

7 Riboflavin (Vitamin B₂)

7.1 Introduction

Subsequent to the discovery of thiamin or vitamin B₁, was the discovery of another B vitamin, vitamin B₂ or riboflavin. The primary form of the vitamin is as an integral component of the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). Through these two flavoco-enzymes, riboflavin functions as a catalyst for redox reactions in numerous metabolic pathways and in energy production.

7.2 Deficiencies

The clinical features of human riboflavin deficiency do not have the specificity that may characterise deficits of some other vitamins, such as ascorbic acid. A shortage of this vitamin may manifest itself as weakness, fatigue, cracks and sores at the corners of the mouth, eye disorders, inflammation of the mouth and tongue, and skin lesions. More advanced deficiency may result in cheilosis, angular stomatitis, dermatitis, corneal vascularisation, anaemia and brain dysfunction (Rivlin, 2001). Vitamin B₂ deficiency almost invariably occurs in combination with a deficiency of other B-complex vitamins. Some of the symptoms observed (eg glossitis and dermatitis) may result from other complicating deficiencies.

The major cause of hypo-riboflavinosis is inadequate dietary intake. Children in developing countries will commonly demonstrate clinical signs of riboflavin deficiency during periods of the year when gastrointestinal infections are prevalent.

7.3 Food sources

Like thiamin, riboflavin is found at least in small amounts in a wide variety of plant and animal tissues. Indeed, the food sources of riboflavin are similar to those of other B vitamins. Therefore, it is not surprising that if an individual's diet has inadequate amounts of riboflavin, it will very likely be inadequate in other B vitamins as well. Some data from the nutrient composition of Malaysian foods are extracted to indicate the riboflavin content of various local foods (Tee *et al.*, 1997).

Various types of legumes, including chick peas, lentils, red and black gram and soya bean contain fairly high levels of riboflavin, around 0.3-0.7 mg/100 g. Various meat products have moderate amounts of the vitamin. Pork (0.3 mg) may have slightly higher amounts, whilst other meats eg beef, mutton, chicken and duck contain about 0.2 mg per 100 g. Fishes, with 0.1 mg/100 g have lower amounts of riboflavin. Hen eggs are a good source of the vitamin, with about 0.6 mg/100 g, with slightly more being concentrated in the egg yolk. A food with exceptionally high riboflavin is beef extract (6.9 mg/100 g), but small amounts of this food is generally consumed.

As is the case for thiamin, fruits and vegetables are poor sources of riboflavin. There are several processed products in the market, especially bread, cereal products and

biscuits, that are fortified or enriched with riboflavin and several other B vitamins and can become important sources of these vitamins.

7.4 Factors affecting requirements

There are no reported studies that examined the effect of energy intake on riboflavin requirement. Despite this lack of direct experimental data, the known biochemical function of riboflavin in the metabolism of carbohydrate suggests that at least a small (10%) adjustment to the estimated requirement to reflect differences in the average energy utilisation and size of men and women (IOM, 1998). A 10% increase in the requirement is also suggested to cover increased energy utilisation during pregnancy, and a small increase to cover the inefficiencies of milk production is needed.

Riboflavin status measurements seem to be affected by physical activity. Some studies have demonstrated a moderate rise in the erythrocyte glutathione activity coefficient (EGRAC) as well as a decrease in urinary riboflavin excretion with an increase in physical activity. It is possible that riboflavin requirement is increased for those who are ordinarily very active physically. However, there is no available data on which to quantify the adjustment that should be made.

7.5 Setting requirements and recommended intakes of riboflavin

There are no known local studies on riboflavin requirements of communities that the Technical Sub-Committee (TSC) on Vitamins could use as a reference when considering RNI for the vitamin. Compared to thiamin and the other vitamins, there are even fewer reports of the biochemical status of the vitamin amongst the population groups.

The TSC on Vitamins decided to adapt the FAO/WHO (2002) values as the revised RNI for Malaysia, given in bold in the following paragraphs according to age groups and summarised in Appendix 7.1. The FAO/WHO Consultation did not provide details for the methods of deriving at the RNI for riboflavin. The levels recommended are very similar to the RDA values of IOM (1998). The method as used by the Dietary Reference Intake Committee of IOM are summarised below.

Infants

In determining riboflavin requirement, the IOM (1998) report took the same approach as that used for estimating intake of thiamin. As there was no sufficient data that reliably reflected response to dietary riboflavin intake in infants, adequate intake was estimated. This was estimated based on the mean riboflavin intake of infants fed principally with human milk.

On the basis of several available studies, a riboflavin concentration of 0.35 mg/l was used for human milk consumed by infants younger than 6 months. Using the mean value of 750 ml/day for intake of human milk, the estimated adequate intake was 0.3 mg/day, after rounding up. By extrapolation from adequate intake for younger infants, the intake for riboflavin for older infants was estimated to be 0.4 mg/day after rounding up.

RNI for infants

0 - 5 months	0.3 mg/day
6 - 11 months	0.4 mg/day

Children and adolescents

As there was a lack of data concerning the riboflavin requirements of children or adolescents, the requirement for these age groups have thus been determined by IOM (1998) by extrapolating downwards from the average requirement of young adults by using a metabolic body weight ratio multiplied by a growth factor. The RDA for riboflavin was next set by assuming a coefficient of variation (CV) of 10% because information is not available on the standard deviation of the requirement for riboflavin. As RDA is defined as equal to the estimated average requirement (EAR) plus twice the CV to cover the needs of 97 to 98% of the individuals in the group, therefore, the recommended intake is 120 % of the EAR.

RNI for children

1 – 3 years	0.5 mg/day
4 – 6 years	0.6 mg/day
7 – 9 years	0.9 mg/day

RNI for adolescents

Boys 10 – 18 years	1.3 mg/day
Girls 10 – 18 years	1.0 mg/day

Adults and elderly

The DRI Committee established estimated requirements based on findings from several studies of riboflavin requirements of adults that addressed clinical deficiency signs and biochemical values including erythrocyte glutathione reductase activity coefficient (EGRAC) in relation to measured dietary intake of riboflavin (IOM, 1998). The reviewed data showed that clinical signs of deficiency appear at intakes of less than 0.5 to 0.6 mg/day whereas most studies reported normal EGRAC values at intakes of less than 1.3 mg/day. And because there is an expected curvilinear biological increase of

values from deficient to minimally adequate, the requirement for riboflavin for men was set at 1.1 mg/day and for women at 0.9 mg/day.

Recommended intake was set by assuming a coefficient of variation (CV) of 10% because information is not available on the standard deviation of the requirement for riboflavin. Since RDA is defined as equal to the estimated requirement plus twice the CV to cover the needs of 97 to 98% of the individuals in the group, the RDA for riboflavin was calculated as 120% of the estimated requirement or 120% of 1.1 for men and 120% of 0.9 for women. The recommended intake, after rounding, is thus 1.3 mg/day and 1.1mg/day respectively for men and women.

Few additional studies estimating riboflavin requirements have been conducted in the elderly. Although there is a decrease in energy expenditure with aging and the estimated requirement for older adults would be expected to decrease, the IOM (1998) report decided to use the same requirement for the elderly as for younger adults.

RNI for adults

Men	19 – 65 years	1.3 mg/day
Women	19 – 65 years	1.1 mg/day

RNI for elderly

Men	> 65 years	1.3 mg/day
Women	> 65 years	1.1 mg/day

Pregnancy and lactation

The additional requirement of 0.3 mg for pregnancy is an estimate based on increased growth in maternal and foetal compartments. For lactating women, an estimated 0.3 mg riboflavin is transferred in milk daily and, because utilisation for milk production is assumed to be 70% efficient, the value is adjusted upward to 0.4 mg/day.

RNI for

Pregnancy	1.4 mg/day
Lactation	1.6 mg/day

Discussions on revised RNI for Malaysia

The RNI values for riboflavin for Malaysia, adapted from FAO/WHO (2002), are also the same as those adopted by the Working Group for the Harmonisation of RDAs in SEAsia (2002). Appendix 7.1 provides a summary of these revised RNI, compared with the previous Malaysian RDI of 1975, the FAO/WHO (2002) recommendations and the values recommended by IOM (1998).

For almost all the age groups, the revised RNI is lower than the amounts recommended in the 1975 Malaysian RDI. The revised recommended intakes are also identical to the IOM (1998) values. There should therefore be little controversy on these values. It can be noted that recommended intakes for riboflavin have generally been scaled downwards. Roughead and McCormick (1991) found that most of a 1.7-mg dose of riboflavin given to healthy adults consuming at least this amount was largely excreted in the urine. Such findings corroborate earlier work indicating a relative saturation of tissue with intakes above 1.1 mg/day (FAO/WHO, 1998).

7.6 Toxicity and tolerable upper intake levels

Riboflavin intake of many times the RDA is apparently without demonstrable toxicity. A normal yellow discoloration of the urine is seen with an increased intake of this vitamin - but it is generally rather harmless. The apparent lack of harm resulting from high oral doses of the vitamin may be due to its limited solubility and limited capacity for absorption in the human gastrointestinal tract. No adverse effects associated with riboflavin consumption from food or supplements have been reported.

The IOM (1998) concluded that the data on adverse effects from high riboflavin intake are not sufficient for a quantitative risk assessment, and a tolerable upper intake level (UL) cannot be derived for the vitamin.

7.7 Research recommendations

The following priority areas of research are recommended:

- The magnitude of riboflavin deficiency among high risk groups such as alcoholic individuals, elderly people and also psychiatric patients.
- Efficacy of riboflavin supplementation on high risk individuals or groups.
- Determine effects of food preparation and cooking methods on riboflavin content of selected foods to enable establishing conversion factors for calculating riboflavin losses for a wide variety of foods
- Study nutrient values (including vitamin B content) of the various types of rice available in the market and their claims of health benefits for various chronic diseases.

7.8 References

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Appendix 7.1 Comparison of recommended intake for riboflavin (vitamin B₂): RDI Malaysia (1975), RNI Malaysia (2005), RNI of FAO/WHO (2002) and RDA of IOM (1998)

Malaysia (1975)		Malaysia (2005)		FAO/WHO (2002)		IOM (1998)	
Age groups	RDI (mg/day)	Age groups	RNI (mg/day)	Age groups	RNI (mg/day)	Age groups	AI (mg/day)
Infants		Infants		Infants		Infants	
< 1 year	0.8	0 – 5 months	0.3	0 – 6 months	0.3	0 – 6 months	0.3
		6 – 11 months	0.4	7 – 11 months	0.4	7 – 12 months	0.4
							RDA
							(mg/day)
Children		Children		Children		Children	
1 – 3 years	0.8	1 – 3 years	0.5	1 – 3 years	0.5	1 – 3 years	0.5
4 – 6 years	1.1	4 – 6 years	0.6	4 – 6 years	0.6	4 – 8 years	0.6
7 – 9 years	1.3	7 – 9 years	0.9	7 – 9 years	0.9		
Boys		Boys		Boys		Boys	
10 – 12 years	1.6	10 – 18 years	1.3	10 – 18 years	1.3	9 – 13 years	0.9
13 – 15 years	1.5					14 – 18 years	1.3
16 – 19 years	1.5						
Girls		Girls		Girls		Girls	
10 – 12 years	1.4	10 – 18 years	1.0	10 – 18 years	1.0	9 – 13 years	0.9
13 – 15 years	1.3					14 – 18 years	1.0
16 – 19 years	1.3						
Men		Men		Men		Men	
20 – 39 years	1.5	19 – 65 years	1.3	19 – 65 years	1.3	19 – 30 years	1.3
40 – 49 years	1.4	> 65 years	1.3	> 65 years	1.3	31 – 50 years	1.3
50 – 59 years	1.4					51 – 70 years	1.3
≥ 60 years	1.2					> 70 years	1.3
Women		Women		Women		Women	
20 – 39 years	1.2	19 – 65 years	1.1	19 – 65 years	1.1	19 – 30 years	1.1
40 – 49 years	1.2	> 65 years	1.1	> 65 years	1.1	31 – 50 years	1.1
50 – 59 years	1.2					51 – 70 years	1.1
≥ 60 years	1.2					> 70 years	1.1
Pregnancy		Pregnancy		Pregnancy		Pregnancy	
1 st trimester	1.2		1.4		1.4	14 – 18 years	1.4
2 nd trimester	1.4					19 – 30 years	1.4
3 rd trimester	1.4					31 – 50 years	1.4
Lactation		Lactation		Lactation		Lactation	
1 st 6 months	1.5		1.6		1.6	14 – 18 years	1.6
2 nd 6 months	1.2					19 – 30 years	1.6
						31 – 50 years	1.6