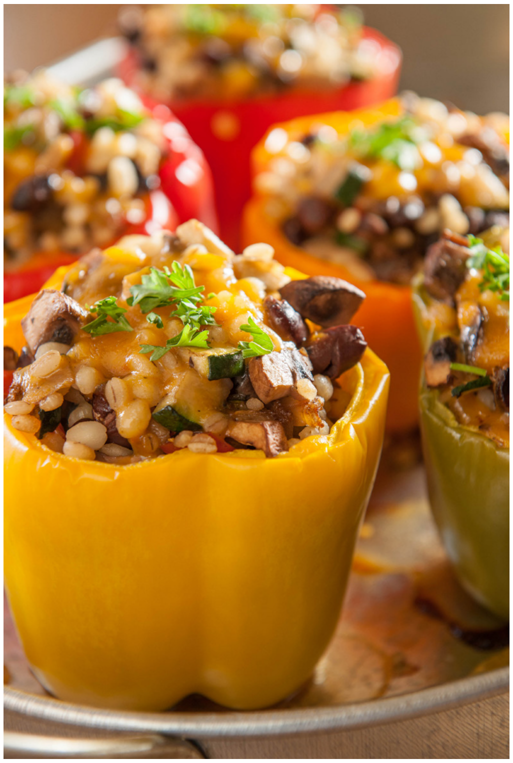
A comparison of three healthful diets, all with reduced saturated fat intake, was performed to determine the effect on blood pressure and serum lipids.[24] One diet was rich in carbohydrates, another rich in protein (about half from plant sources), and the third diet was rich in unsaturated fat (primarily monounsaturated fat). Compared to baseline, all diets resulted in lower LDL-cholesterol and blood pressure. However, the diets higher in protein or fat showed greater improvements in these parameters compared to the high-carbohydrate diet.[24]

An "Eco-Atkins" diet was compared to a lacto-ovo vegetarian diet to determine the effects on LDL-cholesterol and weight loss.[25] The "Eco-Atkins" diet was reduced in carbohydrates and high in plant protein, with 31 per cent of total calories from protein, 26 per cent carbohydrate and 43 per cent fat. The plant proteins were derived from gluten, soy, nuts, fruits, vegetables and grains. The lacto-ovo diet provided 58 per cent of energy from carbohydrates, 16 per cent from protein, and 25 per cent from fat. After four weeks, both groups recorded similar levels of weight loss—approximately four kilograms. Reductions in serum LDL-cholesterol concentration, total cholesterol to HDL-cholesterol ratio, and apolipoprotein B to apolipoprotein A1 ratio were greater for the "Eco-Atkins" diet compared with the high-carbohydrate diet. Apolipoprotein A1 is a protein found in HDL "good" cholesterol, whereas apolipoprotein B is found in "bad" serum lipids—chylomicrons, VLDL- and LDL-cholesterol. Systolic and diastolic blood pressures were also significantly lower following the high-plant-protein diet. The "Eco-Atkins" diet appeared to have lipid-lowering advantages over a conventional high-carbohydrate, low-fat diet that included animal products.[25]

Diabetes

The number of adults with diabetes worldwide has more than doubled over three decades and is now estimated to be 8.3 per cent, or 371 million people.[26] Studies indicate that nutrition therapy aimed at improved glycemic control can significantly lower hemoglobin A1C by approximately 1 per cent in type 1 diabetes and one to two per cent in type 2 diabetes within three to six months.[27] Glycated hemoglobin occurs when glucose molecules attach to the hemoglobin in red blood cells. A hemoglobin A1C value of ≥6.5 per cent is a criterion for the diagnosis of diabetes.[28]

Barley is a rich source of total dietary fibre and β-glucan, a soluble fibre that positively impacts the postprandial glycemic and insulinemic response. Barley may also make beneficial dietary contributions to preventing diabetes as part of a vegetarian diet. The age-adjusted risk for developing diabetes was found to be two times greater in non-vegetarians compared to vegetarians.[7] Meat and processed meat intake appears to be an important independent risk factor for the development of diabetes even after adjustment for body mass index, dietary fibre, magnesium, fat and glycemic load.[7] Higher intakes of vegetables, grains, legumes and nuts are associated with significantly lower risk of insulin resistance and type 2 diabetes, and improved glycemic control in both normal and insulin-resistant individuals.[7]



Obesity is a major risk factor for type 2 diabetes, and high-protein diets have become popular as a weight loss strategy. But these diets are often high in animal protein and may result in negative health consequences due to concomitant intake of saturated fat and replacement of other healthful foods. Plant proteins can help to increase dietary protein intake and have been shown to be inversely associated with body mass index in adults and adolescents.[29,30]

Barley, a protein source rich in β-glucan, is a wise food choice for supporting human health as well as the health of the planet.

Appendix A – Protein Assessment

The quality of a protein is determined by assessing its essential amino acid composition, digestibility and bioavailability of amino acids.[31] The following sections describe several of the measurement scales and techniques that are used in protein quality assessment. The protein quality ranking of select foods using the various assessment techniques are shown in Table 4.

Protein Efficiency Ratio

The protein efficiency ratio (PER) determines the effectiveness of a protein through the measurement of animal growth. This technique requires feeding rats a test protein and then measuring the weight gain in grams (per gram of protein consumed). The computed value is then compared to a standard value of 2.7, which is the standard value of casein protein. Any value that exceeds 2.7 is considered to be an excellent protein source. However, this calculation provides a measure of growth in rats and does not provide a strong correlation to the growth needs of humans.

Biological Value

Biological value measures protein quality by calculating the nitrogen used for tissue formation divided by the nitrogen absorbed from food. This product is multiplied by 100 and expressed as a percentage of nitrogen utilized. The biological value provides a measurement of how efficient the body utilizes dietary protein. A food with a high value correlates to a high supply of the essential amino acids. The biological value does not take into consideration several key factors that influence the digestion of protein and interaction with other foods before absorption.

Net Protein Utilization

Net protein utilization is similar to the biological value except that it involves a direct measure of retention of absorbed nitrogen. Net protein utilization and biological value both measure the same parameter of nitrogen retention. The difference is that the biological value is calculated from nitrogen absorbed whereas net protein utilization is from nitrogen ingested.

Amino Acid Score

The amino acid score (AAS) provides a measure of the actual amounts of individual amino acids in a food relative to requirements. It does not, however, evaluate whether the proteins are digestible.

The AAS is determined by dividing an AA in food protein by the AA in a high-quality reference protein (usually egg and/or milk protein). Scores of 1.0 or greater for an amino acid indicate that this amino acid is not limiting relative to requirements. The lowest score over the range of all essential amino acids is taken as the amino acid score for the entire protein source, irrespective of the relative contributions of other amino acids.

Animal sources of proteins have the highest PER, BV, net protein utilization and PDCAAS. The most common way to improve these variables in plant-based proteins is to combine them with animal proteins source. However, many food products developed with plant-based proteins are meant for applications in which people are avoiding animal proteins. Hence the need to combine one plant source with another to provide complementary proteins containing all EAA.

Protein Digestibility Corrected Amino Acid Score

For human nutrition, the most recent recommendations suggest that the quality of a protein is defined by: (i) the relative contribution that the amino acids contained in the protein make to an individual's amino acid requirement; and (ii) the digestibility of the protein. Thus, the protein digestibility corrected amino acid score (PDCAAS) was developed using the AAS while taking digestibility into account. The reference values used for the PDCAAS are based upon the essential amino acids requirements of preschool-age children. The PDCAAS is the preferred method for measurement of protein value.

Table 4. Protein quality rankings of select foods

Protein Type	PER	BV	Net Protein Utilization	PDCAAS
Beef	2.9	80	73	0.92
Casein	2.5	77	76	1.00
Egg	3.9	100	94	1.00
Milk	2.5	91	82	1.00
Peanuts	1.8	-	-	0.52
Soy protein	2.2	74	61	0.91
Wheat gluten	0.8	64	67	0.25
Whey protein	3.2	104	92	1.00

PER, protein efficiency ratio; BV, biological value; PDCAAS, protein digestibility corrected amino acid score
Adapted from U.S. Dairy Export Council[32] and Sarwar[33]

Digestible Indispensable Amino Acid Score (DIAAS)

In February 2013, an expert consultation panel of the Food and Agriculture Organization (FAO) of the United Nations recommended a new, advanced method for assessing the quality of dietary proteins. The report recommends that the Digestible Indispensable Amino Acid Score (DIAAS) replace the PDCAAS as the preferred method of measuring protein quality.[34]

The report recommends that more data be developed to support full implementation, but in the interim, protein quality should be calculated using DIAAS values derived from fecal crude protein digestibility data. Under the current PDCAAS method, values are truncated to a maximum score of 1.00, even if derived scores are higher.

The DIAAS method is believed to provide a more accurate measurement of the amounts of amino acids absorbed by the body and the contribution of an individual protein source to a human's amino acid and nitrogen requirements. Using the DIAAS method, protein sources can be differentiated by their ability to supply amino acids for use by the body and puts the importance of protein quality at the core of healthy, sustainable diets.

The FAO report ascertains that food proteins differ in their relative nutritional value, and places a greater emphasis on the importance of protein quality. Mixed North American diets generally meet basic protein and amino acid needs because intake of high-quality proteins dominates over low-quality proteins. On that basis, some believe that regulators do not recognize the importance of protein quality for the general healthy population. However, if the DIAAS method is adopted by both FAO and Codex, the debate will be re-opened.

Protein efficiency directly impacts the commercial value of a protein product. The current PDCAAS method has been widely used to market the nutritional value of both plant and animal protein ingredients. However, in changing the method to DIAAS, differences in protein quality may become apparent.

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