Nutritional Benefits of Meat. A White Paper

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Summary

A “nutrient dense” food contains a generous amount of nutrients relative to it caloric content. Meat, poultry, fish, dry beans and peas, eggs, nuts, and seeds supply many nutrients including protein and essential amino acids, B vitamins (niacin, thiamin, riboflavin, B6 and B12), vitamin E, iron, zinc, and magnesium. Beef, lamb, pork, and poultry all provide 20-30 g of protein / 100 calories, however the iron content of poultry is less than half that in beef. The soybean products, boiled green soybeans and tofu, contain about half the amount of protein as red meat and poultry, less iron and no vitamin B12. While corn, rice and kidney beans contain significantly fewer calories than the animal protein sources, they also contain less protein and iron, and no vitamin B12. Soybeans, black beans, pinto beans and kidney beans contain substantially more iron than lamb or beef, however, the iron in animal food products is present in the heme form, while that in vegetable protein sources is in the non-heme form. Absorption of heme iron is efficient while that of non-heme iron is not. Zinc and niacin are required for a number of enzymes in the energy production pathways. The majority of the zinc and niacin in the American diet are derived from meat, poultry and fish. Vitamin B12 is required for the formation of red blood cells and for fatty acid metabolism in the formation of the myelin sheath surrounding nerves. It is found in essentially all animal food sources, particularly in fish, milk, eggs, meat, poultry and liver, but not in vegetable foods.

The amino acid balance in an “ideal” protein (5.5% lysine, 3.5% sulfur-containing amino acids, 4% threonine, 1% tryptophan and 7% leucine) is based on egg protein, the standard to which all others are compared. Lamb, pork, chicken breast, turkey breast, tuna and salmon meet all the requirements; beef meets the proportional requirements with the exception of tryptophan. Soy beans (boiled, mature), black beans and kidney beans meet all the proportional requirements except the sulfur-containing amino acids. Pinto beans and split peas meet all except for the sulfur-containing amino acids and threonine. The most commonly deficient proportional essential amino acid among the vegetable-based protein sources are the sulfur-containing amino acids.

The glycemic response is the increase in blood glucose after consuming a food. The concept of the Glycemic Index has been controversial because it reflects how quickly a food raises blood sugar levels, but it does not take into account the total carbohydrate content in a serving of the food which is an important component of the glycemic response. However, animal-derived muscle foods contain no carbohydrate, so they do not increase blood sugar. In addition, dietary protein significantly reduces the glycemic response of carbohydrate. Vegetable protein sources contain varying amounts of carbohydrate which must be considered in the total glycemic load of the food.

Animal protein intake has been suggested as a cause for demineralization of bone due to its effects on urinary calcium excretion. There is no consistent evidence for superiority of one type of protein over another on calcium metabolism, bone loss prevention or fracture risk reduction, however total protein does appear to be positively related to bone loss prevention. Plant-based diets are often high in phytate and fiber content, which decrease iron, zinc, and calcium bioavailability. They lack vitamin B12, are of low energy density, and contain poorer quality protein than diets that contain some animal-based products. This over-all lack of nutrient availability and protein quality may have a greater impact on bone health than any one factor alone.

Nutritional deficiency of protein is often associated with impaired immune responses (cell-mediated immunity, phagocyte function, cytokine production, secretory antibody response, antibody affinity, and the complement system). Glutamine, the most abundant amino acid in the body, is a "conditionally" essential amino acid because, when the body is under extreme stress (during infection or inflammation), the need for glutamine increases, however the production does not. Red meat and poultry contain > 4 mg glutamic acid/100g while plant foods contain significantly less, particularly beans (< 2 mg/100g). Low vitamin B6 intake is also associated with impaired immune function.

Meat, poultry and fish are generally good sources of vitamin B6 (>0.3 mg/100 g) while most plant-derived foods contain considerably.

It has been suggested that increasing iron stores from iron derived from red meat initiates oxidative damage and inflammation via free radicals. Increasing red meat intake can reduce leukocyte counts. Some studies suggest decreased (rather than increased) oxidative stress and inflammation when lean red meat intake is increased at the expense of dietary carbohydrate-rich foods. Overall differences in dietary patterns ("Western" vs "prudent" diets) have been associated with various measures of inflammation, lipoprotein-lipid profile, serum glucose and insulin. However, weight (BMI) appears to be a bigger factor in development of chronic diseases of an inflammatory nature than does protein source. Taurine, glutathione, and choline found in animal food products appear to down-regulate inflammatory responses.

Loss of muscle mass (wasting) is especially apparent during the aging process. There is a growing body of research indicating that dietary protein intakes above the RDA help maintain muscle function and mobility. For muscle protein maintenance to exceed degradation, the amino acid building blocks must be consistently supplied. Dietary leucine appears to have a particular function in that it enhances muscle growth by stimulating mammalian protein synthesis. Meat, poultry and fish are typically excellent sources of leucine, isoleucine and valine suggesting that they would enhance muscle protein synthesis. Meat and poultry products contain more than 2 g leucine/100g of food while most beans and cereal grains contain less than 1g leucine/100g.

Cognition, the ability to perceive, think, and remember, can be affected by deficiencies of specific nutrients, iron and zinc in particular, secondary to protein-calorie deficiency. A positive correlation has been reported between diets containing animal protein source foods, iron, zinc and cognitive performance. Animal protein also contributes choline and carnitine which appear to affect/maintain cognition.

Introduction

That humans evolved as omnivores, consuming both animal and plant materials, as food, is generally accepted. They have both canine and incisor teeth for biting, and molars for grinding. Several dietary nutrient requirements can be found only in animal-based tissues (vitamin B12) or only in plant-based tissues (vitamin C, fiber). Meat is a nutrient-dense food. The nutritional benefits of human consumption of meat make it an essential part of a healthy diet. However, there are those who criticize the value of meat in the human diet.

The *Dietary Guidelines for Americans* state that a healthy diet emphasizes a variety of fruits, vegetables, whole grains, and fat-free or low-fat milk and milk products; includes lean meats, poultry, fish, beans, eggs, and nuts; is low in saturated fats, trans fats, cholesterol, salt (sodium), and added sugars; and stays within a person's daily calorie needs (USDA, 2005).

Meat, poultry, fish, dry beans and peas, eggs, nuts, and seeds supply many nutrients including protein and essential amino acids, B vitamins (niacin, thiamin, riboflavin, B6 and B12), vitamin E, iron, zinc, and magnesium. Proteins function as building blocks for bones, muscles, cartilage, skin, blood, enzymes, hormones, and vitamins, and can, like carbohydrates and fats, provide calories. B vitamins in this food group help the body release energy, assist in the function of the nervous system, aid in the formation of red blood cells, and help the body build tissues. Iron carries oxygen in the blood. Many teenage girls and women in their child-bearing yrs have iron-deficiency anemia and which can be addressed by consuming foods high in heme-iron (meats), which have high iron-bioavailability, or eat other non-heme iron containing foods, with lower iron-bioavailability, along with foods rich in vitamin C, which can improve absorption of non-heme iron. Vitamin B12 is an important nutrient in prevention of anemia as well.

In this white paper, both the benefits and limitations of meat and non-meat sources of protein in the diet are presented. Wherever appropriate, information is expressed in tabular form. This paper is divided into two parts: Part 1—*A Comparison of Red Meat vs. Poultry and Meat vs. Non-Meat Protein* including nutrient density, protein quality and glycemic response and Part 2—*Nutritional Benefits of Meat Protein* including bone health, immune function, inflammation, aging/wasting, and cognition.

Part 1-- A Comparison of Red Meat vs. Poultry and Meat vs. Non-Meat Protein

Nutrient density

"Nutrient density" measures a nutrient or nutrients relative to the caloric content of the food. Foods that supply generous amounts of one or more of the required dietary nutrients compared to the number of calories they supply are considered to be nutrient dense (Hunter and Cason, 2009). Eggs, for example, have a high nutrient density, because they provide complete protein and many vitamins and minerals in proportion to their calories. The protein, fat, calorie, iron, zinc, thiamin, riboflavin, niacin, B6 and B12 contents of selected dietary protein sources is shown in Table 1. While the plant protein sources are generally lower in fat and calories, they are also significantly lower in protein and iron content, lacking in niacin, and vitamin B6 and devoid of vitamin B12.

In 2006, 67% of US adults ($\geq$20 yrs) were overweight (BMI>25) or obese (BMI>30; CDC, 2006). According to the Center for Disease Control, that is a 37% increase between 1998 and 2006. Based on 2009 data, overall self-reported obesity prevalence in the United States was 26.7% which is a 1.1% increase since 2007 (CDC, 2010). Clearly, calorie intake is a concern. For this reason, maximizing nutrient density while minimizing calorie intake is of significant importance for a large portion of the US population. Nutrient density has significant impacts on both over-nourished and under-nourished populations. However, making dietary choices based on calorie content alone can result in either a low-calorie diet or a high–calorie diet which is lacking a number of important nutrients. Iron provides an example. Iron deficiency is the most widespread dietary deficiency in the world. Iron in animal tissues has much higher bioavailability than does the non-heme iron found in plant materials.

Diets high in meat as a protein source are often high in saturated fats and can raise low-density lipoprotein (LDL) cholesterol levels in the blood. High LDL cholesterol increases the risk for coronary heart disease. Some foods that are high in saturated fat include fatty cuts of beef, pork, and lamb, regular (75% to 85% lean) ground beef, sausages, hot dogs, and bacon. These sources are also high in cholesterol. Foods from vegetable sources are rarely high in saturated fats and contain no cholesterol (MyPyramid (http://www.mypyramid.gov/ 2009).

Beef, lamb and pork are higher in 16:0 (palmitic acid) and 18:0 (stearic acid) than poultry, and most vegetable protein sources (Table 2). However, peanut butter, sunflower seeds and walnuts contain more of these fatty acids than the red meat sources. Red meats are generally low in monounsaturated fatty acids (16:1 [palmitoleic acid] and 18:1[oleic acid]) and polyunsaturated fatty acids (18:2 [linoleic], 18:3 [linolenic], 20:5 [eicosapentaenoic acid] and 22:6 [docosahexaenoic acid]) which are known to have protective/beneficial effects relative to atherosclerocis. Peanut butter, sunflower seeds and walnuts are high in 18:1 and 18:2. Soybeans, tofu and oat bran also contain significant amounts to 18:2. Only salmon, tuna, flounder and shrimp contain any measurable amounts of omega-3 fatty acids (20:5, 22:6). The red meats and other animal protein sources contain cholesterol while the vegetable protein sources which is a drawback of animal-source protein foods. Pork, lamb, chicken, turkey, flounder and salmon contain more cholesterol than beef. Eggs and shrimp are particularly high in cholesterol.

One of the arguments in favor of eliminating animal food products from the diet is that cholesterol is found only in foods from animal sources, and vegetable foods are generally low in saturated fats. However, animal food protein sources do provide a significant amount of the essential fatty acids, linoleic and linolenic acids, in the American diet.

Protein

Beef, lamb and pork are not higher in protein content than chicken and turkey on an absolute basis (Table 1) or on a per 100 calories basis (Table 3). Beef, lamb, pork, chicken and turkey provide 20-30 g of protein/100cal. On an absolute basis, salmon, flounder, tuna and shrimp contain similar amounts of protein as red meat and poultry. Nutrient densities are shown in Table 2. On a per 100 calories basis, the protein content is: beef lean > chicken and turkey breast > lamb > 90/10 ground beef and salmon > tuna > pork > 80/20 ground beef > 70/30 ground beef, shrimp, and flounder (Table 3). However, on a 100 calorie basis the iron content of poultry is less than half that found in beef. While flounder, tuna and shrimp are significantly lower in fat content than most of the red meat and poultry products, salmon is not (Table 1).

On an absolute basis, cottage cheese and hard boiled eggs contain about half the protein as red meat and poultry. American cheese contains just slightly less protein than red meat and poultry but significantly more fat (>22%; Table 1)). Milk (2% fat) contains slightly more than 10% the amount of protein /100 cal as beef pork, lamb and chicken (Table 2). On a per 100 calories basis, eggs contain a similar amount of protein as pork and salmon and about 2/3 that of beef and lamb.

The soybean products, boiled green soybeans and tofu, contain less protein than the animal food products. They contain about half the amount of protein as red meat and poultry on an absolute basis (Table 1), however the protein content / 100 calories is about 2/3 that of the animal products. Soy beans, kidney beans, lentils and oat bran contain 2 to 9 mg of protein/100 calories compared to 15 to 17 mg of protein/100 calories for red meat and poultry (Table 3). While corn, rice and kidney beans contain significantly fewer calories than the animal protein sources, they also contain less protein and iron, and no vitamin B12 (Table 1). Black beans contain about the same amount of protein/100 calories as tuna and about half that of beef.

Iron

The recommended dietary iron intake for adults aged 19-50 yrs is 8 mg (men) to 12 mg (women) / day (NAS, 2006). Red meat protein sources provide 1 to 3 mg of iron (Table 1). They contribute just over one mg of iron/100 calories. Beef provides substantially more iron than pork. Chicken and turkey contain only 60% to 70% as much iron (1.1 to 1.4 mg) /100 grams as beef and pork and on a per 100 calorie basis (0.63 to 0.74 mg) (Tables 1 and 3). Pork contains the least amount of iron on an absolute basis (0.8 mg/100 g) and on a per 100 calorie basis (0.5 mg/100 calories) of the red meat and

poultry groups. Salmon and flounder contain less than one third the amount of iron and even less zinc than beef. They contain less than half the amount of iron and zinc as poultry.
Soybeans, black beans, pinto beans and kidney beans contain substantially more iron (3 to 5 mg/100g) than lamb or beef (1.8 to 2.3 mg/100 g). On a per 100 calories basis, corn has an iron content similar to poultry (Table 3). However, the availability of this iron is an issue. Iron absorption is influenced by the form in which it is consumed. It is important to note that the iron in animal food products is present in the heme form, while that in vegetable protein sources is in the non-heme form. Absorption of heme iron is efficient ranging from 15% to 35%. It is not generally affected by diet. Only 2% to 20% of the non-heme iron in plant foods is absorbed (rice, corn, black beans, soybeans) (Beiseigel et al., 2007). Non-heme iron absorption is influenced by various food components. Cereal grains and beans often contain high amounts of phytic acid and tannins, strong metal chelators, which bind iron reducing its bioavailability. Consuming lean meat, fish, or poultry with beans or dark leafy greens can improve absorption of the iron in vegetable sources by up to three times. Vitamin C (L-ascorbic acid) also increases iron absorption (Hamdaoui et al., 2003; Medline, 2010).

Zinc, Niacin and Vitamin B12

Zinc is required for the activity of many enzymes in functions in the immune system in the body. However, the dietary requirement is very low. Zinc is widely distributed in the food supply; the richest sources are oysters, liver, beef, dark poultry meat, veal, and crab. Estimates suggest that 43% of dietary zinc is provided by meat, poultry, and fish, and 25% is provided by milk, cheese, ice cream, and eggs (Welsh and Marston, 1982). For most Americans, the major dietary source of zinc is beef. Chicken and turkey contain one third to one half as much zinc (1 to 2 mg) / 100 g as beef and lamb (3.3 to 5.4 mg; Table 1). Zinc content follows the same general trend on a per 100 calorie basis. The zinc content of beans is slightly lower (1 to 5 mg / 100g) than that found in the animal products on an absolute basis, however these differences are essentially lost when these foods are compared on a per 100 calorie basis (red meat = 1.8 to 2.3; beans = 1.4 to 3.0 mg / 100 calories). The RDI for zinc is 8 mg/d for women and 11 mg/d for men 19-70 yrs of age (NAS, 2006).

Niacin (niacinamide) functions as a coenzyme in the Krebs Cycle during the metabolism of carbohydrate to release energy. The RDI for niacin is 14 mg/d for women and 16 mg/d for men 19-70 yrs of age (NAS, 2006). The best sources of niacin are lean meat, poultry, fish, and peanuts. The niacin content of beef, pork, lamb, chicken and turkey ranges from 6.3 to 12.7 mg / 100g (Table 1). Pork contains approximately the same amount of niacin as beef and lamb / 100 g of meat but less than half that of beef on a per 100 calorie basis. Soybeans, black beans, pinto beans and kidney beans contain significantly less niacin (0.3 to 0.6 mg/100 g) than red meat, poultry and fish (2 to 12.7 mg/100g), a difference which is even more dramatic on a per 100 calorie basis. It is also present in adequate amounts in whole grains. Dietary tryptophan can be converted to supply some of the niacin needs if niacin intake is insufficient. However, this conversion is inefficient (60 units of tryptophan = 1 unit of niacin).

Vitamin B12 (cobalamin) is required for the formation of healthy red blood cells and for fatty acid metabolism in the formation of the myelin sheath surrounding nerves. It is found in essentially all animal food sources, particularly in fish, milk, eggs, meat, poultry and liver, but not in vegetable foods. In animal-based foods, vitamin B12 is found in a protein-bound form. The recommended daily allowance of Vitamin B12 is 2.0 mcg/d for both men and women. Vitamin B12 content of beef and lamb (1.5 to 2.6 mcg/100g) is four times that of chicken and turkey (<0.4 mcg/100) (Table 1). The differences between these sources are maintained when calculated on a per 100 calorie basis. All fish (salmon, tuna, flounder, shrimp) contain more vitamin B12 than beef and poultry, on both an absolute basis and on a per 100 calories basis (Tables 1 and 3). Salmon contains substantially more vitamin B12 than do beef (sirloin), lamb, pork and the other seafood sources. Eggs contain about 2/3 as much vitamin B12 as beef (1.11 mcg/100g and 1.47 mcg/100 g, respectively). On a per 100 calories basis, eggs and low fat milk contain amounts of vitamin B12 similar to beef and greater than pork and poultry. One of the major nutrient deficits of the vegetable protein sources, aside from their amino acid inadequacies, is their lack of vitamin B12. The RDI for B12 is 2.4 mcg/d for adults 19-70 yrs of age.

Protein quality

The quality of a protein is often described in terms of its ability to maintain body functions and support growth. Individual amino acids are often described as "essential", based on requirements for optimal growth, maintenance of positive nitrogen balance and the ability (or inability) of the body to synthesize them (Daley et al., 1990). Originally, the essential amino acids were considered to be histidine, isoleuine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Protein quality has been evaluated in a variety of ways. Chemical score compares the protein in a food to the protein in egg in terms of g of amino acids (lysine, methionine, phenylalanine, tryptophan) / 100 g nitrogen, and provides information about the first limiting amino acid. The chemical scores for animal food products are highest when considered individually compared to egg. Protein Efficiency Ratio (PER) is a biological test. Weight gain over a 28-d period in weanling rats fed a diet containing 10% of the protein is studied then compared to weight gain in animals fed casein (adjusted to 2.5, the PER of casein). A protein with a PER $\geq$ 2.5 is considered to be of high quality. Biological Value (BV) measures the percent of absorbed nitrogen that is retained (for growth and maintenance) minus the fecal loss in a test animal. Nitrogen balance is a derivative of Biological Value. However, other factors, besides protein quality, can affect growth and result in substantial variation due to overall calorie consumption, diet in general, growth, age of the subject, etc (Labuza and Erdman, 1984). If insufficient calories are consumed to supply energy needs, protein will be catabolized to meet energy needs.

In 1991, the "protein digestibility–corrected amino acid score" (PDCAAS) was adopted by FAO/WHO as the method for measuring protein value in human nutrition (Boutrif, 1991). The PDCAAS compares the concentration of the first limiting essential amino acid in the test protein with the concentration of that amino acid in a reference (scoring) pattern. The scoring pattern is derived from the essential amino acid requirements of the preschool-age child. The score obtained is then corrected for true fecal digestibility of the test protein (Schaafsma, 2000).

> PDCAAS = (mg of limiting amino acid in 1 g of test protein / mg of same amino acid in 1 g of reference protein) x fecal true digestibility %

A number of criticisms of this method have been made regarding the actual amino acid requirements of the preschool child and the way in which protein digestability is measured (ileal vs fecal; Schaafsma, 2005). In addition, the food matrix can have effects unrelated to the amino acid content. The PDCAAS of a number of food groups is shown in Table 4. With the exception of soybeans, (PDCAAS = 0.91), the PDCAAS of the vegetable protein sources are substantially lower (0.50-0.78) than those of the animal food sources (0.91-1.0).

A more recent method of evaluating protein quality is by comparing the balance of "indispensab;e amino acids" (IAA; Millward, et al. 2008; Ullman, 2009). Millward et al. (2008) considers lysine, threonine, valine, isoleucine, leucine, methionine, phenylalanine, tryptophan, and histidine to be indispensable amino acids. Because the metabolic pathways that synthesize these amino acids are not fully developed, cysteine, taurine, tyrosine, histidine and arginine are semi-essential amino acids in children (Young, 1994). Egg protein is the standard against which all other proteins are compared. Proteins can be considered to be "complete" (high quality) or "incomplete" (low quality) based on the presence of the essential amino acids (phenylalanine, tryptophan, lysine, methionine, isoleucine, leucine, valine, threonine) and / or their balance with respect to an "ideal" protein (5.5% lysine, 3.5% sulfur-containing amino acids, 4% threonine, 1% tryptophan and 7% leucine (Ullman, 2009).

Using the lysine (5.5%), sulfur-containing amino acid (3.5%), threonine (4.0%), tryptophan (1.0%), and leucine (7%) distribution for an ideal protein as suggested by Ullman (2009), beef lean meets the requirements with the exception of being slightly low in tryptophan (Table 5). Lamb, pork, chicken breast, turkey breast, tuna and salmon meet all the proportional amino acid requirements. Shrimp and flounder are low in two or more of the essential amino acids. Low fat milk and American cheese are somewhat low in sulfur-containing amino acids; cottage cheese and American cheese are somewhat low in threonine. Egg (hard boiled) contains 7.15% lysine, 5.40% sulfur-containing amino acids, 4.76% threonine, 1.19% tryptophan, and 8.76% leucine which easily meets the requirements for the distribution of ideal amino acids (Ullman, 2009). By comparison, peanut butter meets none of the proportional amino acid requirements and walnuts meet only three (lysine, sulfur-containing, and threonine. Sunflower seeds meet the proportional requirements for all the essential amino acids except lysine, and soy beans (boiled, mature), black beans and kidney beans meet all of the requirements except for sulfur-containing amino acids. Pinto beans and split peas meet all of the proportional requirements for the essential amino acids except for the sulfur-containing amino acids and threonine. Peanut butter, walnuts, lentils, brown rice and corn are deficient in three or more of the essential amino acids. The most commonly deficient proportional essential amino acids among the vegetable-based protein sources are the sulfur-containing amino acids.

Methionine is an essential dietary amino acid required for normal growth. It can be converted to cysteine. Homocysteine, with vitamin B12 as a cofactor for methionine synthase and L-methylmalonyl-CoA mutase, can be converted to methionine. Methionine is an intermediate in the biosynthesis of carnitine, taurine, and lecithin as well. The ability of cysteine to provide a portion of the total sulfur amino acid requirement in humans, thereby sparing the dietary methionine requirement, has been an area of considerable debate (Ball et al., 2006). Vegetable proteins are generally lower in total sulfur-containing amino acid content, however this is not always the case. Red meat, poultry and fish contain 1 to 1.26 g of sulfur-containing amino acids /100 g of protein while vegetable protein sources generally contain less than 0.6 g / 100g (Table 5). For humans, vegetable proteins generally have poorer nutritional quality than animal proteins because they are imbalanced in the ratio of cysteine to methionine needed to meet growth requirements (Table 2). The cysteine to methionine ratio of red meat, poultry and fish is generally in the range of 1 part cysteine to 2-2.5 parts methionine (Table 6). Of the total sulfur-containing amino acids, 30-40% is cysteine and 60-70% is methionine. However, the cysteine to methionine ratio of soybeans, kidney beans, split peas and lentils are generally more heavily weighted in the direction of cysteine (60% cysteine, 40% methionine) as a proportion of the total sulfur-containing proteins than the animal protein sources. It is this cysteine to methionine ratio that is responsible for the lower quality of vegetable proteins, not the total amount of sulfur-containing amino acids / g of protein (Massey, 2003).

The essential branched chain amino acid (leucine, isoleucine, valine) content of a protein source is important with respect to its ability to support growth (Millward et al., 2008). Animals cannot synthesize these amino acids, however they are able to store them when they are obtained in sufficient amounts from the diet. Adults need about 20 mg/d of isoleucine and 31 mg/d of leucine.

Plant proteins, in combination, can complement each other making the protein amino acid profile “complete” in total. The use of the “complementary” proteins concept requires knowledge of the amino acid profile in various foods. Vegetable protein sources can be divided into cereal grains maize, legumes (soybeans) and nuts. The first limiting amino acid in most cereal grain protein (wheat, rice) is lysine, that in corn is tryptophan, while that in most legumes is the sulfur-containing amino acid, methionine. While none of these vegetable-based sources provides all the essential amino acids in the ideal proportions for growth, used together, they can.

Effect of diet on composition of beef, pork, poultry and fish tissues

Commercially, cattle are grazed on grass or pasture for some or all of their lives. Cattle have bacteria in the rumen and gut that break down the cellulose in plant materials. Many go to feed lots at 12-18 mo of age where they are fed a high carbohydrate (usually grain) diet for 4-6 months to increase their growth rate and bring them to market more quickly. High-producing dairy cattle are also fed large grain rations as a calorie source to increase milk production.

One of the major draw-backs of animal food products is their content of saturated fatty acids relative to polyunsaturated fatty acids (PUFA). Attempting to alter the fatty acid profile in the meat of ruminant animals is difficult, at best. In ruminants (cattle and sheep), dietary unsaturated fatty acids are saturated in the rumen making the challenge to increase the polyunsaturated:saturated fatty acid ratio while retaining the n-6 fatty acid / n-3 fatty acid ratio found in livestock finished on forage diets. Polyunsaturated fatty acids can be protected chemically, or by feeding them in the seed coat. These produce different flavors in cooked meat due to oxidative changes that occur during storage and cooking (Wood and Enser, 1997). The source of forage can affect growth performance. Hersom et al. (2004) grazing on native range tallgrass have a reduced rate of gain compared to those on winter wheat, but when cattle were grazed to a common endpoint, carcass composition was similar. Feeding grain generally increases average daily gain, carcass weight, grade fat, and intramuscular fat content when compared with forage feeding at similar times on feed. However, effects on individual fatty acids and palatability scores vary widely with source grain (or concentrate) and level of feeding (Mandell et al., 1998). Smet et al. (2000) found that, compared to a low energy diet, a high energy diet fed to finishing cattle increased the monounsaturated (MUFA) and decreased the PUFA proportion with no change in the saturated fatty acid proportion. The high energy diet increased the proportions of C14:0, C16:0, C16:1, and C18:1 and decreased the proportions of C18:2 and C20:4.

Faucitano et al. (2008) reported that, compared to a grain diet, a forage-based diet increased the concentration several intermediates of ruminal biohydrogenation in the intramuscular fat (cis-9, trans-11, cis-15 C18:3; trans-11, cis-15 C18:2; trans-11 C18:1). Forage feeding also increased the proportion of cis-9, trans-11 C18:2) and decreased the concentration of trans-10 C18:1. Diet can also affect subcutaneous adipose tissue levels of 15:0, 17:0, and n-3 fatty acids in cattle on low corn stalk compared high corn stalk or alfalfa hay diets. Intramuscular adipose tissue proportions of 16:0, 18:1(n-9), 18:2(n-6), 20:4(n-6), 22:5(n-3), MUFA, PUFA, and n-6 fatty acids also differed (Jenschke et al., 2008). Feeding cattle dietary fish oil increases levels of omega-3 fatty acids in tissues resulting in lower n-6/n-3 ratios (Wistuba et al., 2007).

Unlike cattle and sheep, pigs are monogastric animals with less capacity to biohydrogenate dietary fat sources. There has been recent work to manipulate the n-6/n-3 ratio by feeding higher levels of alpha-linolenic acid (rapeseed) or its products, eicosapentaenoic acid (20:5) and docosahexaenoic acid (22:6) (derived from fish oils; Gerber et al. (2009)). Reducing the dietary PUFA content of the porcine diet has been shown to lower 18:2 content of pork fat (Gatlin et al. 2002). Lopez-Bote et al. (2002) found that partial replacement of PUFA with MUFA in swine diets resulted in a lower n-6/n-3 fatty acid ratio in the neutral lipid fraction than the subcutaneous fat, however, intramuscular polar lipids were unaffected. Weber et al. (2006) found that conjugated linoleic acid (CLA), fat, and ractopamine (added to porcine diets to enhance growth and carcass quality) work in an additive fashion. Feeding CLA and MUFA to pigs also results in reduced lipid oxidation in the pork (Martin et al., 2008). Alpha- and gamma-tocopherol contents of muscle also reflect the tocopherol concentration of the diets (Daza et al., 2005; Boler et al., 2009).

Feeding fish oil to pigs results in a dose-dependent response between dietary and tissue fatty acids (Hallenstvedt et al, 2010) It increases the level of very long chain n-3 fatty acids, especially C22:5n3 (docosapentaenoic acid; DPA). Feeding tuna oil increases the proportion of n-3 fatty acids to total fatty acids especially Eicosapentaenoic acid (EPA) and docosapentaenoic acid (DHA), but not l-linolenic acid (Jaturasitha et al 2009). It increases oleic acid slightly but has a large effect on n-6 fatty acids. Kloareg et al. (2007) reported that, in pigs, one-third of the n-3 fatty acids deposited in the tissues result from the conversion of 18:3 to other metabolites (EPA, DPA , DHA). Haak et al. (2009) showed that feeding fish oil rich in l-linolenic acid, EPA and EHA increases the EPA and DHA content of the meat. However, high n-3 fatty acid concentrations in meat are often associated with fishy flavors whose development can be prevented with high dietary levels of vitamin E (Wood and Enser, 1997).

Diet, especially sources of energy and protein, can have significant effects on the composition of poultry meat. Poureslami et al. (2010) compared several oil sources (soybean, linseed, palm, fish) in chicken diets. Soybean oil resulted in a 2 to 3 fold increase in the proportion of C18:2n-6 and C20:4n-6 in breast and thigh muscle. Feeding dietary linseed oil increased C18:3n-3 by 4 to 20 times compared to diets containing soybean, palm or fish oil. It also increased of C22:6n-3. A fish oil increased the proportion of C22:6n-3 than the proportions of C20:5n-3 and C22:5n-3 in breast and thigh meat. Jeun-Horng et al. 2002) reported that feeding supplementary fish oil to chickens decreased total n-6 fatty acid content in frankfurters and increased total n-3 fatty acid content. Gibbs et al. (2010), acknowledging the advantage of using fish oil or fish meat to increase the human dietary supply of long chain n-3 PUFA, especially EPA and DHA, have suggested the use of algal biomass as an alternative source of long chain n-3 PUFA for poultry diets.

Inclusion of dried distillers grains and solubles (DDGS) in poultry diets has been an interest of the industry for several yrs. Schilling et al. (2010) found that including up to 12% resulted in high-quality breast and thigh meat quality, however more than 12% results in thigh meat that is more susceptible to oxidation. Min et al. (2009) reported similar results. Galonja et al (1995) found that enzyme modification of a corn-based diet fed to chickens decreased the myristic acid and increased the linoleic acid contents in the intramuscular fat.

Micronutrients such as copper and vitamin E can also modify composition of poultry meat. Skrivan et al. (2000, 2002) reported that feeding supplementary copper to broilers decreased total lipid and cholesterol content of breast meat and increased long-chain PUFA. Suchy et al. (2010) reported that feeding broiler chickens lupin meal, as a partial replacement for soybean meal, increased calcium content and decreased magnesium content in both breast and thigh. Jensen et al. (1998) found that feeding gamma tocopherol, retinol and beta carotene to broilers affected concentrations of these compounds in thigh meat. Gamma-tocopherol increased as dietary retinol and beta-carotene increased.

Fish is a good source of digestible proteins, fluoride, iodine, selenium, and vitamin D3 (Usydus et al., 2008). The fundamental nutritive benefit is the highly advantageous fatty acid composition, especially the long chain PUFA not found in other food products. Some farm-raised fish contain more n-3 fatty acids than their wild-caught counterparts, while some contain less. This is likely due to diet. Haliloglu et al. (2002) reported farm raised trout contain significant amount of n-3 fatty acids, especially DHA. Cultured pike fillets contain several times more fat than their wild caught counterparts, however the relative quantity of saturated fatty acids and unsaturated fatty acids as a percent of total fatty acids is similar (Jankowska et al., 2008). However, cultured pike contain significantly less DHA and arachidonic acid than their wild-caught counterparts. The increasing aquaculture of cold water fish has resulted in the use of common plant oils that contain only traces of the long-chain PUFA (Pickova et al., 2007). They are lacking in n-3 fatty acids and result in fish tissues with significantly lower concentrations of these fatty acids. When plant oil-based diets are fed during the growing phase and replaced by a fish oil-based diet prior to harvest, most of the beneficial lipid composition of fish, in terms of human dietary components, is restored. Feeding Artic charr fish oil/rapeseed oil at various levels, Pettersson et al. (2009) reported profound reductions in 20:5n-3 and 22:6n-3 and an increase in 18:2n-6 as dietary rapeseed oil content increased.

Effect of cooking on meat composition

Cooking can have significant effects on fat and moisture content. It decreases the absolute fat content of veal by about 18-44% concomitantly influencing the content of the component fatty acids (Gerber et al. 2009). Poon et al. (2000) reported that high heat transfer rate cooking of cooked ground beef patties resulted in greater MUFA and cholesterol loss compared to cooking using a low heat transfer rate indicating that heat conductivity of the cooking surface impacts the lipid composition.

Cooking generally decreases the content of all vitamins, with potential thiamine losses exceeding 70% (Gerber et al. 2009). Cooksey et al. (1990) found that cooking beef roasts reduced thiamin content irrespective of cooking method. Uherova et al. (1993) demonstrated that conventional roasting of beef and pork resulted in a thiamine retention of 48-96%, while microwave cooking resulted in 87% to 94%. Conventional roasting resulted in 22% to 49% vitamin B6 retention, while microwave cooking allowed retention of 60% to 81%. Dahl and Mathews (1990) reported microwave reheating of cooked, chilled beef loaf accounted for approximately 10% of the 30% loss in thiamin content. Two-thirds of the nutrient loss occurred during initial cooking (63C to 66C). Pinheiro-Santana et al. (1999) reported that, during cooking, beef had the highest nicotinic acid retention (61% to 92%), followed by chicken (65% to 84%) and pork (63% to 77%). Cooking by steam/convection oven preserved the nicotinic acid better than charbroiling, frying, roasting and stir frying.

Heme iron from meat is much more bioavailable than non-heme iron (Kristensen and Purslow, 2001). Distribution of iron among the various compartments can be altered by cooking. Heme iron relative to non-heme iron decreases by 62% after heating for 2 h at 80C (Kristensen and Purslow, 2001). Clark et al. (1997) reported that heme and total iron content of deep fried chicken breasts and legs was 1.7 and 6.5 mg Fe/g meat. Han et al (1993) found that heating beef and chicken decreased iron content in water-soluble fractions and increased it in water-insoluble fractions as temperature increased from 27C to 100C. The greatest decrease in heme-iron occurred between 55C and 85C. Schricker and Miller (1983) found that microwave heating reduced non-heme iron levels in ground beef patties from below 10% to over 100%. Cooking fresh beef using common household methods increased non-heme iron less than 10%.

As well as nutrient losses, cooking can generate compounds which may have potential health implications. It has been suggested that red meat, itself, causes cancer. Heterocyclic aromatic amines (HAA), in particular, are of concern because of their potential mutagenic and carcinogenic effects. These mutagens formed during cooking of meat may be responsible for increases in rectal cancer risk, not red meat itself (Murtaugh et al., 2004). HAA content varies with the cut of beef, cooking method, and doneness level. 2-amino-3,4-dimethylimidazo[4,5-f]quinoline content increases with doneness for steak and hamburger patties, up to 8.2 ng/g. 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine was the predominant heterocyclic amine produced in steak (1.9 to 30 ng/g), but was formed only in very well done fried or grilled hamburger. Roast beef did not contain any of the heterocyclic amines studied (Sinha et al., 1994). HAA concentration in beef patties has been shown to increase from < 1 mg to 33 mg/kd as frying time increases from 3 to 6 min (Jautz et al., 2008). Tureskey et al. (2008) reported that the concentrations of HAA ranged from <0.03 to 15 ppb in cooked meats and poultry.

Knize et al. (1995) evaluated a number of foods (fried or charbroiled hamburgers, fried chicken, chicken breast sandwiches, fish sandwiches, breakfast sausages) for HAA. They found undetectable levels in 53% of samples and only low levels [≤ 1 ng/g total of 2-amino-3,8-dimethylimidazo[4,5-f] quinoxaline (MeIQx), 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP) and 2-amino-3,4,8-trimethylimidazo[4,5-f]quinoxaline] in the remaining samples.

Pence et al. (1998) reported that feeding rats a beef diet high in HAA resulted in more dimethylhydrazine-induced colon cancer, but only in the context of a low-fat diet. However, in a case-controlled study (n>1,000) by Muscat and Wynder (1994), there was no association between consumption of well-done or medium-cooked beef and colorectal cancer. Shen et al. (1998) found that feeding rats PhIP (72 ng/g) at the level found in cooked beef, resulted in no adducts of this compound in the stomach or colon or gene mutations. This suggests that, at the levels found in cooked beef, PhIP is not persistant like feeding high levels of the pure compound.

The association/mechanism between meat, meat cooked to high temperatures, and/or fat and various cancers of the digestive tract remains somewhat unclear.

Glycemic response

The glycemic response is the increase in blood glucose after consuming a food. The glycemic index (GI) is the ratio of the blood glucose value after eating a particular food to the value after eating the same amount of white bread or glucose (GI = 100). A GI of 55 or below is considered low, 56-69 is intermediate and 70 or above is considered high. The GI for selected foods is shown in Table 7.

The concept of the GI has been controversial for sometime because it reflects how quickly a food raises blood sugar levels, but it does not take into account the total carbohydrate content in a serving of the food which is an important component of the glycemic response. Since the actual amount of carbohydrates consumed in a meal varies greatly, the GI concept has been expanded to include the concept of glycemic load (GL). Glycemic load incorporates the amount of digestible carbohydrates better assessing the impact of a meal or snack on glucose response. A low GL food is considered 10 or less, medium 11-19 and high is 20 or more (Yale-New Haven Nutrition Advisor, 2005).

Glycemic Load=GI/100 x grams of carbohydrate per serving

A lower glycemic index suggests a slower rate of digestion and absorption of carbohydrates. This may imply that the products of carbohydrate digestion are being removed by the liver more slowly. This slows the glycemic response (increase in serum glucose) which often indicates a lower insulin demand. The leveling of glycemic response and insulin demand may improve long-term blood glucose control and blood lipids. Dietary protein significantly reduces the glycemic response of carbohydrate. The Glycemic Load of various foods is also shown in Table 7. Berry et al. (2003) found that feeding a mixed meal of 300 g of ground beef with a 50-g glucose drink resulted in a slower gastric emptying time and a longer time to reach peak blood glucose. Cui et al. (1999) reported that adding pork to rice (stir fry) decreased the GI from 83 to 72. Adding beef to steamed bread decreased the GI from 68 to 49.

Because of the association of high blood glucose levels and development or exacerbation of chronic disease, diets that emphasize foods with a low GI may offer health benefits (Levitan et al, 2008). Increased dietary GI and GL may increase risk of coronary heart disease (CHD), stroke, and type 2 diabetes mellitus through adverse effects on blood lipids and systemic inflammation. Liu et al. (2000) followed women aged 38-63 yr with no previous diagnosis of diabetes mellitus, myocardial infarction, angina, or stroke for 10 yr. After adjustment for age, they found that dietary glycemic load was directly associated with risk of CHD. In addition, classifying carbohydrate by glycemic index, as opposed the traditional classification of either simple or complex, was a better predictor of CHD risk. McMillan-Price et al. (2006) compared the impact of 4 diets on various health outcomes for obese adults. Diets 1 and 2 were high carbohydrate (55% of total energy intake), with high and low GIs, respectively; diets 3 and 4 were high protein (25% of total energy intake) with high and low GIs, respectively. They found that body fat loss occurred with both high-protein and low-GI regimens but cardiovascular risk reduction was optimized by a high-carbohydrate, low-GI diet. Oh et al (2005) reported a relationship between fat intake, BMI, and risk of cardiovascular disease (CVD) in young women.

Over nearly 9 yrs, Song et al. (2004) evaluated more than 37,000 women over 45 yr of age. They found positive associations between intakes of red meat and processed meat and risk of type 2 diabetes (after adjusting for age, BMI, total energy intake, exercise, alcohol intake, cigarette smoking, and family history of diabetes). Fung et al. (2004) concluded that a diet higher in processed meats could increase the risk of type 2 diabetes in women. In men aged 40-75 with no initial diagnosis of diabetes, CVD or cancer, van Dam et al. (2002) found that, in an 8-yr follow up study, total fat and saturated fat intakes were associated with a higher risk, of type 2 diabetes. These results were not independent of consumption of processed meats. However, in a 10 yr study with more than 38,000 participants, when 5% of the energy was derived from protein rather than carbohydrate or fat, Sluijs et al. (2010) found that diabetes risk increased. Animal protein increased diabetes risk while vegetable protein was unrelated to risk.

In a 5 yr study of more than 70,000 women age 40-60, Villegas et al. (2006) found that processed meat intake was positively associated with the risk of type 2 diabetes. In addition, it appeared that the effect of unprocessed meat intake on diabetes may be modified by BMI. Snowdon and Phillips (1985) reported that after following more than 25,000 adult, white adults for 21 yr, male vegetarians had a substantially lower risk than non-vegetarians of diabetes as a contributing cause of death. Authors state that the associations observed between diabetes and meat consumption did not appear to be confounded by, other selected dietary factors, or physical activity. Tonstad et al (2009) reported that the BMI was lowest in vegans. It was incrementally higher in lacto-ovo vegetarians, pesco-vegetarians, semi-vegetarians, and nonvegetarians. Vegans, lacto-ovo vegetarians, pesco-vegetarians, and semi-vegetarians, had a lower risk of type 2 diabetes than nonvegetarians. The 5-unit BMI difference between vegans and nonvegetarians suggests a substantial potential of vegetarianism to protect against obesity and diabetes as result. Linde et al. (2006) reported that, for men, hamburger and beef consumption were associated with higher BMI. In women, higher BMI was associated with hamburger, fried chicken, hot dog, bacon, sausage, egg, French fry, and overall fat consumption. Lower fat intake and higher fruit/vegetable/fiber intake were associated with reductions in BMI. However, in a study of normal and overweight high school boys, Chai et al. (2008) found that the intake of animal foods was significantly higher in the normal weight group than in the overweight group. The mean daily dietary GI and GL of the normal weight group were 67.7 and 214.6, respectively, while those of the overweight group were 68.2 and 202.7, respectively. In this case, consumption of animal food products did not increase weight, GI or GL.

In addition, genetic influences appear to exist. Hasselbalch et al. (2008), studying 600 pairs of twins, demonstrated genetic influence on total energy, macronutrient energy, and dietary fiber intakes, the GI and the GL of the foods consumed, and the dietary energy density, with significant heritability estimates ranging from 0.25 to 0.47 in men and 0.32 to 0.49 in women. No genetic influence was found for some food groups (poultry and eggs for men) while genetic effects were demonstrated for other food groups (juice and eggs for women)

Taken together, these studies reflect the difficulty of separating out dietary components (low vs high GI and GL carbohydrate and fat) as risk factors for the development of chronic disease.

Foods that have a GI of 0 (red meat, poultry, fish, eggs, nuts and tofu) contain no carbohydrate and therefore, make no contribution to serum glucose. Because red meats, poultry and fish all have a GIs of 0, none of these three groups has an advantage over the other. However, this may not be the case for processed products. For example, pork sausage has a GI of 28 and hot dogs have a GI of 40. These are still in the “low” range but would add into the total GL of a meal.

Vegetable protein sources in the legume category, such as lentils, peas, and beans, have higher GIs but remain below 55 indicating that they have some effect on blood sugar but not nearly as much as rice (72-87). In addition, their GLs range between 1 and 10. Blair et al. (2006) reported that 3 out of 4 low carbohydrate soy foods containing 15 to 40 g protein/100g had a low GI and insulin index compared to a glucose reference.

Part 2--Meat Protein Benefits

Bone Health

Bone health is influenced by calcium absorption and urinary calcium excretion, both of which of are affected by a variety of factors. Allegations have been made that protein, particularly that from animal sources, induces chronic metabolic acidosis which increases calciuria and accelerates mineral dissolution ultimately having negative effects on bone health (susceptibility to fracture). This thought is based on short term human studies where a calciuric response is generated in response to increased protein intakes.

Catabolism of dietary protein generates ammonium ion and sulfates from sulfur-containing amino acids. Citrate and carbonate are mobilized from bone to neutralize these acids (Massey, 2003). Some plant proteins (soy, corn) have similar total amounts of sulfur / g of protein as animal proteins (eggs, milk, meat, fish, poultry). Increasing the intake of purified proteins, whether from animal or plant sources, increases urinary calcium (Massey, 2003). Urinary calcium and bone metabolism can be and are modified by other nutrients found in protein-containing foods. The high potassium content in some plant proteins (legumes, grains) can decrease urinary calcium. Increased calcium in the urine in response to an increased dietary protein intake, either animal or vegetable, is at least partially explained by a stimulation of the intestinal calcium absorption. (Bonjour, 2005). Abelow et al. (1992) suggests that endogenous acid production due to the metabolism of animal proteins compromises bone health. Animal protein is a rich source of sulfur-containing amino acids, which are metabolized to (fixed acid) sulfuric acid. Theoretically, vegetable protein sources could conteract this effect, because they are a rich source of organic anions (bicarbonate) which can neutralize protein-derived acid and supply substrate (carbonate) for bone formation.

On the other hand, Wengreen et al. (2004) found that middle-aged adults who consume more protein-rich foods, such as beef, have fewer hip fractures resulting from osteoporosis. In the elderly, low protein intakes are often observed in patients with hip fracture (Bonjour, 2005). Abelow et al. (1992) and Barzel and Massey (1998) suggest that the correlation between hip fracture rate and animal protein intake is a function of the negative effects on bone of prolonged exposure to dietary acid. If that is the case, the net rate of endogenous acid production (from all dietary sources of both acid and base), not just the fixed acid produced from animal protein breakdown, would be a primary determiner of bone health. Dietary factors such as endogenous base production (i.e. bicarbonate from vegetable protein) reduce the rate of endogenous (sulfuric) acid production from animal protein.

While protein intake can increase urinary calcium excretion, phosphorus can decrease it. A higher phosphate diet can compensate for the hypercalciuric effect of higher protein intake. These relationships have critical implications for bone health. Spencer et al. (1988) found no adverse effects of high protein meat and milk diets on calcium balance which they attributed to the phosphorus content of these proteins. Hunt et al. (1995) studied low meat, low meat supplemented with minerals, and high meat diets. Urinary calcium was lower on the mineral-supplemented diet but did not differ between the low and high meat diets suggesting that the higher phosphate intake of the high meat diet was an important factor; its hypocalciuric effect may have compensated for the hypercalciuric effect of the higher protein intake. Many other food components (vitamin D, isoflavones, caffeine, salt, antioxidants, oxalate, phytates) affect the potential renal acid load which predicts the effect on urinary acid and urinary calcium. The net rate of endogenous acid production can vary substantially depending on the relative intakes of animal and vegetable foods at any level of protein intake. To assess the net acid / base effect of the diet and to determine whether the hip fracture rate correlates with net endogenous acid production, vegetable food intake must be taken into consideration (Hu et al. 1993). Protein is usually consumed with other nutrients which is likely why the effects on urinary calcium are inconsistent (Beef Facts, 2008a). Excess dietary protein intake, from either animal or plant sources, could be detrimental to bone health, but its effect is likely to be modified by other nutrients in the diet.

Many studies indicate that selective dietary protein deficiency results in deterioration in bone mass and strength. In a population (>900) with an average age of 75 yr and a mean protein intake of 68 g/d, Misral et al. (2010) found a reduced risk of hip fracture with higher dietary protein intake. Koh et al. (2009) reported that hip fracture was inversely correlated with BMI. Protein deficiency, due to decreased bone mass and altered muscle function, contribute to osteoporotic fractures. With respect to the adult bone, dietary protein enhances the somatomedin system (insulin-like growth factor 1; IGF-I), which exerts a positive effect on skeletal development and bone formation ((Schurch et al., 1998). According to Rizzoli et al. (2001), IGF-I may be directly involved in the pathogenesis of osteoporotic fractures and their complications in elderly patients. If vitamin D and calcium intakes are adequate, dietary protein supplementation to correct inadequate intake increases circulating IGF-I levels. Increased IGF-1 levels are associated with increased bone mineralization and fewer fractures (Heaney and Layman, 2008). Protein may be as essential as calcium and vitamin D to maintain bone health and prevent osteoporosis (Bonjour 2005). Meat as a protein source appears to be associated with higher blood levels of IGF-1.

In the Framingham study, Hannan et al. (2000) found that lower total and animal protein intakes were associated with higher rates of bone loss. Higher intakes had no adverse effects. Intakes of both protein and calcium must be adequate to fully realize the benefit of each nutrient on bone health. Optimal protein intake for bone health is likely higher than current recommended intakes, particularly for the elderly.

Frasetto et al. (2000) evaluated hip fractures / 100,000 women over the age of 50 in 33 countries and the country-specific data on per capita consumption of vegetable and animal foods. Hip fracture incidence varied directly with total and animal protein intake and inversely with vegetable protein intake. However, when adjusted for total protein intake, vegetable food consumption independently, negatively predicted hip fracture. They concluded that the critical determinant of hip fracture risk (in relation to the acid/base effects of diet) is the net load of acid in the diet, when the intake of both acid and base precursors is considered. There is no consistent evidence for superiority of one type of protein over another on calcium metabolism, bone loss prevention or fracture risk reduction, however total protein does appear to be positively related to bone loss prevention (Massey, 2003). Frasetto et al (2000) suggest that moderating animal food consumption and increasing the ratio of vegetable / animal foods may offer protective effects in with respect to hip fracture.

Plant-based diets are generally high in phytate and fiber, which decrease iron, zinc, and calcium bioavailability, lack vitamin B12, are of low energy density, and contain poorer quality protein (Gibson, 1994). This over-all lack of nutrient availability and protein quality may have a greater impact on bone health than any one factor alone.

Immune function

Nutritional deficiency, especially of protein, is commonly associated with impaired immune responses, especially cell-mediated immunity, phagocyte function, cytokine production, secretory antibody response, antibody affinity, and the complement system (Chandra, 1996; Casteneda et al., 1995, Fielding, 1995). Reductions in body protein due to protein-calorie malnutrition or due to the aging process can impair wound and fracture healing, reduce the ability to fight infection, and maintain tissue integrity (Casteneda et al., 1995; Fielding, 1999). In general, animal proteins are superior to vegetable proteins in sustaining growth and maintaining immunity (Bloom et al., 1996) however, it may be that deficiencies of concominant nutrients (zinc) or malabsorbtion of required nutrients for optimal immune system function also occur. Daley et al. (1990) demonstrated that arginine enhances cellular immune mechanisms, in particular T-cell function. Arginine also has an immunopreserving effect during protein malnutrition-induced immunosuppression.

Reduction of protein compartments (red and white blood cells, platelets, stem cells, antigens, antibodies, hormones, enzymes) contributes to impaired wound and fracture healing, loss of skin elasticity, an inability to fight infection, and muscle weakness and decreased in functional capacity which can lead to falls, and an inability to maintain tissue integrity (Casteneda et al., 1995; Fielding, 1995). These changes may have a profound effect on the health and well-being of older adults. Castaneda et al. (1995) demonstrated that feeding elderly women a low protein diet (0.45 g/kg body wt/d) resulted in negative nitrogen balances accompanied by losses in lean tissue and muscle function, and depressed immune response, compared to those fed adequate (0.92 g/kg body wt/d) protein diets. Those in the adequate protein group maintained nitrogen balance with no changes in lean tissue. They also had improved immune response, serum immunoglobulins, albumin, total protein values, and muscle function.

There appear to be specific amino acids involved in immune function. Several controlled studies have concluded that glutamine supplementation has beneficial effects on the clinical outcome of critically ill and surgical patients (Coëffier, and Déchelotte, 2008). These results may be explained by glutamine's influences on the inflammatory response, oxidative stress, cell protection, and the gut barrier. Glutamine, found mostly in the muscles and lungs, is the most abundant amino acid in the body. It can be manufactured by the body, but it is a "conditionally" essential amino acid because when the body is under extreme stress (during infection or inflammation), the need for glutamine increases, however production does not. A glutamine deficiency can cause the immune response to fail. This amino acid is the primary energy source for small intestine enterocytes, lymphocytes, macrophages, and fibroblasts (Andrews and Griffiths, 2002; Newsholme, 2001). In immune cell culture, Calder (1999) reported that glutamine is used at a high rate and is required for optimal lymphocyte proliferation and cytokine production by lymphocytes and macrophages. However, Yeh (2001) found that glutamine supplementation had no effect on production of inflammatory mediators nor did it enhance cellular immunity in septic rats. Red meat and poultry generally contain > 4 mg glutamic acid / 100g while plant foods contain significantly less, particularly beans which consistently contain < 2 mg / 100g (Table 4).

Low vitamin B6 intake and nutritional status are associated with impaired immune function, especially in the elderly. Vitamin B6, a coenzyme for glycogen phosphorylase, an enzyme that catalyzes the release of glucose from stored glycogen, must be obtained from the diet because humans cannot synthesize it (Higdon and Drake, 2007). Vitamin B6 deficiency decreases production of immune system cells and decreases production of interleukin-2. Restoring vitamin B6 status normalizes lymphocyte proliferation and interleukin-2 production which suggests that adequate vitamin B6 intake is important for optimal immune system function in older individuals (Meydani et al. 1991). Meat, poultry and fish are generally good sources of vitamin B6 containing >0.3 mg / 100 g of food while most plant-derived foods contain considerably less (Table 1). Beef contains more than twice the amount of vitamin B6 (per 100 g of protein) as soybeans and lentils with other vegetable protein sources containing significantly less than that (Table 3). In addition, some plant foods contain pyridoxine glucoside, a form of vitamin B6 which is only about half as bioavailable as vitamin B6 from other food sources or supplements. Vitamin B6 in a mixed diet has been found to be approximately 75% bioavailable (Food and Nutrition Board, Institute of Medicine. 1998). The recommended daily intake of B6 for adults aged 19 to 50 is 1.3 mg/d. This increases to 1.5 mg/d for women and 1.7 mg/d for men over 50. Those who follow a very restricted vegetarian diet need vitamin B6 supplementation.

Inflammation

Inflammation is the response of tissues to injury or irritation. Inflammation is of concern with respect to diet because of its potential contribution to the pathogenesis of atherosclerosis (and ultimately, CHD) as well as other chronic diseases. A variety of nonspecific indicators of inflammation such as blood leukocyte counts, high-sensitivity C-reactive protein, serum amyloid A protein and plasma fibrinogen concentrations have been used to assess the effects of dietary components on inflammatory reactions.

Dietary Pattern-Induced Inflammation

It has been suggested that increasing iron derived from red meat increases iron stores and initiates oxidative damage and inflammation via the generation of free radicals in the body. Increasing red meat intake can reduce leukocyte counts (which is correlated with serum ferritin), however, it is unclear whether these associations are causally related to red meat protein *per se* or to iron. As a measure of immune function, Johnathan et al. (2007) evaluated whether increased red meat intake reduced leukocyte counts. In the red meat-consuming group, the change in leukocyte count was correlated with change in serum ferritin. The results of this study suggest decreased (rather than increased) oxidative stress and inflammation when lean red meat intake is increased at the expense of dietary carbohydrate-rich foods.

Fung et al. (2001) evaluated 2 major dietary patterns, "Western" and "prudent", with biomarkers of obesity and CVD risk. The prudent diet was characterized by higher intakes of fruit, vegetables, whole grains, and poultry, while the Western diet was characterized by higher intakes of red meats, high-fat dairy products, and refined grains. The Western diet was positively correlated with insulin, C-reactive protein (CRP), leptin, and homocysteine concentrations, and inversely correlated with plasma folate concentrations. The prudent diet was positively correlated with plasma folate and inversely correlated with insulin and homocysteine concentrations. Lopez-Garcia et al. (2004) found that food consumption patterns are directly associated with markers of inflammation and endothelial dysfunction. The prudent diet pattern was inversely associated with plasma concentrations of CRP and E-selectin. The Western diet pattern was positively correlated with CRP, interleukin 6, E-selectin, soluble intercellular adhesion molecule 1, and soluble vascular cell adhesion molecule 1. Schulze et al. (2005) reported that processed meat consumption produced results similar to the Western diet pattern. The dietary patterns identified (high in sugar-sweetened and diet soft drinks, refined grains, processed meat, and vegetables other than yellow, cruciferous, and leafy greens, tomatoes, and legumes, but low in wine, coffee, cruciferous and yellow vegetables) may increase chronic inflammation and raise the risk of developing type 2 diabetes. Azadbakht and Esmaillzadeh (2009) identified an association between red meat intake and metabolic syndrome, and inflammation (as measured by C-reactive protein) in 40-60 yr old women. Mahon et al. (2007) compared the short-term effects of two moderately high protein (24% of energy) diets that differed in protein source (beef or chicken) vs. a lacto-ovo vegetarian low protein (17% of energy) diet on changes in body mass and body composition, lipoprotein-lipid profile, CRP, glucose, insulin, leptin and adiponectin concentrations in overweight and mildly obese postmenopausal women. All three groups lost weight, and decreased BMI, total and LDL cholesterol by 12%. However no differences existed in CRP.

Joosen et al. (2010) evaluated the influence of isocaloric replacement of red meat with fatty fish on endogenous nitrosation, inflammation and genotoxicity in apparently healthy adults. Increasing fish intake and reducing red meat intake had no effect on inflammation or fecal water-induced (oxidative) DNA damage; however, it did reduce the formation of mutagenic and potentially carcinogenic nitroso compounds. Authors suggested that this could potentially reduce colorectal cancer risk.

Sulfur-containing Amino Acids

Three major products of sulfur amino acids, glutathione, taurine, and homocysteine influence inflammatory aspects of the immune response both *in vitro* and *in vivo* (Grinble, 2006). Oxidation of lipids and glycation of proteins resulting in advanced glycoxidation end products (AGE) are generated exogenously and endogenously. AGE can be bound by immunoglobulin cell surface molecules. This, in turn, can suppress endogenous autoregulatory functions converting proinflammatory signals into inflammatory signals (Bengmark, 2007). Taurine, glutathione, and homocysteine modulate these signals *in-vivo*.

Taurine is found in animal foods (cod, 108 mg/100 g; mackerel, 78 mg/100 g; salmon, 60 mg/100 g) while vegetable foods are essentially devoid of this amino acid. Sources of histidine include egg white, 1.8 g/100 g; cheese, soy flour, 1.3 g/100 g; beef, lamb, 1.0 g/100 g; 0.8-1.2 g/100 g; chicken, turkey, 0.8 g/100 g; lentils, 0.7 g/100g (USDA 2009). Beef is an excellent source of carnitine (steak, 56-162 mg/4 oz; ground beef, 67-99 mg/4 oz); milk (4 mg/ 4 fl oz), codfish (4-7 mg/ 4 oz) and chicken (3-5 mg/4 oz) are significantly lower, while vegetables generally contain less than 1 mg/half cup (NIH 2004).

Taurine is a sulfonic acid compound found in the highest concentrations in neutrophils. It has been suggested that it reduces inflammation by down-regulating neutrophil activation and endothelial adhesion (McCarty, 1999). Park et al. (1997) demonstrated that taurine can function as an inhibitory modulator of inflammation by inhibiting NO production in macrophages. Animal products are generally rich in taurine while plant products are devoid of this amino acid (Laidlaw et al., 1990). For this reason, those who consume diets which contain no animal products are likely to have poor taurine status as well as higher serum levels of homocysteine. In rats, supplementing a high-fructose diet with taurine has been shown to prevent *in-vitro* glycation of protein and hemoglobin, and the accumulation of AGEs (Nandhini et al., 2004).

Glutathione is a tripeptide composed of γ-glutamic acid, cysteine and glycine. It can be synthesized intracellularly from its constituent amino acids, therefore, it is not a dietary requirement. When pathogens invade the mucosa, epithelial cells and macrophages produce pro-inflammatory cytokines, (e.g. interleukin-1β; IL-1β) that recruit neutrophils. Neutrophils produce reactive oxidants which participate in the immune response and inactivate microbes. Glutathione can protect gut epithelial cells from free radical damage during bacterially-induced neutrophil production of oxidative species (van Ampting et al., 2009). Cysteine stimulates glutathione synthesis and its availability is often the limiting factor for intracellular glutathione synthesis (Meister 1991). For this reason, sufficient amounts of all three precursor amino acids is necessary for glutathione synthesis and so that immune system functions normally preventing tissue damage.

An elevated plasma homocysteine level is considered to be a risk factor for CVD. Various mechanisms have been proposed to explain this association including oxidative activity of homocysteine. Some evidence exists that this may be due to reactive oxygen species which cause tissue damage. Moat et al. (2000) found that in adults with plasma total homocysteine levels > 20 μM had elevated levels of erythrocyte superoxide dismutase and plasma glutathione peroxidase (GSHPx). Elevated plasma homocysteine levels represent oxidative stress which results in an adaptive increase in the activity of antioxidant enzymes. However, in a number of studies, reducing total homocysteine levels via addition of folate or ascorbate has had mixed effects on oxidative damage.

There is some evidence that choline is anti-inflammatory as well. In a cross-sectional survey of > 3,000 adults with no CVD history, Detopoulou et al. (2009) collected fasting blood samples, measured inflammatory markers and collected food-frequency questionnaires from participants. Choline intake was calculated from food-composition tables. Compared with participants consuming <250 mg choline/d, participants who consumed >310 mg/d had 22% lower concentrations of C-reactive protein, 26% lower concentrations of interleukin-6, and 6% lower concentrations of tumor necrosis factor. These results support an association between choline intake and the inflammation process in free-eating and apparently healthy adults. Beef liver (355mg/3 oz serving)is an excellent source of choline however, egg (126 mg/ 1 large), Atlantic cod (71 mg/3 oz), beef (67 mg/3 oz), salmon (56 mg/3 oz) (Zeisel et al., 2003). High protein vegetable sources are lower in choline content (peanut butter, 20 mg/2 Tbsp) (NIH, 2004). According to Bengmark (2007) histidine, carnitine and carnosine have similar effects in animal studies.

Aging/Muscle Wasting

Sarcopenia is the unintentional, involuntary loss of lean body mass (muscle and bone mass), functional strength and power associated with aging (Hector and Joseph, 2007; Hoffman and Falvo, 2004). As people age, body composition changes. Of special interest is the reduction in total body protein most noticeable as a decrease in skeletal muscle. According to Lopez and Jimenez (2007), sarcopenia, in the non-obese, frail elderly population, is a consequence and manifestation of chronic energy deficit and malnourishment coupled with decreased physical activity. Between 30 and 60 yrs of age, muscle mass decreases at a rate of 0.3% to 0.8% per yr, dramatically accelerating after age 60 (Lopez and Jimenez, 2007). The negative change in body composition is associated with increased risk for CVD, insulin resistance, and type II diabetes. When adjusted for age and gender, the prevalence of sarcopenia varies from 6 to 15% after 65 yrs of age (Melton, 2000). Up to 25–40% of muscle mass has been lost by age 80. This can lead to decreased weight-bearing physical activities and energy expenditure, ultimately increasing osteoporosis, risk of falls, fractures, and hospitalizations. The mechanisms leading to sarcopenia remain unclear but result from an imbalance between rates of protein synthesis and degradation. However, other physiologic proteins (organ tissue, blood components, immune bodies) also decline (Chernoff, 2004).

The loss of skeletal muscle mass is associated with an increase in body fatness; it decreases basal metabolic rate and daily energy needs. The current Dietary Guidelines for Americans recommendations for protein intake are based on the 2005 recommendations which recommends that 10-35% of calories come from protein. Healthy adults are encouraged to consume 0.8 g / d / kg body weight. Studies suggest that older adults require more protein (up to 1.6 g/kg/d) than younger people in order to maintain positive nitrogen balance (Evans, 2004). Because of their decreased energy requirement and calorie intake, compared to their younger counterparts, the elderly benefit most from an increased intake of high quality but low fat protein (eggs, low fat meat and fish, whey, casein) (Evans, 2004). Protein intakes higher than the current Dietary Reference Intake of 0.8g/kg/ body weight may enhance muscle protein development and reduce progressive muscle loss with age (Paddon-Jones et al., 2008; Symons et al., 2007). Consuming at least 15 g of essential amino acids at each meal may help maintain muscle mass and strength (Wolfe, 2006).

To assess whether a protein-rich food can stimulate anabolism in the young and in the elderly, Symons et al. (2007) characterized changes in plasma amino acid concentrations and muscle protein synthesis in healthy young and elderly persons after ingesting lean beef (113g). Mixed-muscle fractional synthesis rate increased by 51% in both the elderly and younger subjects after beef ingestion. Plasma amino acid concentrations peaked 100 min after beef ingestion in both age groups but were substantially higher in the elderly. Despite the differences in the amino acids in the plasma precursor pool, aging did not impair the ability to synthesize muscle protein after ingestion of a common protein-rich food. Aging *per se* does not appear to impair the ability to synthesize muscle protein. Paddon-Jones and Rasmussen (2009) reported maximal muscle protein synthesis in both young and older individuals consuming 25-30 g of protein per meal. However, in the elderly, muscle protein synthesis is blunted when protein and carbohydrate are consumed at the same meal or when protein consumption is < 20 g / meal. Comparing the effects of a meat-free, lacto-ovo vegetarian diet *vs*. a diet containing meat on gains in muscle size from resistance exercise, Campbell et al. (1999) found that subjects who consumed meat (as part of normal dietary intake) gained more muscle than did those who excluded meat. This may be because of the caloric displacement of protein by carbohydrates and/or fats especially in a diet which is borderline in terms of meeting caloric needs.

Altering the protein source in the diet, generally alters the proportions of other macro- and micro-nutrients (fat, carbohydrate, cholesterol, etc) which may also affect muscle anabolism and catabolism.

Haub et al. (2005) compared the effects of soy protein vs beef (0.6 g/kg) on response of men (average = 65 yr) to resistance training. Resistance training increased overall muscle strength. Power increased in both groups, however, the group receiving beef as a protein source also experienced increased high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, total cholesterol, with no changes in triglycerides. They concluded that the lipoprotein-lipid changes were predicted by differences in the saturated fat/fiber ratio and cholesterol/fiber ratio and increases in carbohydrate intake over time.

The primary dietary source of high biological value protein, iron, vitamin B12, folic acid, biotin and other essential nutrients is animal protein (Chernoff, 2004). In addition, there is a growing body of research indicating that dietary protein intakes above the RDA help maintain muscle function and mobility (Layman, 2009). Flakoll (2004) found that daily supplementation of arginine and lysine, which support protein synthesis, and β-hydroxy-β-methylbutyrate (HMB), which can slow protein breakdown, could blunt the gradual loss of muscle, functionality, strength, fat-free mass, and protein synthesis in elderly (>75 yr) women. This suggests that targeted nutrition may have the ability to affect muscle health. Asp et al. (2007) reported that beef intake was positively correlated to muscle mass and was not associated with overall nutrition status as measured by the Mini Nutrition Assessment (MNA), or other measurements of body composition and strength. Beef intake was negatively correlated to total and HDL cholesterol but not LDL cholesterol or triglycerides. Consuming beef in moderation can be a healthy way for older adults to preserve muscle mass and decrease the risk of sarcopenia.

Because muscle atrophy occurs when tissue breakdown exceeds synthesis, a deficiency of muscle-building amino acids can contribute to muscle wasting. Therefore, amino acid therapy may be helpful in regenerating atrophied muscle tissue. The branched-chain amino acids, leucine, isoleucine, and valine, appear to be critical to the process. In growing muscle of animals, protein synthesis is sensitive to nutrient intake (Garlick et al., 2002). It depends especially on amino acid supply and insulin secretion. In healthy adults there is no growth, however, protein is replaced. Muscle protein synthesis appears to be less sensitive to food intake or insulin infusion in adults than in infants and children, other than during infection and trauma.

Dietary leucine enhances muscle growth by stimulating mammalian protein synthesis. Han et al. (2007) reported that treating rats in a simulated weightless situation with 5% leucine mitigated muscle atrophy. Rieu et al (2006) found that leucine supplementation to complete meals (containing protein, carbohydrates and lipids) appeared to increase fractional synthesis rate (FSR) of myofibrillar protein in elderly men. Because only plasma free leucine concentration differed significantly between the control and leucine-supplemented groups, they concluded that leucine supplementation, independently of an overall increase of other amino acids, can improve muscle protein synthesis. They suggested that increasing leucine intake could limit muscle protein loss during ageing. Paddon-Jones and Rasmussen (2009) made similar recommendations. Much effort has been spent on strategies for reversing muscle wasting by nutritional and pharmacological means. However, nutritional support supplemented with branched-chain amino acids or glutamine has produced varying results.

Meat, poultry and fish are typically excellent sources of leucine, isoleucine and valine suggesting that they would enhance muscle protein synthesis. Meat and poultry products contain more than 2 g leucine/100g of food (Table 4). Most beans and cereal grains generally contain less than 1g leucine/100g.

Cognition

Cognition is the ability to perceive, think, and remember. Deficiencies of specific nutrients, iron and zinc in particular, secondary to protein-calorie malnutrition may impair cognitive function (Black

2003). A positive correlation has been reported between diets containing animal protein source foods and cognitive performance. Children supplemented with meat as a protein source, compared to those supplemented with vegetable protein sources, perform better on measures of cognitive function, exhibit improved school performance (test scores), and exhibit more positive behavior during free play (Neuman et al., 2007).

In many of the clinical studies, the target population is the elderly for whom cognition is more likely to be a significant problem. Because the elderly consume primarily low nutrient density foods, during times of high energy requirements such as acute or chronic illness, the energy deficit results in general malnutrition (Seiler, 2009). The most important deficits in this population are those relating to protein, iron, zinc, selenium, and vitamins B12, B1, B6, and D. Hypocaloric diets insufficient in energy, protein, fat, carbohydrate, Ca, P, Fe, vitamin A, thiamin, riboflavin, and niacin have also been linked to poor cognitive function in the elderly. Kaplan et al. (2001) found that in elderly patients with poor cognitive function, fat, carbohydrate and protein all improved cognitive function in the short term (15 min), while protein delayed forgetting after 60 min. Elderly (60-90 yr) subjects who made no errors on the Pfeiffer's Mental Status Questionnaire had higher iron, zinc, foliate, vitamin C, vitamin A and total food intakes and lower saturated fatty acid intakes than those who made errors. However, among adults with normal caloric intakes, Lindseth et al. (2009) found high-fat and high-carbohydrate diets increased performance more than high protein diets. Response time was faster for participants when fed the high-fat diet, especially at higher memory loads.
While meat consumption has sometimes been suggested as a potentiator of diminished cognitive function in the elderly, there are few studies that present data on the association of meat intake, *per se*, with risk of dementia. Barberger-Gateau et al. (2002) reported that, while constituents of meat, such as saturated fat and cholesterol, are more frequently associated with cognitive decline, there was no association between reported meat intake and dementia risk among >1,400 people aged 68+ who were followed for 7 yrs. Morris et al (2004) reported that, while higher intakes of saturated fat and trans-unsaturated fat were linearly associated with greater decline in cognitive score over a 6 yr period in adults 65 and over, however total fat intake, vegetable and animal fat intakes, and cholesterol intake were not associated with cognitive change.

Iron

The positive impact of dietary meat consumption may be due to its contribution of iron and zinc to the diet. Beef protein enhances iron and zinc absorption from other dietary sources which may indirectly affect cognition (Etcheverry et al., 2006). Iron, in particular, appears to improve cognition in the elderly (Ortega et al. 1997). This may relate to the overall low calorie intake of this population. Among school-aged children and adolescents (National Health and Nutrition Examination Survey III data), Halterman et al. (2001) demonstrated an association between iron-deficiency and lower standardized math scores. In an iron supplementation study, Murray-Kolb and Beard (2007) demonstrated that, initially, iron-sufficient women performed better on cognitive tasks, completing them more rapidly than women with iron deficiency anemia. After 16 wk of iron supplementation, the previously iron-deficient women exhibited a 5 to 7-fold improvement in cognitive performance. It appears that increasing the iron status of iron-deficient children and adults, whether by including a dietary source or as a supplement, improves cognitive functioning.

Zinc

Zinc is present in the brain and contributes to both its structure and function. Although the mechanisms linking zinc deficiency with cognitive development are unclear, it appears that it may lead to deficits in children's neuropsychologic functioning, activity, or motor development, and thus interfere with cognitive performance (Black, 1998).

Reviewing the studies on the relationship between zinc and neurological function, Black (2003) concluded that while zinc deficiency has been linked to depressed motor development (among the most vulnerable children) associations with cognitive development are less clear. Stoecker et al.

(2009) reported that zinc-deficient (plasma zinc <7.6 µmol/l) pregnant women had significantly lower Raven's Coloured Progressive Matrices scale A scores (simplest measure of cognition) than non-deficient women (zinc >7.6 µmol/l). Zinc deficiency appeared to be a major factor affecting cognition. Maylor et al. (2006) demonstrated that zinc supplementation (15 and 30 mg/d) had a beneficial effect on special working memory of nearly 400 adults between 55 and 87 yr of age. Tupe and Chiplonkar (2009) found that zinc supplementation increased plasma zinc levels by more than 60% and improved cognitive performance in adolescent girls.

Zinc is present in a wide variety of foods and is found particularly in protein-containing foods. Vegetarian diets often contain less zinc than meat-containing diet. Zinc content of red meat ranges from 2.2-6.3 mg/100g; that of poultry ranges from 1-2 mg/100 g; that of fish ranges from 0.5-3.0 mg/100 g; beans range from 2.1 to 5.0 mg/100 g; cereal grains contain less than 1 mg/100g (Table 1). Only 20% of the zinc present in the diet is actually absorbed by the body (The Vegetarian Society Information Sheet, 2010). Phytate and dietary fiber contained in vegetable protein sources can form insoluble complexes with zinc inhibiting absorption. Overall, zinc supplementation may be beneficial for non-meat consuming individuals who may be consuming insufficient dietary zinc.

Vitamin B12

Vitamin B12 is required for normal nerve function. The body needs small amounts and can store it in large amounts. A deficiency takes a long time to develop, however, once it does develop, it can cause irreversible nerve damage (Anderson and Prior, 2010). Vitamin B12 deficiency has been suggested as a culprit for depressed cognitive function in some populations who consume only vegetable foods. Vegans and strict vegetarians are at higher risk of developing vitamin B12 deficiency than lacto-ovo vegetarians and non-vegetarians because natural food sources of vitamin B12 are found in animal foods (Institute of Medicine, 1998). This many be one of the reasons (but not the only reason) why cognition is improved in those who consume animal foods. Despite evidence that vitamin B12 lowers homocysteine levels and that correlations exist between low vitamin B12 levels and cognitive decline, research has not shown that vitamin B12 supplementation necessarily improves cognitive function (NIH, 2009).

Choline

Choline, a precursor for acetylcholine, is a neurotransmitter that is involved in sleep, muscle control, pain regulation, learning, and memory (Higdon and Drake, 2009). Humans can synthesize choline in small amounts by converting the phospholipid phosphatidylethanolamine to phosphatidylcholine. Phosphatidylcholine can then be metabolized to provide choline. For this reason, choline has not previously been considered to be an essential nutrient. Human populations at risk for choline deficiency include strict vegetarians, who often do not eat any animal products, including milk or eggs, endurance athletes and people who consume excessive amounts of alcohol (University of Pittsburgh Medical Center, 2010).

Recent research indicates that humans cannot synthesize sufficient choline to meet their metabolic needs. The RDI for choline is 425 mg/d for women and 550 mg/d for men 19-70 yrs of age (NAS, 2006). Zeisel (2000) demonstrated that the availability of choline for normal brain development is critical in rats. When pups received choline supplements (in utero or during the second week of life), their brain function changed, resulting in lifelong memory enhancement.

Alzheimer's disease has been associated with a deficit of acetylcholine in the brain. It has been suggested that this deficiency results from a reduction in an enzyme that converts choline into acetylcholine in the brain (McCann et al., 2006). Large doses of phosphatidylcholine have been used to treat patients with dementia associated with Alzheimer's disease in an effort to increase the amount of acetylcholine available in the brain. However, Higgins and Flicker (2002) reviewed of the various trials and found phosphatidylcholine to be no more beneficial than placebo in the treatment of patients with dementia or cognitive impairment. In a community-based population of non-demented individuals, Poly (2008) reported that current choline intake was related to better neuropsychological performance suggesting that dietary intervention has the potential for decreasing the risk for age-related cognitive decline.

In foods, most choline is found in the form of phosphatidylcholine. Eggs and liver are rich in choline (see section on Inflammation). Phosphatidylcholine (lecithin) contains about 13% choline by weight. The RDI for choline is 425 mg/d for women and 550 mg/d for men 19-70 yrs of age (NAS, 2006)

Carnitine

Carnitine is involved in mitochondrial function (NIH, 2004). Concentration of carnitine in tissues declines with age. This reduces the integrity of the mitochondrial membrane (Ames and Liu, 2004) Reviewing human studies, Montgomery et al. (2003) concluded that carnitine (1.5-3.0 g/d of acetyl-L-carnitine for 3-12 mo) appeared to improve mental function and reduce deterioration in older adults with mild cognitive impairment and Alzheimer's disease. Dietary sources of carnitine can be found in the section on “Inflammation”.

Omega-3-fatty acids

An increasing body of research has shown that omega-3 fatty acids, found primarily in fish and organ meats, and DHA-enriched foods, such as eggs, improve cognitive function and vision, anti-inflammatory functions, and reduce the risk for CVD (Anderson and Prior, 2010). Based on their avoidance these food sources, vegetarians may not get enough omega-3 fatty acids in their diets. This may have cognitive, inflammatory and cardiovascular consequences. Using 15N:14N isotopic ratios of body proteins to estimate long-term dietary habits, independent of memory, Williams and O'Connell (2002) reported that a diet rich in fish may ameliorate Alzheimer's disease, possibly by lowering homocysteine. Vegetarian diets did not consume omega-3 fatty acid food sources. In addition, eating beans correlated with poorer cognition in patients with Alzheimer's disease.

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Table 1. Nutrient content / 100 grams of selected protein sources

Food	**Protein, g**	**Fat, g**	**Calories**	**Iron, mg**	**Zinc, mg**	**Thiamin, mg**	**Riboflavin, mg**	**Niacin, mg**	**B6, mg**	**B12, mcg**
Beef sirloin (lean only)*	29.59	5.11	172	1.81	5.38	0.08	0.16	8.65	0.65	1.47
Beef frankfurter, boiled	11.24	29.57	330	1.51	2.46	0.04	0.15	2.37	0.09	1.72
70/30 ground beef, pan broiled	22.86	15.54	273	2.41	5.82	0.04	0.18	5.03	0.33	2.37
80/20 ground beef, pan broiled	24.04	15.94	246	2.59	6.07	0.04	0.18	5.53	0.36	2.66
90/10 ground beef, pan broiled	25.21	10.68	204	2.77	6.33	0.04	0.18	6.03	0.38	2.95
Lamb (lean only)*	29.31	8.24	199	2.34	3.29	0.13	0.43	7.89	0.14	2.58
Pork loin (lean only)*	26.76	7.29	180	0.80	2.20	0.62	0.24	8.49	0.71	0.54
Pork sausage, cooked	19.43	28.36	339	1.36	2.08	0.29	0.20	6.26	0.33	1.18
Chicken (breast), roasted	30.06	7.78	197	1.07	1.02	0.07	0.12	12.71	0.55	0.32
Turkey (breast), roasted	28.71	7.41	189	1.40	2.03	0.06	0.13	6.37	0.48	0.36
Sockeye salmon	27.31	10.97	215	0.55	0.51	0.22	0.17	6.67	0.22	5.80
Flounder	24.16	1.53	117	0.34	0.63	0.08	0.11	2.18	0.24	2.51
Shrimp, moist heat	20.91	3.06	99	3.09	1.56	0.03	0.03	2.59	0.18	1.49
Tuna, canned in water	25.51	0.82	116	1.53	0.77	0.03	0.07	13.28	0.35	2.99
2% Low-fat milk (+A, D)	3.30	1.98	110	0.02	0.48	0.04	0.19	0.36	0.38	0.73
Cottage cheese, 2% fat	11.83	2.45	86	0.15	0.41	0.04	0.19	0.11	0.01	0.45
American cheese	22.15	31.25	375	0.39	2.99	0.03	0.35	0.07	0.07	0.07

Eggs, hard boiled	12.60	10.6	155	1.2	1.1	0.07	0.51	0.68	0.12	1.11
Peanut butter	25.09	50.39	588	1.87	2.91	0.07	0.11	13.04	0.54	0.00
Walnuts	15.23	65.21	654	2.91	3.09	0.34	0.15	1.13	0.53	0.00
Sunflower seeds	17.21	56.80	619	6.81	5.30	0.33	0.29	4.20	0.81	0.00
Soybeans, mature cooked	16.64	8.97	173	5.14	1.15	0.16	0.29	0.40	0.23	0.00
Tofu	8.19	8.72	145	0.27	1.57	0.16	0.10	0.38	0.09	0.00
Black beans, boiled	8.86	0.54	132	2.10	1.12	0.24	0.06	0.51	0.07	0.00
Pinto beans, boiled	9.01	0.65	143	2.09	0.98	0.19	0.06	0.32	0.23	0.00
Kidney beans, canned	8.67	0.5	127	2.98	1.07	0.16	0.05	0.58	0.22	0.00
Split peas, boiled	8.34	0.39	118	1.29	1.00	0.19	0.06	0.89	0.06	0.00
Lentils, boiled	9.02	0.38	116	3.33	1.27	0.17	0.07	1.06	0.18	0.00
Oat bran, cooked	3.21	0.86	40	0.88	0.53	0.16	0.03	0.14	0.03	0.00
Brown rice, long grain cooked	2.58	0.90	111	0.42	0.63	0.10	1.53	0.30	0.15	0.00
Yellow corn, boiled	3.41	1.50	96	0.45	0.62	0.09	0.06	1.68	0.14	0.00

*Broiled

USDA National Nutrient Database for Standard Reference, Release 22 (2009). http://www.ars.usda.gov/ba/bhnrc/ndl

Table 2. Fatty acids of various food sources (g / 100 g sample)

	Fat/ 100g	16:0 g	18:0 g	16:1 g	18:1 g	18:2 g	18:3 g	20:5 n-3, g	22:6 n-3 g	Cholesterol, mg
Beef sirloin	5.03	*1.12*	0.66	0.15	1.85	0.14	0.01	0.00	0.00	51
Beef frankfurter	29.57	0.15	6.48	1.22	12.43	1.01	0.18	0.00	0.00	53
70/30 ground beef*	15.54	3.54	1.73	0.61	6.37	0.34	0.03	0.00	0.00	78
80/20 ground beef*	15.94	3.39	1.88	0.58	6.06	0.36	0.05	0.00	0.00	86
90/10 ground beef*	10.68	2.55	1.62	0.40	4.41	0.31	0.06	0.00	0.00	85
Lamb	7.74	1.49	0.95	0.13	3.14	0.41	0.05	0.00	0.00	16
Pork	9.44	1.81	0.91	0.22	3.35	0.85	0.04	0.00	0.00	89
Pork sausage, cooked	28.36	5.80	2.89	0.78	11.28	3.29	0.00	0.00	0.00	84
Chicken breast	4.51	0.87	0.32	0.18	1.30	0.74	0.04	0.00	0.00	85
Turkey breast	0.74	0.11	0.07	0.02	0.11	0.13	0.00	0.00	0.00	83
Salmon	10.97	1.01	0.16	0.32	1.34	0.11	0.01	0.53	0.70	87
Tuna, in water	0.82	0.16	0.06	0.03	0.09	0.01	0.00	0.02	0.22	30
Flounder	1.53	0.23	0.06	0.07	0.17	0.01	0.02	0.05	0.26	68
Shrimp, steamed	1.08	0.14	0.10	0.06	0.11	0.02	0.01	0.17	0.14	195
Milk, 2% fat	1.98	0.56	0.24	0.03	0.47	0.07	0.01	0.00	0.00	8
Cottage cheese, 2%	2.45	0.44	0.20	0.03	0.41	0.06	0.01	0.00	0.00	10
American cheese	31.25	9.10	3.80	1.03	7.51	0.61	0.38	0.00	0.00	0
Eggs, hard boiled	10.61	2.35	0.83	0.31	3.73	1.19	0.04	0.01	0.04	424
Soybeans, boiled	8.97	0.95	0.32	0.03	1.96	4.67	0.60	0.00	0.00	0
Tofu	4.78	0.51	0.17	0.01	1.04	2.38	0.32	0.00	0.00	0
Black beans, boiled	0.54	0.13	0.01	---	0.05	0.13	0.11	0.00	0.00	0
Pinto beans, boiled	0.65	0.13	0.00	0.00	0.13	0.10	0.14	0.00	0.00	0
Kidney beans	0.50	0.06	0.01	0.00	0.04	0.11	0.17	0.00	0.00	0
Peanut butter	50.39	5.77	1.75	0.00	23.15	13.79	0.08	0.00	0.00	0
Walnuts, English	65.21	4.40	1.66	0.00	8.80	38.09	9.08	0.00	0.00	0
Oat bran, raw	7.01	1.13	0.07	0.01	2.37	2.62	0.12	0.00	0.00	0
Split peas, boiled	0.39	0.01	0.01	0.00	0.08	0.14	0.03	0.00	0.00	0
Lentils, boiled	0.38	0.05	0.01	0.00	0.06	0.14	0.04	0.00	0.00	0
Sunflower seeds	56.80	3.20	2.52	0.05	10.72	37.39	0.08	0.00	0.00	0
Brown rice, cooked	0.90	0.12	0.02	0.00	0.32	0.31	0.01	0.00	0.00	0
Yellow corn, boiled	1.50	0.19	0.01	0.00	0.37	0.59	0.02	0.00	0.00	0

Table 3. Nutrient Density / 100 Calories of Selected Protein Sources

Food	Protein (g)	Iron (mg)	Zinc (mg)	Thiamin (mg)	Ribo-flavin (mg)	Niacin (mg)	B6 (mg)	B12 (mcg)
Beef (lean only)*	17.20	1.05	3.13	0.05	0.10	5.03	0.38	0.82
Beef frankfurter*	3.41	0.46	0.75	0.01	0.05	0.72	0.03	0.52
70/30 ground beef*	8.37	0.88	2.13	0.01	0.07	1.84	0.13	0.87
80/20 ground beef*	9.77	1.05	2.47	0.01	0.07	2.25	0.15	1.08
90/10 ground beef*	12.36	1.36	3.10	0.02	0.09	2.96	0.19	1.45
Lamb (lean only)*	14.78	1.18	1.65	0.07	0.22	3.96	0.08	1.30
Pork (lean only)*	11.6	0.50	1.50	0.30	0.15	2.18	0.18	0.36
Pork sausage, cooked	5.73	0.40	0.61	0.09	0.06	1.85	0.10	0.35
Chicken (breast), roasted	15.75	0.63	1.10	0.04	0.08	4.84	0.25	0.17
Turkey (breast), roasted	15.26	0.74	1.07	0.04	0.06	3.37	0.25	0.19
Sockeye salmon*	12.35	0.26	0.25	0.10	0.08	3.10	0.10	2.70
Flounder*	8.19	0.30	0.56	0.29	0.54	1.86	0.21	2.15
Shrimp, steamed	8.86	3.12	1.58	0.03	0.03	2.62	0.35	3.02
Tuna, in water	9.01	1.33	0.66	0.03	0.03	2.23	0.16	2.58
2% Low-fat milk	6.7	0.10	0.8	0.08	0.33	0.17	0.09	0.73
Cottage cheese	11.83	0.17	0.48	0.05	0.22	0.13	0.00	052
American cheese	22.15	0.10	0.80	0.00	0.09	0.02	0.02	0.02
Eggs, hard boiled	12.6	0.77	0.06	0.05	0.32	0.05	0.08	0.72
Peanut butter	25.09	0.32	0.49	0.01	0.02	2.22	0.09	0.00
Walnuts	15.23	0.44	0.47	0.05	0.02	0.17	0.08	0.00
Sunflower seeds	17.21	0.84	0.86	0.05	0.04	0.68	0.13	0.00
Soybeans, mature boiled	9.62	2.97	0.66	0.09	0.17	0.23	0.13	0.00
Tofu	8.34	0.19	1.10	0.11	0.07	0.26	0.06	0.00
Black beans, cooked	9.02	1.46	0.69	0.13	0.04	0.22	0.02	0.00

Pinto beans, boiled	3.21	1.46	0.69	0.13	0.04	0.22	0.02	0.00
Kidney beans	2.58	2.35	0.28	0.84	0.00	0.10	0.05	0.00
Split peas, boiled	2.64	1.09	0.90	0.16	0.06	0.73	0.06	0.00
Lentils, boiled	7.78	2.87	1.09	0.15	0.06	0.91	0.16	0.00
Oat Bran, cooked	8.25	2.20	1.33	0.08	0.06	0.35	0.08	0.00
Brown rice, cooked	12.6	0.38	0.57	0.09	1.38	0.28	0.14	0.00
Yellow corn. cooked	3.55	0.47	0.65	0.05	0.63	1.75	0.10	0.00

*Broiled

Calculated from USDA National Nutrient Database for Standard Reference, Release 22 (2009). http://www.ars.usda.gov/ba/bhnrc/ndl

Table 4. Protein digestibility–corrected amino acid score of selected foods (PDCAA; Schaafsma, 2005)

Food	PDCAA
Milk	1.00
Egg	1.00
Beef	0.92
Soybeans	0.91
Chickpeas	0.78
Fruits	0.76
Vegetables	0.73
Legumes	0.70
Cereals	0.59

Table 5. Protein (g/100g of food) and amino acid content (g/100 g of food and % of protein) of selected protein sources.

	Protein	**Lysine**	**S-AA**	**Threonine**	**Tryptophan**	**Leucine**	**Phenylalanine**	**Isoleucine**	**Valine**	**Glutamic acid**
Ideal protein		**5.5%**	**3.5%**	**4.0%**	**1.0%**	**7%**				
Beef sirloin (lean only)	29.59	2.50 ***(8.45%)***	1.14 ***(3.81%)***	1.18 ***(4.00%)***	0.20 ***(6.81%)***	2.35 ***(7.94%)***	1.17 (3.95%)	1.35 (4.56%)	1.47 (4.97%)	4.62 (15.61%)
Beef frankfurter	11.24	1.06 ***(9.43%)***	0.43 ***(3.83%)***	0.51 ***(4.53%)***	0.12 ***(1.06%)***	0.58 *(5.16%)*	0.99 (8.81%)	0.56 (4.98%)	0.61 (5.43%)	1.80 (16.01%)
Lamb (lean only)	29.31	2.59 ***(8.73%)***	1.10 ***(3.75%)***	1.25 ***(4.27%)***	0.34 ***(2.41%)***	2.28 ***(7.78%)***	1.19 (4.58%)	1.41 (4.78%)	1.58 (5.39%)	4.25 (14.51%)
Pork (lean only)	28.71	2.46 **(8.57%)**	1.04 ***(3.62%)***	1.24 ***(4.32%)***	0.34 ***(1.18%)***	2.19 ***(7.63%)***	1.09 (3.82%)	1.27 (4.42%)	1.48 (5.16%)	4.47 (15.57%)
Pork sausage, cooked	19.43	*1.48* ***(7.62%)***	0.88 ***(4.53%)***	0.70 *(3.63%)*	0.16 *(0.82%)*	1.30 *(6.69%)*	0.65 (3.35%)	0.71 (3.65%)	0.78 (4.01%)	2.69 (13.84%)
Chicken (breast	31.02	2.64 ***(8.51%)***	1.26 ***(4.06%)***	1.31 ***(4.22%)***	0.36 ***(1.16%)***	2.33 **(7.51%)**	1.23 (3.97%)	1.64 (5.29%)	1.54 (4.98%)	4.65 (15.00%)
Turkey (breast)	28.71	2.83 ***(9.86%)***	1.18 ***(4.11%)***	1.34 ***(4.67%)***	0.34 ***(1.18%)***	2.40 ***(8.36%)***	1.19 (4.15%)	1.56 (5.44%)	1.60 (5.57%)	4.57 (9.26%)
Sockeye salmon, cooked	27.31	2.51 ***(9.19%)***	1.10 ***(4.03%)***	1.20 ***(4.39%)***	0.31 ***(1.13%)***	2.22 ***(8.21%)***	1.07 (3.92%)	1.23 (4.51%)	1.41 (5.16%)	4.08 (14.95%)
Flounder	28.71	2.22 ***(7.73%)***	0.98 *(3.41%)*	1.06 *(3.69%)*	0.27 *(0.94%)*	1.96 *(5.76%)*	0.94 (3.28%)	1.11 (3.87%)	1.25 (4.36%)	3.61 (12.58%)
Shrimp, steamed	20.91	1.82 ***(8.70%)***	0.82 *(3.00%)*	0.85 *(3.92%)*	0.29 ***(1.39%)***	1.66 ***(7.94%)***	0.88 (4.21%)	1.01 (4.83%)	0.98 (4.69%)	3.57 (17.07%)
Tuna, in water	25.51	2.34 ***(9.17%)***	1.03 ***(4.04%)***	1.12 ***(4.39%)***	0.29 ***(1.01%)***	2.07 ***(8.11%)***	1.00 (3.92%)	1.18 (4.63%)	1.31 (5.10%)	3.81 (14.94%)
2% Low-fat milk	3.30	0.23 ***(6.97%)***	0.19 ***(5.76%)***	0.10 *(3.03%)*	0.40 ***(12.12%)***	0.33 ***(10.00%)***	0.16 (4.85%)	0.18 (5.45%)	0.22 (6.67%)	0.78 (23.64%)
Cottage cheese, 2% fat	11.83	0.99 ***(8.37%)***	0.36 *(3.04%)*	0.53 ***(4.48%)***	0.16 ***(1.35%)***	1.19 ***(10.06%)***	0.61 (5.16%)	0.63 (5.33%)	0.80 (6.76%)	2.77 (23.42%)
American cheese	22.15	2.20 ***(9.93%)***	*0.71* *(3.21%)*	0.72 *(3.27%)*	0.32 ***(1.44%)***	1.96 ***(8.85%)***	1.13 (5.10%)	1.02 (4.63%)	1.33 (6.00%)	4.60 (20.77%)

Eggs, hard boiled	12.60	0.90 ***(7.14%)***	*0.68* ***(5.40%)***	0.60 ***(4.76%)***	0.15 ***(1.19%)***	1.08 ***(8.57%)***	0.67 (5.32%)	0.69 (5.48%)	0.77 (6.11%)	1.64 (13.02%)
Peanut butter	25.09	0.67 *(2.67%)*	*0.49* *(1.95%)*	0.52 *(2.07%)*	0.23 *(0.92%)*	1.52 *(6.06%)*	1.18 (4.70%)	0.61 (2.39%)	0.77 (3.07%)	5.00 (19.93%)
Walnuts	15.23	0.42 *(2.76%)*	*0.45* *(2.95%)*	0.60 *(3.94%)*	0.17 ***(1.12%)***	1.17 ***(7.68%)***	0.71 (4.66%)	0.63 (4.13%)	0.75 (4.92%)	2.82 (18.52%)
Sunflower seeds	17.21	0.71 *(4.13%)*	*0.71* ***(4.13%)***	0.70 ***(4.07%)***	0.26 ***(1.51%)***	1.25 ***(7.26%)***	0.88 (5.12%)	1.86 (10.8%)	0.99 (5.76%)	4.22 (14.18%)
Soybeans, boiled green	16.64	1.11 ***(6.67%)***	*0.26* *(1.56%)*	0.72 ***(4.33%)***	0.24 ***(1.44%)***	1.36 ***(8.18%)***	0.87 (5.23%)	0.81 (4.87%)	0.83 (4.99%)	3.22 (19.35%)
Tofu, raw	8.19	0.53 *(6.47%)*	*0.41* ***(5.01%)***	0.33 ***(4.03%)***	0.13 *(1.59%)*	0.6 ***(7.33%)***	0.39 (4.76%)	0.40 (4.88%)	0.41 (5.00%)	1.40 (17.09%)
Black beans, boiled	8.86	0.61 ***(6.88%)***	*0.23* *(2.60%)*	0.37 ***(4.18%)***	0.11 ***(1.24%)***	0.71 ***(8.01%)***	0.48 (5.42%)	0.39 (4.40%)	0.46 (5.19%)	1.35 (15.24%)
Pinto beans, boiled	9.01	0.63 ***(6.99%)***	*0.22* *(2.44%)*	0.33 *(3.66%)*	0.11 ***(1.22%)***	0.77 ***(8.55%)***	0.53 (5.89%)	0.43 (4.78%)	0.52 (5.78%)	1.27 (14.10%)
Kidney beans, boiled	8.67	0.60 ***(6.92%)***	*0.22* *(2.54%)*	0.37 ***(4.27%)***	0.10 ***(1.15%)***	0.69 ***(7.96%)***	0.47 (5.42%)	0.38 (4.38%)	0.45 (5.17%)	1.32 (15.22%)
Split peas, boiled	8.34	0.60 ***(7.19%)***	*0.22* *(2.64%)*	0.30 *(3.60%)*	0.09 ***(1.08%)***	0.60 ***(7.19%)***	0.38 (4.56%)	0.34 (4.13%)	0.39 (4.68%)	1.43 (17.15%)
Lentils, boiled	9.02	0.63 ***(6.98%)***	*0.20* *(2.23%)*	0.32 *(3.55%)*	0.08 *(0.87%)*	0.65 ***(7.21%)***	0.45 (5.00%)	0.39 (4.33%)	0.45 (5.00%)	1.40 (15.52%)
Oat bran, cooked	3.21	0.13 *(4.05%)*	*0.16* ***(4.98%)***	0.09 *(2.80%)*	0.06 ***(1.87%)***	0.24 ***(7.48%)***	0.16 (5.00%)	0.11 (3.43%)	0.17 (5.31%)	0.64 (19.94%)
Brown rice, cooked	2.58	0.10 *(3.88%)*	*0.08* *(3.10%)*	0.10 *(3.88%)*	0.03 ***(1.16%)***	0.21 ***(8.14%)***	0.13 (5.04%)	0.11 (4.26%)	0.15 (5.81%)	0.53 (20.54%)
Yellow corn	3.41	0.14 *(4.11%)*	*0.10* *(2.93%)*	0.13 *(3.81%)*	0.02 *(0.06%)*	0.36 ***(0.11%)***	0.16 (4.71%)	0.13 (3.82%)	0.19 (5.59%)	0.66 (19.35%)

“Ideal” protein = 5.5% lysine, 3.5% sulfur-containing amino acids, 4% threonine, 1% tryptophan, 7% leucine (Ullman, 2009). “Ideal” protein = 5.5% lysine, 3.5% sulfur-containing amino acids, 4% threonine, 1% tryptophan, 7% leucine (Ullman, 2009).

Table 6. Sulfur-containing amino acids / 100g protein and cysteine / methionine ratio

	Cysteine g/100g protein	**Methionine g/100g protein**	**Cys to Met (Cys = 1)**	**Cys / Met % of total S-protein**	**S-containing amino acids, g/100g**
Beef top loin	0.38	0.76	1 to 2.00	33/77	1.14
Beef frankfurter	0.12	0.32	1 to 2.67	28/82	0.43
Pork loin	0.31	0.73	1 to 2.35	42/58	1.04
Pork sausage, cooked	0.20	0.47	1 to 2.35	30/70	0.67
Lamb (lean only)	0.35	0.75	1 to 2.14	37/68	1.10
Chicken, white meat	0.40	0.86	1 to 2.15	47/53	1.26
Turkey (breast)	0.31	0.87	1 to 2.81	28/72	1.18
Sockeye salmon	0.29	0.81	1 to 2.79	26/74	1.10
Flounder	0.26	0.72	1 to 2.77	29/71	0.98
Shrimp, steamed	0.23	0.59	1 to 2.57	28/72	0.82
Tuna, in water	0.27	0.76	1 to 2.81	21/79	1.03
2% Low-fat milk	0.11	0.08	1 to 0.73	29/71	0.19
Cottage cheese	0.07	0.29	1 to 4.14	24/76	0.36
American cheese	0.14	0.57	1 to 4.07	20/80	0.71
Eggs, hard boiled	0.28	0.39	1 to 1.38	43/57	0.68
Peanut butter	0.23	0.26	1 to 1.13	44/56	0.49
Walnuts	0.21	0.24	1 to 1.14	47/43	0.45
Sunflower seeds	0.34	0.37	1 to 1.09	34/37	0.71
Soybeans, boiled	0.22	0.27	1 to 1.27	55/45	0.49
Tofu	0.11	0.10	1 to 0.91	52/48	0.21
Black beans, cooked	0.10	0.13	1 to 1.30	42/58	0.23
Pinto beans, boiled	0.09	0.13	1 to 1.44	41/59	0.22
Kidney beans	0.09	0.13	1 to 1.44	41/59	0.22
Split peas, boiled	0.13	0.09	1 to 0.30	59/41	0.22
Lentils, boiled	0.12	0.08	1 to 0.67	60/40	0.20
Oat Bran, cooked	0.10	0.06	1 to 0.50	63/37	0.16
Brown rice, cooked	0.03	0.06	1 to 2.00	33/67	0.09
Yellow corn. cooked	0.03	0.07	1 to 2.33	30/70	0.10

Data derived from USDA National Nutrient Database for Standard Reference, Release 22 (2009).
http://www.ars.usda.gov/ba/bhnrc/ndl

Table 7. Glycemic Index and Glycemic Load of Selected Foods

Food	GI	GL
High GI (>70)		
Glucose	100	
Baked potato	85	26
Corn flakes	81	22
Popcorn	72	8
Whole wheat (100%) bread	71	9
White bread	70	10
Medium GI (> 55 < 69)		
Cantaloupe	*65*	*4*
White rice	*64*	*23*
Beets	*64*	*5*
Sweet potatoes	*61*	*17*
Pineapple	*59*	*7*
Wild rice	*57*	*18*
Low GI (<55)		
Sweet corn	54	9
Bananas	52	12
Green peas	48	3
Carrots	47	3
Grapes	46	8
Ice cream, low fat	46	7
Spaghetti	42	20
Strawberries	40	1
Pinto beans	39	10
Apples	38	6
Whole milk	42	5
Black beans	30	7
Kidney Beans, canned	28	7
Chickpeas, dried	28	8
Apples	28	4
Lentils	26	5
Wild rice	18	55
Soy beans, boiled	16	1
Peanuts	14	1
Beef, fish, pork, lamb	0	--
Chicken, turkey	0	--
Salmon, tuna, shellfish	0	--
Whole egg	0	--

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