Protein Composition & Quality

Researched and Composed by Jacob Wilson, BSc. (Hons), MSc. CSCS

Protein composition and quality

There are 20 total amino acids, comprised of 9 essential amino acids (EAAs) and 11 non essential amino acids (NEAAs). EAAs cannot be produced in the body and must therefore be provided exogenously (through diet). Protein quality is typically defined as a protein's capacity to provide essential amino acids (EAAs) to an individual (Gertjan, 2000, Tome, 2000). There are a number of methods utilized to determine protein quality, and there is much debate in their use (Gertjan, 2000; Reeds, 2000). In general these methods include the Chemical Score, Protein Efficiency Ratio, Biological value, and the Protein Digestibility–Corrected Amino Acid Score (PDCAAS) (Gertjan, 2000).

The *Chemical Score* was introduced by Block and Mitchell (1946). This method first assigns a score of 100 to egg albumen (or a comparable or hypothetical reference protein) as it is considered to be nutritionally complete (Brody, 1999). Investigators then compare the essential amino acid profile of a number of proteins to the amount of each essential amino acid in Egg Albumen. The essential amino acid which is lowest in quantity in the protein of interest is compared to the quantity of that amino acid in egg protein, and its Chemical score is then calculated (Table – 4). For example, Oatmeal has 3.5 grams of the amino acid lysine per 16 grams of protein nitrogen, where as egg protein has 7 grams (Brody, 1999). This gives oat protein a rating of 50 (3.5 / 7 = 0.5 X 100 = 50). The limiting amino acid typically determines the capacity that the protein has for being utilized by the body. For example, in a classic study by Munavor and Harper (1959) animals were fed wheat protein which is lacking in the amino acid lysine. The animals were fed a diet ranging from 10 to 80 % wheat protein. It was found that the group of rats that ingested 70 % protein had the greatest amount of growth. However, when their diet was supplemented with lysine (the amino acid that was lacking), they grew an equivalent amount with only 20 % protein in their diet!

Table - 4.* Chemical score, Protein Efficiency Ration (PER), and Biological Value

Protein	Chemical score	PER	Biological Value
Egg	100	3.92	94
Fish	71	3.55	76
Beef	69	2.30	74
Casein	58	2.86	80
Oats	57	2.19	65
Rice	56	2.18	64
Peanuts	55	1.65	55
Soy Beans	47	2.32	73
Wheat	43	1.53	65
Lima Beans	41	1.53	66
Lentils	31	0.93	45

* Source: Brody (1999)

The Biological Value (BV) of a food is determined by measuring how much nitrogen is retained divided by how much nitrogen was absorbed (Brody, 1999). Typically a protein's BV is enhanced with a greater chemical score (Table-5). An interesting concept on BV is that it is not only affected by the essential amino acid profile of a protein but also by energy intake. In this context Chiang and Huang (1988) investigated the effects of maintenance, 15 % above maintenance, and 30 % above maintenance energy intake in young men fed 1.2 grams of protein per kg/bw. It was found that as energy intake increased nitrogen retention and thus biological value increased.

The Protein Efficiency Ratio (PER) is determined by administering a 10 % protein diet to growing animals from various sources of protein (Mitchell, Jenkins & Grundel, 1989). It is calculated by the ratio of weight gained to the weight of the protein consumed (weight gained / weight of protein consumed) (Table-5). The PER is important as it is the only measure which examines the direct effect of a protein on growth rates. Unfortunately it is difficult to compare this rating to bodybuilders, as growing animals incorporate a great deal of protein intake into growing organs, while bodybuilders are primarily interested in skeletal muscular hypertrophy.

Finally the PDCAAS is similar to the Chemical Score; however it is corrected for digestibility of the protein and is based on the essential amino acid requirements of a preschool-age child. Unfortunately the validity of generalizing the amino acid requirements for a preschool aged child to resistance training adults is questionable. Because certain proteins can provide a greater quantity of essential amino acids then the recommended requirements for pre school aged children, a protein can acquire a higher score (table-6).

Table 5. Digestability, chemical score and PDCAAS for selected proteins based on preschool requirements [1]

Protein	Digestibility	AAS	PDCAAS
		%	
Egg	98	121	118
Cow's milk	95	127	121
Beef	98	94	92
Soy	95	96	91
Wheat	91	47	42

[1] Data from FAO/WHO Expert Consultation 1990 , European Dairy Association 1997 , and Renner 1983 *as referenced in Gertjan (2000)*

The effect of the composition / quality of a protein on lean tissue gains in chronic studies

Generally animal based products contain the highest array of essential amino acids, while vegetable based products typically lack one or more EAAs (table – 5)(Mcardle, Katch, & Katch, 1999). In this context Campbell et al. (1999) investigated the effects of a lactovegan (meat free) diet compared to a omnivorous diet on body composition and muscular strength in male adults aged 51–69 years of age. The participants in the lactovegan diet were assisted by dieticians to ensure that they obtained adequate protein intake. Further there was no significant difference between mean energy and macronutrient intakes between groups. Both conditions participated in a 12 week resistance training program. Results found a significant increase in fat free mass, and a decrease in fat mass in the omnivourous condition. However, there was a decrease in fat free mass in the vegetarian condition, and an increase in fat mass. These results indicate that a diet with the majority of its protein from meat products is more effective for supporting the goals of a resistance training program then a vegetarian diet.

In another study from McMaster University, Phillips et al. (2005 as referenced in Phillips et al. 2005) had participants consume 1 of three drinks immediately and one hour after exercise. The drinks consisted of a 500 mls of milk (18.2 grams of protein), anisonitrogenous and isoenergetic soy protein mixture, or a maltodextrin energy control condition. After 12 weeks of resistance training it was found that the milk consumption condition gained significantly greater lean muscle mass than the energy control, while there were no significant differences between the energy control and soy protein conditions.

The effect of protein composition on peripheral and splanchnic tissues

Whole body protein synthesis (WBPS) is affected by splanchnic protein synthesis, such as that which occurs in the liver and skeletal muscular protein synthesis. Studies indicate that proteins which are deficient or have a low quantity of one or more EAAs preferentially increase splanchnic protein synthesis while decreasing peripheral skeletal muscular protein synthesis (Lecavalier et al., 1991). As an illustration Fouillet et al. (1991) had participants consume a mixture of sucrose and either 30 grams of milk or soy proteins. While soy is considered a complete protein, it contains 85 % lower EAAs than milk. Further the EAA methionine is considered low in Soy. The results indicated that whole body nitrogen retention was higher in the milk protein than the soy protein. Further it was found that compared to milk protein, soy protein increased splanchnic protein synthesis and decreased peripheral protein synthesis.

These results may be attributed to the faster digestion rate of soy, or to the low methionine content. The latter contention was supported by Lecavalier et al. (1991) who induced lowered the concentrations of one of two amino acids (either leucine or threonine) with hyperinsulemia, while maintaining the concentration of the other essential amino acids. The results were compared to a condition which maintained all of the amino acids. Their findings indicated that peripheral protein synthesis was lowered while the synthesis of the two liver proteins measured was maintained.

Further support comes from Martinez and colleagues (1987) who found that a legume diet which is deficient in the EAA methionine severely impaired weight of the gastrocnemius muscle compared to casein in rats. This was attributed to lowered muscular protein synthesis. However liver protein synthesis was slightly increased in the legume-fed animals.

A second aspect of the milk protein compared to the soy, is that Milk protein contains 120 % more BCAAs than soy protein (Fouillet et al., 2002). Studies demonstrate that BCAAs are preferentially taken up by skeletal muscle tissue and poorly oxidized in splanchnic tissues (Biolo and Tessari, 1997).

The effect of protein composition on skeletal muscular protein synthesis

Amino acids have two critical attributes in the regulation of protein synthesis. First they act as building blocks for the formation of new muscle tissue, and secondly they act as signaling molecules which stimulate the protein synthetic pathway. In this context a number of investigations have examined which amino acids are critical for the stimulation of protein synthesis. Numerous lines of research suggest that EAAs are the rate limiting nutrient that must be provided through diet for muscle tissue growth to occur (Millward et al. 1996; Wolfe & Miller, 1999, Tipton et al., 1999). In this context, Borsheim et al. (2002) investigated the effect of the ingestion of 6 grams of EAAs compared to 6 grams of mixed NEAAs and EAAs on protein synthesis post exercise. Comparison of protein synthesis among conditions found double the rate of protein synthesis in the EAA condition than the mixed amino acid condition. The authors concluded that the NEAAs were already provided in adequate amounts endogenously, and that EAAs act as signaling molecules independently of NEAAs. This finding was also supported by Volpi and colleagues (2003) who found that 18 grams of EAAs increased protein synthesis equally to a mixture of 18 grams of EAAs with additional ingestion of 22 NEAAs. Therefore evidence strongly supports the contention of protein synthesis being directly related to the EAA content provided by a particular protein source.

Complementary proteins

Generally by consuming high quality, animal based products (meat, milk, eggs, cheese) an individual will achieve optimal growth as compared to vegetable products (Campbell et al., 1999). This is generally related to the quality of the proteins. However, with a greater quantity of lower grade proteins an individual should be able to achieve maximal growth rates at the expense of caloric efficiency (i.e. you will have to consume more of the lower quality proteins such as soy, than you would of meat based products).

This concept may therefore place vegetarians at a higher risk for protein deficiencies or at least place them in a position of less than optimized athletic performance and body composition. If however, vegetarians can supplement with milk based products such as whey and casein, then they will be more likely to achieve optimal growth.

Another concept that applies to vegetarians and omnivorous consumers alike is the consumption of complementary proteins to enhance protein quality. Complimentary proteins are incomplete proteins (lacking or deficient in one or more EAAs) which when combined provide a complete array of essential amino acids. The most common combinations come from grains and legumes (i.e. beans, lintels). Grains lack the EAA lysine, while legumes have lysine but lack the EAA methionine (Mcardle, Katch, and Katch, 1999). As an illustration of how proteins are combined, Hulse et al. (1977, as referenced in Brody, 1999) compared 100 % rice protein, or varying combinations of rice and bean protein, and found the PER was maximized with a combination of about 50-80 % rice protein with the remainder of proteins coming from bean protein.

It is generally thought that complimentary proteins must be eaten at the same time to be most effective. Meaning that growth will be lowered when protein sources are consumed too far apart. Evidence suggests that proteins deficient in an amino acid will enhance splanchnic protein synthesis and decrease peripheral synthesis. However if complementary proteins are consumed contiguously this may be avoided. For example, one study found alternating incomplete combinations of amino acids on rat growth, led to decreased weight, where as providing them contiguously increased growth (Brody, 1999).

For omnivorous athletes, the protein quality of a diet can be enhanced through consuming a variety of protein sources, as opposed to only relying on one protein source. As an illustration Hernandez (1996) examined animal proteins alone or in combination with other proteins on the protein efficiency ratio. They found that the " best protein quality were egg (3.24), sirloin beef (3.16), lamb (3.11) and chicken breast (3.07), which were significantly different ($P < 0.05$) from milk powder (2.88) and beef liver and beef round (2.81 and 2.70, respectively). The ham (2.63) and the pork loin (2.57) had a similar protein quality to that of casein (2.50). The lowest protein quality was found in sausages (2.14)." However, the greatest protein efficiencies were found when proteins were combined. This concept has been utilized in a number of protein powders. For example Met Max contains Lactalbumin, Whey Protein Concentrate, Beef Protein, Calcium Caseinate, Egg Albumen, and Whey Protein Hydrolysate.

Non essential amino acids

While non essential amino acids are not required, as they can be produced endogenously, their presence in the diet can spare essential amino acids from being utilized to form non essential amino acids. For instance the requirements of Methionine are based on the availability of cysteine (Brody, 1999). As methionine is utilized frequently for the formation of cysteine.

Summary of protein Quality

Protein quality is dependent on the availability of essential amino acids in a given protein source. Typically protein quality is maximized in animal products, and increases when various protein sources are combined contiguously.