

5 Protein

5.1 Introduction

Next to water, protein is the major component of body tissues. It is the essential nutrient for growth. The body is in a dynamic state, with protein and other nitrogenous compounds being degraded and resynthesised continuously. More protein is turned over daily in the body than is ordinarily consumed in the diet.

Proteins are large molecules made up of amino acids bonded together by peptide linkages. They provide the essential amino acids, which are the initial materials for tissue synthesis and constituent of tissue protein. Thus, it was often referred to as the “currency” of protein nutrition and metabolism (Young, 2001). The maintenance of body tissue is essential because the body is constantly undergoing wear and tear, and proteins and amino acids provide continuous repairs. Some of the important physiological functions of proteins are summarised below.

Proteins are important for the formation of regulatory compounds. Some hormones, all enzymes, and most other regulatory materials in the body are proteins substances. Proteins defend the body against disease. When the body detects invading antigens, it manufactures antibodies, giant protein molecules designed specifically to combat them. The antibodies work so swiftly and efficiently that in normal, healthy individual, most diseases never have a chance to get started. The body’s fluids are contained within the cells (intracellular) and outside the cells (extracellular). Extracellular fluids are found either in the spaces between cells (interstitial) or within blood vessels (intravascular). Wherever proteins are, they attract water and this helps to maintain the fluid balance in their various compartments. In addition, proteins help maintain the balance between acids and bases within the body fluids by accepting and releasing hydrogen ions. Even though proteins are needed for growth, maintenance and repair, they will be used to provide glucose when the need arises.

5.2 Food Sources

Proteins in human diet are derived from two main sources, namely animal proteins (e.g. egg, milk, meat and fish.) and plant proteins (e.g. pulses, cereals, nuts, beans and soy products). Animal proteins are more “biologically complete” than vegetable proteins with regards to their amino acid composition. The term “complete proteins” refers to foods that contain all the essential amino acids needed by the body, whereas, incomplete proteins refers to foods lacking in one or more essential amino acids. There are more complete proteins from animal sources than most vegetable proteins, which are “biologically incomplete”. However, an incomplete protein can be converted into a complete protein if two incomplete proteins are added together by employing what is called “complementarity of proteins”. Two plant proteins such as legumes and grains or legumes and nuts/seeds can be mixed to produce a complete protein from two incomplete ones.

Animal proteins

Meat, poultry and seafood are mainly complete proteins with almost equal protein content among them, e.g. beef, lamb, pork, fish and poultry. Other sources include organs and glands such as liver, kidney, brain, heart and sweetbreads, which are also rich in vitamins and minerals.

Milk is not only a valuable source of protein but also a rich source of calcium and vitamins. A glass (250 ml) of fresh whole milk contains about 8.5 g of protein. In addition, nonfat dry milk or fortified skim milk also contains equivalent amount of proteins and other nutrients to whole milk. Milk products such as cheese and ice cream can provide generous amount of protein in the diet. Breast milk is not only a complete protein but also a complete food for infant up to 6 months of age.

Egg is a complete protein with excellent quality; one egg will give 6 g or protein. The egg yolk contains protein, fat and cholesterol; however, the white contains mostly protein with no fat or cholesterol.

Plant proteins

Most proteins from plant sources are incomplete proteins and contain smaller amounts of proteins than their animal sources counterparts. However, legumes are an exception: peas, lentils, beans, chickpeas, lima beans, soybeans and peanuts have large amounts of proteins in their seeds. In some legumes the protein contents in their dried form are higher than when they were fresh. Plant proteins are good substitutes for meats or animal proteins. Although proteins from legumes are not equal in quality with animal proteins, nonetheless, they can be an adequate substitute if they are eaten in combination with other foods.

5.3 Deficiencies

Protein deficiency

Protein deficiency usually accompanies a deficiency of calories and other nutrients. The effects of protein loss during illness and injury are far-reaching. The most evident result is the wasting of muscle tissue and consequent loss of weight. Other symptoms include anemia and delayed healing of wounds, and fractures. A lowering of serum protein levels and hormonal changes may result in edema, and the reduced production of antibodies makes the affected person susceptible to infection.

Protein-calorie malnutrition (PCM)

Protein-calorie malnutrition refers to a group of diseases caused by deficiencies of both proteins and calories and frequently accompanied by infections. A vicious cycle develops in which the malnutrition creates a susceptibility to infection and the infection further aggravates the poor nutritional condition. The two major manifestations of PCM are marasmus and kwashiorkor. Marasmus is caused by a diet that is severely deficient in calories, as well as protein and other nutrients for a prolonged period. Kwashiorkor, on the other hand, primarily results from a deficiency of protein but a deficiency in calories may be a contributing factor.

Although the basic or primary causes of PCM are an inadequate diet, both in quantity and quality, underlying factors include poverty and ignorance; infectious and parasitic diseases, notably diarrhea, respiratory infections, measles and intestinal worms. There are numerous other contributory factors in the web of causation like poor environmental conditions, large family size, poor maternal health, failure of lactation, premature termination of breastfeeding, and adverse cultural practices relating to child rearing and weaning such as the use of over-diluted cow's milk and cooking water from cereals and delayed supplementary feeding.

5.4 Factors affecting protein requirements

Quality and digestibility of protein are two major determinants whether the dietary protein intake can furnish an adequate level of essential amino acids to satisfy their functions in the body. Thus the availability of proteins from dietary sources will be very much influenced by the factors summarised in the following paragraphs.

The protein content of foods

The determination of protein requirement is based on nitrogen balance, which include total nitrogen in food and excreta. In fact, the real requirement is determined for nitrogen rather than protein. This is also how the food composition tables measured total nitrogen in food, usually by the Kjeldhal method, where the result will be multiplied by a factor to calculate the protein content of food. Normally most proteins contain about 16% nitrogen, thus total dietary nitrogen multiplied by 6.25 will give the estimate of protein intake or "crude protein".

The content of nitrogen in protein differs in different foods; some have a higher percentage, while some foods have lower percentage of presence of non-protein nitrogen. A Joint FAO/WHO Committee (FAO/WHO, 1973) has provided a list of factors to be used for conversion of nitrogen to protein, based on the percentage of nitrogen in the food.

Biological Value

The Biological value (BV) of a protein is a measure of how efficiently food protein, once absorbed from the gastrointestinal tract, can be turned into body tissues. If a food possesses enough of all nine essential amino acids, it should allow a person to efficiently incorporate the food protein into body proteins. The biological value of a food, then, depends on how closely its amino acid pattern reflects the amino acid pattern in the body tissues. The better the match, the more completely food protein turns into body protein. Protein retention is usually measured by measuring nitrogen retention in the body. Both humans and laboratory animals are used to generate data for determining biological value of food proteins.

If the amino acid pattern in a food is quite unlike tissue amino acid patterns, many amino acids in the food will not become body protein. They simply become “leftovers”. Their nitrogen groups are removed and excreted in the urine as urea. Because not much of the nitrogen is retained, the ratio of retained nitrogen to absorbed nitrogen, and the consequent biological value is low.

Egg-white protein has a biological value of 100, the highest biological value of any single food protein. In other words, essentially all nitrogen that is absorbed from egg protein can be retained. Milk and meat proteins also have high biological values. This is so because humans and other animals have similar tissue amino acid compositions. Plant amino acid patterns differ greatly from those of humans. For example, corn has only a moderate biological value of 70; it is high enough to support body maintenance, but not growth. Peanuts consumed as the only source of protein show a low biological value of 40.

Digestibility

The degree to which a protein is digested influences its nutritional value. Animal protein is digested more efficiently than plant protein. This is because digestive enzymes have greater difficulty entering plant cells which are surrounded by cellulose and woody substances. Thorough chewing aids protein digestion. The method of cooking also affects digestibility. Heat alters the structure but not the amino acid content of protein molecules. Over-heating, however, may destroy some amino acids or may cause the formation of products resistant to digestive enzymes. Cooking with water improves the digestibility of wheat and rice proteins.

The amount of N excreted in the faeces usually varies between 10 and 25% of the N intake. Only part of this is derived directly from dietary N that is not absorbed; the rest is from protein and other secretions into the gastrointestinal tract during the process of digestion, and from N contained in faecal bacteria.

Digestibility is usually determined by measuring the faecal N output in individuals consuming the specific N source and subtracting the faecal N output when a protein-free

diet is given. This value is then subtracted from the total N intake and expressed as a proportion of the N intake.

The faecal N on the protein-free diet is a measure of the amount resulting from intestinal secretions, based on the assumption that this component does not vary with different diets. The value thus obtained is called “true” digestibility, and represents the proportion of the dietary N that is absorbed. This portion can generally be assumed to be available for meeting the needs for maintenance and growth. The digestibility of protein is normally expressed in relation to that of egg, milk, meat or fish, which are used as reference proteins (digestibility = 100)

Differences in digestibility will occur based on the nature of food protein (nature of cell wall), the presence of other dietary factors, which can modify digestion (dietary fiber and polyphenols), and chemical reactions that alter the release of amino acids from proteins by enzymatic processes.

Protein Efficiency Ratio

The protein efficiency ratio (PER) is another means of measuring a food’s protein quality. The PER compares the amount of weight (in grams) gained by a growing rat after 10 days or more of eating a standard amount of protein (9.09% of its energy intake) from a single protein source to the grams of protein consumed. The PER of a food reflects its biological value, since both basically measure protein retention by body tissues. Plant proteins, because of their incomplete nature, generally yield PER values, whereas the values for animal proteins are higher, often above 2.0.

Chemical Score of Protein

The chemical score estimates the protein quality of a food. To calculate a food’s chemical score, the amount of each essential amino acid provided by a gram of the food’s protein is divided by an “ideal” amount for that amino acid per gram of food protein. The “ideal” protein pattern is based on the minimal amount (in milligrams) of each of the essential amino acids that is needed per gram of food protein. The lowest amino acid ratio calculated for any essential amino acid is the chemical score. Scores vary from 0 to 1.0

Protein Digestibility Corrected Amino Acid Score (PDCAAS)

The most widely used measure of protein quality is the Protein Digestibility Corrected Amino Acid Score (PDCAAS). This is used in place of Protein Efficiency Ratio (PER) evaluations for foods intended for children over 1 year of age and for nonpregnant adults. To calculate the PDCAAS of a protein, its chemical score is

determined. For example wheat has a chemical score of 0.47. The score is then multiplied by the digestibility of the protein (generally, 0.9 to 1.0), in turn yielding the PDCAAS. The maximum PDCAAS value is 1.0, which is the value of milk, eggs, and soy protein. A protein totally lacking any of the nine essential amino acids has a PDCAAS of 0, since its chemical score is 0.

5.5 Setting requirements and recommended intakes of protein

General considerations

The methods used as basis for estimating protein requirements are the factorial method and the nitrogen (N) balance method. For young infants, estimates of protein requirements are based on human milk intake (FAO/WHO/UNU, 1985).

The factorial method involves the measurement of obligatory losses (the amount of N present in urine, feces, sweat, etc.) when the diet consumed contains no protein, but is otherwise adequate. The requirement is considered to be the amount needed to replace this loss, after adjustments for the efficiency of dietary protein utilization and quality of dietary protein based on its amino acid pattern. For children and pregnant and lactating women, an additional amount of protein required to support tissue growth and milk formation is incorporated into the factorial estimates of requirements.

The nitrogen-balance technique involves the determination of the difference between the intake of nitrogen and the amount excreted in urine, faeces, and sweat, together with minor losses by other routes. In most experiments only the nitrogen content of the diet, urine, and faeces has been directly measured. Allowances are made for losses by other routes on the basis of a limited number of published studies. Thus, to allow for these other losses, any estimate of nitrogen balance limited to measurements of diet and excreta in non-growing individuals must be positive if overall body N maintenance is to be achieved.

When the quantity of nitrogen from food proteins is about equal to the quantity lost in the feces and urine, the person is said to be in nitrogen balance. Nitrogen balance indicates that body tissue is being adequately replaced and repaired and that there is no increase or decrease in total amount of body tissues (Harper and Yoshimura, 1993). In positive nitrogen balance, more nitrogen is taken in than is lost. Positive nitrogen balance is seen when new tissue is being built, as in infancy and childhood, in adolescence, in pregnancy and lactation, and during recovery from an illness or injury in which protein has been lost. In negative nitrogen balance, more nitrogen is lost than is consumed in food protein. In other words, body tissue is breaking down faster than it is being replaced. Negative nitrogen balance is seen when protein intake is too low or of poor quality. Negative nitrogen balance also develops when insufficient calories are consumed to meet energy needs. In this case, body protein is broken down to supply energy.

Recommended intakes by age groups

The main references used by the Technical Sub-Committee (TSC) on Energy and Macronutrients in making recommendations for protein intake for the revised RNI are the 1985 Joint FAO/WHO/UNU committee report (FAO/WHO/UNU, 1985) and the report of the DRI Committee of IOM (2002). Upon reviewing these documents, as well as reports of dietary intakes and patterns of communities, the proposed recommended protein intake for the revised RNI is largely based on the afore-mentioned FAO/WHO/UNU publication (Appendix 5.1). The TSC also decided to use 80% protein quality in the calculations and considerations for recommended protein intake (third column in Appendix 5.1). This is in contrast to the 70% protein quality used in the previous Malaysian RDA (Teoh, 1975). The TSC is of the opinion that the use of the higher protein quality is justifiable as the quality of the Malaysian diet has improved over the years.

The recommended protein intake for the revised RNI for the various groups are given in the following sections in bold and summarised in Appendix 5.2.

Infants (0 – 5 months)

In the 1985 joint FAO/WHO/UNU report, protein requirements for infants during the first 6 months were based on estimated intakes of breast-fed infants. The explicit assumption of this approach was that the protein needs of an infant will be met if its energy needs are met and the food providing the energy contains protein in quantity and quality equivalent to that of breast-milk (FAO/WHO, 1985). An estimate of the average protein intake per kilogram (kg) of breast-fed infants up to 4 months is shown in Table 5.1.

Table 5.1 Average protein intake by breast-fed infants aged 0-4 months

Age	Breast milk consumed	Protein intake	Weight	Average protein intake
(months)	(ml)	(g/day)	(kg)	(g/kg per day)
Boys				
0–1	719	9.35	3.8	2.46
1–2	795	9.15	4.75	1.93
2–3	848	9.75	5.6	1.74
3–4	822	9.45	6.35	1.49
Girls				
0–1	661	8.6	3.6	2.39
1–2	731	8.4	4.35	1.93
2–3	780	9.0	5.05	1.78
3–4	756	8.7	5.7	1.53

Source: FAO/WHO/UNU (1985)

The average protein of human milk was assumed to be 1.15 g/100 ml after the first month post partum, calculated from total nitrogen (N) content X 6.25. The average weights of infants in the NCHS reference were used to estimate protein intake per kg body weight. The estimates presented in the 1985 report extended only to 4 months of age because there was insufficient information on the intakes of exclusively breast-fed infants beyond that age.

A similar approach, that based on volume of breast milk and protein content has also been adopted by the DRI Committee of IOM (2002). Because of differences in milk volume and protein concentration, slightly different intake levels have been recommended.

The TSC on Energy and Macronutrients recommended to adopt the 1985 FAO/WHO/UNU recommended intake of 1.86 g protein/kg body weight/day (Appendix 5.1) and using the reference body weight for the Malaysian population of 6 kg for infants 0-6 months.

RNI for infants
0 – 5 months 11 g/day

Infants (6-11 Months)

The period from 6 to 12 months is clearly the most critical, because of rapid growth during this time and because the child increasingly relies on supplementary foods. The first priority must therefore be to establish as reliable an estimate as possible of the safe level of protein intake for children of this age. This estimate can then be used to interpolate the safe level for older children.

A modified factorial approach was used in the 1985 FAO/WHO/UNU report to estimate protein requirements of infants after the age of 6 months. This approach requires the estimation of both maintenance nitrogen needs and the amount of nitrogen required for growth.

The average maintenance nitrogen requirement was assumed to be 120 mg N/kg/day. In determining the requirement for growth, the mean rate of nitrogen (N) accretion during growth can be estimated from the expected daily rate of weight gain (NCHS 50th centile) and the N concentration in the body. This is low at birth, and increases to the adult value by 5 years of age or earlier. The extent of the increase is important between 6 and 12 months, when growth is rapid. 50% was added to the theoretical daily body N increment to account for day-to-day variation in the rate of growth, and thus in the need for protein to support that growth. It was assumed that the efficiency of conversion from dietary protein to body protein during growth is 70%, the same efficiency assumed for maintenance needs.

The coefficient of variation (CV) in the maintenance requirement was assumed to be 12.5% and 35% for growth, the same as the CV found for adults in numerous short-term N-balance studies.

The TSC on Energy and Macronutrients recommended to adopt the 1985 FAO/WHO/UNU recommended intake of 1.56 g protein/kg body weight/day (Appendix 5.1) and using the reference body weight for the Malaysian population of 8 kg for infants 6-12 months.

RNI for infants

6 – 11 months 12 g/day

Children and adolescents

In the 1985 FAO/WHO/UNU report, the factorial approach was used to estimate protein requirements of children and adolescents. For maintenance nitrogen requirements, values were interpolated based on the two “anchor” points of 120 mg N/kg/day at 1 year and 100 mg N/kg/day at 20 years of age. The CV was assumed to be 12.5%. For growth, the expected nitrogen accretion was based on data from Fomon et al (1982) up to age 10. The same assumptions as used for infants were included in the calculations:

- i. The efficiency of conversion from dietary protein was assumed to be 70%.
- ii. The CV for growth was taken as 35%.
- iii. An additional 50% was added to the growth increment to allow day-to-day variation in growth rate.

The safe level of protein intake for children of various ages was thus obtained and tabulated in the FAO/WHO/UNU report. The maintenance and growth components are presented and the amount of protein per kg body weight are tabulated for each age group. The TSC on Energy and Macronutrients recommended to adopt the recommendations of this consultation. Using the recommended protein intake based on 80% protein quality, the values are 1.45, 1.29 and 1.25 g/kg body weight/day for children ages 1-3, 4-6 and 7-9 years (Appendix 5.1). The corresponding reference weights appropriate for Malaysian children used are 12, 18 and 26 kg.

For adolescent boys, the recommended protein intake in g/kg body weight/day, based on 80% protein quality, are 1.24, 1.19 and 1.10 for ages 10-12, 13-15 and 16-18 years respectively (Appendix 5.1). The corresponding recommended protein intake for adolescent girls are 1.23, 1.13 and 1.03 g/kg body weight/day respectively. The reference weights for adolescent Malaysian boys for the three age groups are 36, 53 and 59 mg respectively. The corresponding weight for girls are 37, 49 and 52 mg respectively.

Based on these data, the RNI for protein have been calculated and summarised below.

RNI for children

1 – 3 years	17 g/day
4 – 6 years	23 g/day
7 – 9 years	32 g/day

RNI for adolescents

Boys	10 – 12 years	45 g/day
	13 – 15 years	63 g/day
	16 – 18 years	65 g/day
Girls	10 – 12 years	46 g/day
	13 – 15 years	55 g/day
	16 – 18 years	54 g/day

Adults and Elderly

To derive the protein requirement of young male adults, the FAO/WHO/UNU Consultation reviewed evidence from both short- and longer-term nitrogen balance studies. The safe intake of good-quality, highly digestible protein was set at 0.75 g/kg per day for young men. There are less extensive data available for adult women. Obligatory urinary nitrogen losses do not differ between young men and women. Furthermore, on the basis of short-term N-balance studies performed on young women receiving proteins from different sources, there is no evidence to suggest that the efficiency of utilization of dietary protein for meeting their physiological requirements is substantially different from that of young adult men when expressed per unit of body weight. The Consultation therefore recommended the same safe intake of protein for adult men and women. Upon reviewing available data, it was also felt that the same recommendations should be made for elderly subjects.

The DRI Committee of IOM (2002) has also made the same recommendations for protein intake for men and women, as well as for adults and elderly.

The revised RNI for protein for adults and the elderly are based on the 1985 FAO/WHO/UNU recommendations of 1.00 g protein/kg body weight/day after adjusting for 80% protein quality (Appendix 5.1). The reference body weights for Malaysian adult men and women are 62 kg and 55 kg respectively. For elderly, the reference body weight for men is 57 kg and that for women is 49 kg.

RNI for adults

Men	19 – 59 years	62 g/day
Women	19 – 59 years	55 g/day

RNI for elderly

Men	≥ 60 years	57 g/day
Women	≥ 60 years	49 g/day

Pregnancy

The 1985 FAO/WHO/UNU Expert Consultation estimated the total protein requirement of a woman gaining 12.5 kg during pregnancy and delivering a 3.3 kg infant has been estimated to be 925 g, plus 30% (2 SD of birth weight), or 3.3 g per day throughout pregnancy. An efficiency factor of 0.70 is also accepted as applying to pregnant women. The safe levels of additional protein computed in this manner are 1.2, 6.1, and 10.7 g per day in the 1st, 2nd, and 3rd trimesters, respectively.

The TSC for Energy and Macronutrients decided to recommend an additional 7.5 g protein/day after adjusting for 80% protein quality for pregnant women, based on the 1985 FAO/WHO/UNU recommendation (Appendix 5.1).

RNI for

Pregnancy	+7.5 g/day
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Lactation

Based on the daily volume of breast milk produced and the amount of protein in the milk, the 1985 FAO/WHO/UNU Expert Consultation suggested a safe level of extra protein intake of about 16 g per day during the first 6 months of lactation, 12 g per day during the second six months, and 11 g per day thereafter. These amounts should be added to the normal estimate of the woman's protein requirement and corrected for the digestibility of the dietary protein. Similarly, as for infants and children, an efficiency factor of 70% for the conversion of dietary protein to milk protein and 12.5% CV of breast milk volume was adopted.

The TSC noted that the FAO/WHO/UNU consultation had recommended adding 16 g and 12 g protein per day for the first and second 6 months of lactation respectively (Appendix 5.1). After adjusting for 80% protein quality, the TSC recommends an additional 20.0 g protein per day for the first 6 months of lactation and an additional 15.0 g protein per day for the second 6 months of lactation.

RNI for lactation

1st 6 months	+ 20 g/day
2nd 6 months	+ 15 g/day

Discussions on revised RNI for Malaysia

Comparing the 1975 RDI and the 2005 RNI (Appendix 5.1), recommended intakes of protein for the latter are generally lower for infants, ie 12-13 g/day compared to 11 g/day for infants 0-5 months, and 17-18 g/day compared to 12 g/day for infants 6-11 months. Similarly, for children 1 to 9 years, the revised recommended values are lower by 6g/day for both the 1-3 and 4-6 age groups and by 3 g/day for the 7-9 years age group. However, for adolescent boys and girls (10-19 years), adults and the elderly (men and women, 19-59 years and ≥ 60 years) the recommended intakes are all higher than the previous recommendations. The increases range from about 5-40%. The highest increase is for older men (>60 years), up by 44%. On the other hand, the additional amounts recommended for pregnancy and lactation are generally lower for the revised RNIs.

These changes in the 2005 recommended values are mainly due to the adoption of the FAO/WHO/UNU (1985) recommendations and also to the changes in the reference body weights for Malaysians.

Comparing FAO/WHO/UNU (1985) recommendations with those of IOM (2002), the former intakes are generally higher for all age groups.

5.6 Toxicity and tolerable upper intake levels

There is substantial literature documenting the increase in urinary excretion of calcium with increasing protein intake. In short-term studies, it has been shown that an increase in dietary animal protein intake in healthy subjects increased the urinary calcium and oxalate. This has two potential detrimental consequences; loss of bone calcium and increased risk of renal calcium stone formation. Although there have been studies demonstrating the increased resorption of bone with increased protein intake, at present the available evidence is not strong enough to suggest limiting protein intake to avoid potential risk of bone loss.

High protein intakes have also been implicated in chronic diseases such as osteoporosis, renal stones, renal insufficiency, cancer, coronary heart disease, and obesity. However, the current state of literature does not permit any recommendation of the upper level for protein to be made on the basis of chronic disease risk. In addition, the data on the potential for high protein diets to produce gastrointestinal effects, changes in nitrogen balance, maximum urea synthesis, or chronic disease are often conflicting and do not provide dose-response information or clear indications of a lowest-observed-adverse-effect level (LOAEL) or no-observed-adverse-effect level (NOAEL) for these endpoints.

5.7 Research recommendations

The following priority areas of research are recommended:

- Periodic national nutrition surveys to obtain updates on the intake of protein and amino acids, especially among vulnerable groups
- Generation of data on protein and amino acid contents of Malaysian foods
- Protein intakes and requirements among the elderly group.
- Evaluate the impact of high protein diets such as the Atkin's Diet in weight reduction regiments
- Evaluate vegetarian diets and ways and means to maximize protein and amino acid contents in these diets
- Reevaluation of protein deficiency in relation to energy and micronutrient deficiencies among malnourished children.

5.8 References

FAO/WHO (1973). *Report of a Joint FAO/WHO Ad Hoc Expert Committee on Energy and Protein Requirements*. WHO Technical Report Series No. 522. World Health Organization, Geneva.

FAO/WHO/UNU (1985). *Energy and protein requirements*. Report of a Joint Expert Consultation. WHO Technical Report Series 724. World Health Organization, Geneva.

Fomon SJ, Haschke F, Ziegler EE & Nelson SE (1982): Body composition of reference children from birth to age 10 years. *Am J Clin Nutr* 35:1169-1175.

Harper AE and Yoshimura NN (1993). Protein Quality, amino acid balance, utilization, and evaluation of diets containing amino acids as therapeutic agents. *Nutrition* 9 (5):460-469.

IOM (2002). *Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Protein and Amino Acids (Macronutrients)*. Food and Nutrition Board, Institute of Medicine. National Academy Press, Washington D.C. Chapter 10.

Teoh ST (1975). Recommended daily dietary intakes for Peninsular Malaysia. *Med J Mal* 30:38-42.

Young VR (2001). Protein and amino acids. In: *Present Knowledge in Nutrition*. 8th Edition. Bowman BA and Russel RM (eds). International Life Sciences Institute, Washington DC. Chapter 5, pp. 43-58.

Appendix 5.1 Comparison of recommended intake for protein: RDI Malaysia (1975), RNI Malaysia (2005), FAO/WHO/UNU (1985), and IOM (2002)

Malaysia (1975)		Malaysia (2005)		FAO/WHO/UNU (1985)		IOM (2002)	
Age groups	RDI (g/day)	Age groups	RNI (g/day)	Age groups	Safe intake (g/kg/day)	Age groups	AI (g/kg/day)
Infants		Infants		Infants		Infants	
0 – 5 months	12-13	0 – 5 months	11	0 – 5 months	1.86	0 – 6 months	1.52
6 – 11 months	17-18	6 – 11 months	12	6 – 11 months	1.56	7 – 12 months	
							RDA (g/kg/day)
Children		Children		Children		Children	
1 – 3 years	23	1 – 3 years	17	1 – 3 years	1.45	1 – 3 years	1.1
4 – 6 years	29	4 – 6 years	23	4 – 6 years	1.29	4 – 8 years	0.95
7 – 9 years	35	7 – 9 years	32	7 – 9 years	1.25		
Boys		Boys		Boys		Boys	
10 – 12 years	43	10 – 12 years	45	10 – 12 years	1.24	9 – 13 years	0.95
13 – 15 years	53	13 – 15 years	63	13 – 15 years	1.19	14 – 18 years	0.85
16 – 19 years	54	16 – 19 years	65	16 – 19 years	1.10		
Girls		Girls		Girls		Girls	
10 – 12 years	41	10 – 12 years	46	10 – 12 years	1.23	9 – 13 years	0.85
13 – 15 years	53	13 – 15 years	55	13 – 15 years	1.13	14 – 18 years	0.85
16 – 19 years	54	16 – 19 years	54	16 – 19 years	1.03		
Men		Men		Men		Men	
19 – 59 years	53	19 – 59 years	62	19 – 59 years	1.00	19 – 70 years	0.80
≥60 years	41	≥60 years	59	≥60 years	1.00	≥70 years	0.80
Women		Women		Women		Women	
19 – 59 years	53	19 – 59 years	55	19 – 59 years	1.00	19 – 70 years	0.80
≥60 years	41	≥60 years	51	≥60 years	1.00	≥70 years	0.80
Pregnancy	+ 13	Pregnancy	+ 7.5	Pregnancy	+ 7.5 g/day	Pregnancy	1.1
Lactation	+ 24	Lactation		Lactation		Lactation	1.1
		1 st 6 months	+ 20	1 st 6 months	+ 20 g/day		
		2 nd 6 months	+ 15	2 nd 6 months	+ 15 g/day		