PROTEIN QUALITY

THE NUTRITIONAL ADVANTAGE OF ANIMAL-SOURCED FOODS

WHAT IS PROTEIN?

Dietary protein (termed 'protein' in this resource) falls under the wider group of macronutrients alongside carbohydrates and fats. These macronutrients are required to fuel our bodies and provide us with energy. **Protein can be found in either animal sources (e.g. red meat, fish, eggs, poultry and dairy) or plant sources (e.g. soy, legumes, peas, grains, nuts and seeds).** A healthy diet should include a variety of protein foods at all stages of life.

Proteins are long and folded chains made of amino acids, which are akin to building blocks for the body. Hundreds to thousands of these amino acids join in simple or very complex ways to produce proteins, each with a unique shape and structure[1]. The protein we consume from food is an essential nutrient the human body requires to build muscle, bone, skin and hair[1].

PROTEIN FOR HEALTH

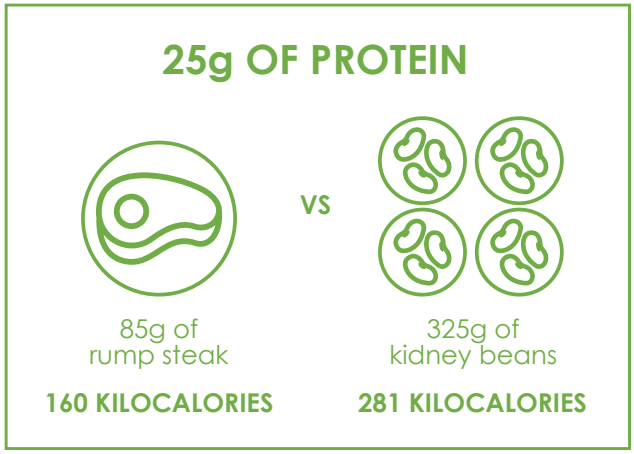
Protein has a direct influence on many aspects of health, including growth and development; maintenance of chemical (hormonal) balance; supporting the immune system and acting as the building blocks of bone, muscle, skin and blood[1]. There is continual turnover of protein in the body, with stores being broken down and replaced in a process called protein turnover[2]. It is important we eat enough dietary protein to prevent breakdown of muscle.

Reasons we need protein:

- **Growth and development:** Protein is essential for the body's growth and development at all stages of life, beginning from conception through puberty, to adulthood[3]. Adequate amounts of protein must be consumed for optimal growth and development to take place.

- **Lean muscle mass and bone health:** Protein is essential for the maintenance and repair of muscle and our organ systems. In addition to calcium and vitamin D, protein has been shown to positively affect skeletal bone development and formation. Protein aids in building bigger and stronger muscles[4]. Protein is also crucial to prevent muscle loss and bone deterioration, which can naturally occur with ageing and is associated with frailty and increased risk of falls[4].

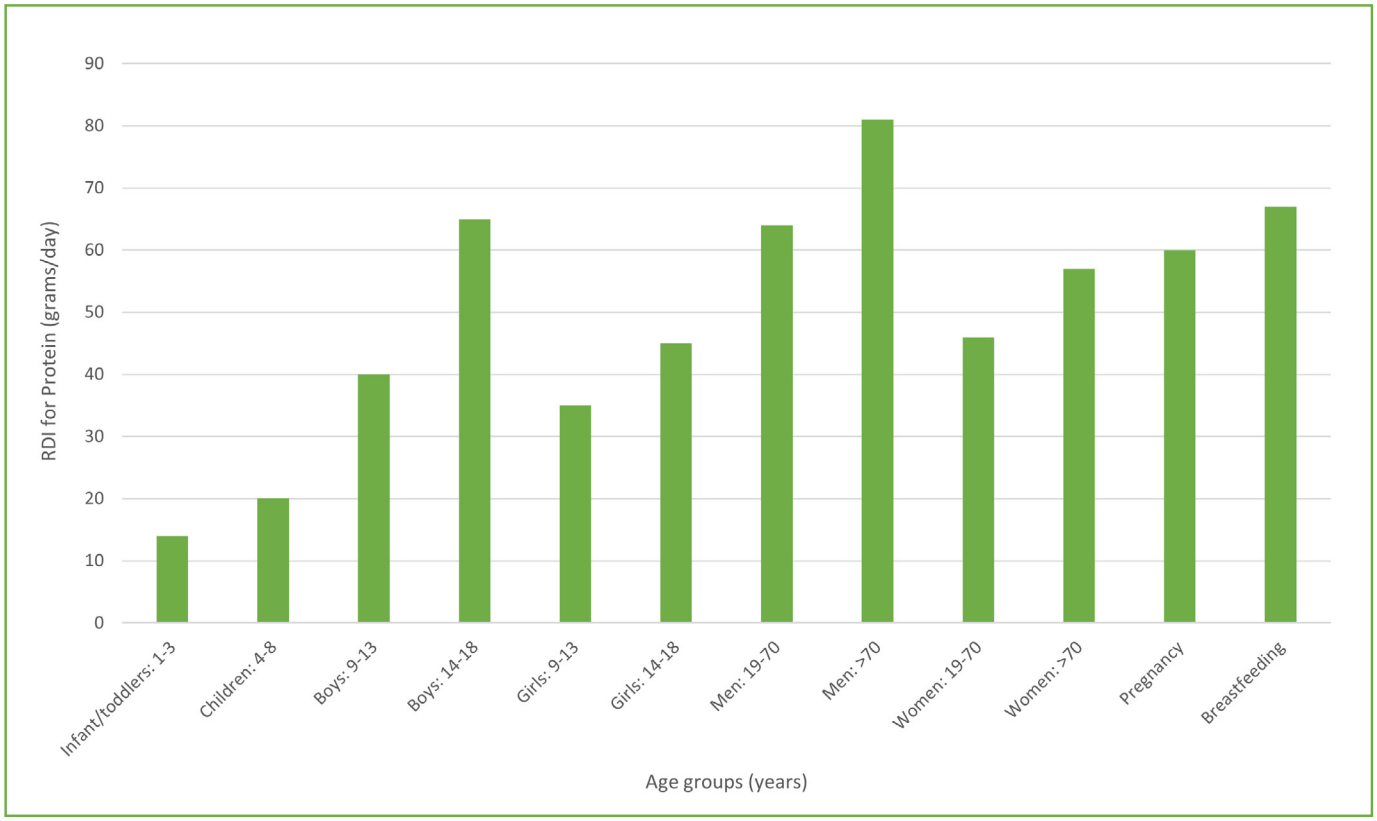
- **Weight management:** Protein can increase satiety (the feeling or state of being full and satisfied) and reduce food cravings[5]. High quality animal proteins can often be lighter on calories and more nutrient dense than plant proteins and highly processed protein sources[6]. For example, 85g of cooked, lean rump steak has 25g of protein and contains 160 kilocalories, whereas to get 25g of protein from cooked kidney beans, one would need to eat over four times the amount (325g or just over one cup) which is nearly double the calories (281 kilocalories)[9]. This feeling of fullness with less calories consumed, may aid in overall weight control.



- **Cardiovascular health:** Evidence has shown higher consumption of dietary protein may decrease systolic and diastolic blood pressure[6,7]. This is of importance to manage high blood pressure (hypertension), which has been shown to be one of the most effective ways to decrease cardiovascular disease risk[8]. For cardiovascular health, the New Zealand Heart Foundation suggests eating lean meat among other protein sources as one of a range of healthy dietary patterns. It recommends consuming less than 350g per week (cooked) spread across three meals per week (with an individual portion size of approximately 100g)[10].

HOW MUCH PROTEIN DO WE NEED?

Protein is essential at all stages of life, however there are certain groups who need a little more, as seen in the graph below[2]. Note the RDI shown on the graph below is the Recommended Dietary Intake of protein per day.



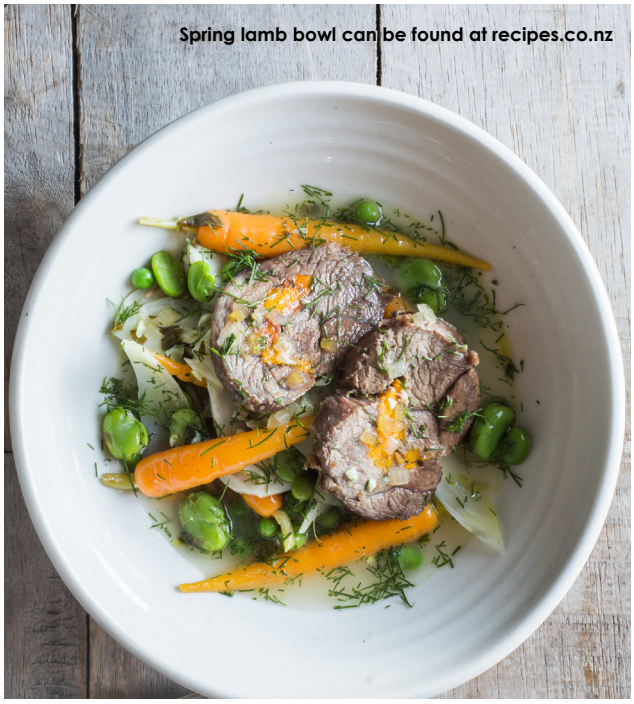
Refer to the Ministry of Health Eating and Activity Guidelines for the number of daily protein serves for each age group. The guidelines recommend adults consume 350-500g of lean red meat per week, which equates to approximately 3 times per week. (reference number 13)

New Zealanders who need extra protein:

On the whole, most New Zealanders are meeting their protein requirements[11]. However, for those who need extra protein to meet their needs, here are some tips:

- **Pregnant and breastfeeding women** need to get enough protein especially in the last trimester of pregnancy to meet the changing demands of both the mother and the growing baby[12]. The Ministry of Health recommends pregnant women have three and a half servings of protein per day and lactating women have two and a half servings per day[13]. Having high-quality protein foods at mealtimes (e.g. lean red meat, poultry, cooked seafood, eggs) and snacking on high-quality protein foods throughout the day (e.g. nuts, yoghurt, cheese or peanut butter) will support optimal protein intake.

- **Infants and children (0-8 years)** grow and develop fast, have small stomachs and tend to feel full quickly, therefore every bite counts[14,15]. It is important their diet contains nutrient dense foods, which help to ensure they meet their energy and nutrient requirements. In some developing countries, protein malnutrition in children leads to Kwashiorkor disease, which can lead to both physical and mental developmental delays[1]. One way to make sure a child is getting enough high-quality protein is to offer it in meals and snacks, in fun and exciting ways (e.g. a boiled egg with toast soldiers, peanut butter on apple slices or make your own burgers).
- **Older children and teenagers (9-18 years)** are constantly growing, encountering puberty and can be very active[14], all of which requires extra protein in the diet. According to Sport New Zealand, 92% of young people participate in play, active recreation and/or sport with an average of 11 hours each week spent doing these activities[16]. One way to help older children and teens meet their protein needs is to have easy grab-and-go meals (e.g. left-over spaghetti Bolognese, Shepherds pie etc) and snacks (e.g. a pottle of yoghurt, hummus and carrot sticks, beef jerky or skewers) in the fridge for them.
- **Athletes and sports people** who do vigorous, intense trainings and/or events need more protein for optimum performance, muscle repair and muscle maintenence[17]. One way athletes can stay on top of their protein intake is to make sure they have a small protein-rich meal and/or snack before exercise and a decent sized protein-rich meal after exercise (both with carbohydrates)[18].
- **Older adults (70+ years)** can experience dental issues, limited budget, decreased appetite and changes to digestion, all of which can result in a reduction of dietary protein[19]. On top of this, older adults are also more prone to muscle loss and reduced strength (sarcopenia) and osteoporosis risk, therefore their protein requirements are higher[19]. Older adults can increase their protein intake by eating high-quality protein with each meal (e.g. 25g protein per meal) and including protein-rich snacks. For those with poor appetites, it is advised to eat the protein part of the meal first before finishing the rest of the meal. If there are dental issues, consider softer texture proteins such as eggs, mince and dairy products e.g. yoghurt [20,21].


Spring lamb bowl can be found at recipes.co.nz

HOW CAN YOU GET PROTEIN IN THE DIET?

Many foods can be a good source of protein. High-quality protein sources, such as animal proteins, are complete in amino acid profile (See 'Is all protein the same?' below) and have a much higher proportion of protein per weight or per serve, as can be seen in the table below.

Protein content (g/100g or by serve) of animal and plant protein foods[9].

Protein serve	Protein (g)
Braised lamb shank (100g)	33.3
Grilled chicken breast (100g)	31.2
Roasted pork leg steak (100g)	30.8
Beef rump steak, fried (100g)	30.2
Canned tuna in spring water (100g)	26.6
Baked hoki fillet (100g)	22.0
Firm tofu, fried (100g)	17.9
Boiled black beans (100g)	8.9
Light blue top milk (250ml)	8.7
Boiled red kidney beans (100g)	7.9
Boiled lentils (100g)	7.6
Raw peanuts (30g)	7.3
Plain low-fat yoghurt (150g pottle)	7.2
Boiled egg (size 7)	7.0
Soy milk (250ml)	7.0
Raw almonds (30g)	6.0

Note: This table does not include all protein foods

IS ALL PROTEIN THE SAME?

There is a general conception that all proteins have the same quality, however this is not the case. **There is a significant difference in protein quality for plant-derived and animal-derived foods** which is due to their different amino acid profiles and bioavailability (the ability of the body to absorb and use protein).

Amino acid profile

There are 20 amino acids in total that combine to form a protein[22]. Many amino acids can be created within the body; these are called non-essential or dispensable amino acids and are not required in the diet. However, there are nine essential amino acids which cannot be formed biologically and need to be acquired through dietary intake[22].

The nine essential amino acids are: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. If a protein food is inclusive of all nine essential amino acids it is considered to be a complete or high-quality protein, whereas protein foods missing one or more amino acids are considered incomplete or low-quality protein[1].

The amino acid profile of a certain food can describe the protein quality of the food. Protein testing methods, such as high-performance liquid chromatography, are used to analyse the presence and level of essential amino acids to deem a protein food to be either a complete or incomplete source of protein [23] (see Bioavailablity overleaf). **Overall, animal proteins such as red meat, poultry, fish, seafood, eggs, and dairy products are generally seen as higher quality proteins when compared to plant proteins except for soya beans[23]**. This is illustrated in the table below.

Daily Adult Essential Amino Acid Requirements and Protein Food Sources								
Essential amino acid	Adult requirement[24] (mg/g protein/ day)**	Food (mg/g protein)						
		Beef[26]	Lamb[26]	Milk[25]	Egg[24]	Soy protein[25]	Pea protein[27]	Brown rice protein[27]
Lysine	45	172	182	80	66	60	47	19
Leucine	59	167	165	97	83	77	57	58
Isoleucine	30	93	96	50	51	48	23	20
Valine	39	98	109	58	48	47	27	28
Phenylalanine	38	86	84	99	60	52*	37	37
Threonine	23	82	103	47	48	36	25	23
Histidine	15	85	43	30	24	26	16	15
Methionine	16	68	68	27	35	13	3	20
Tryptophan	6	25	22	13	18	13	-	-

**value is indicative of phenylalanine and tyrosine*

*** The requirement for each indispenable amino acid divided by the protein requirement for adults aged >18 years*

Essential amino acid values obtained from raw lean tissue of New Zealand beef rump and lamb hind shanks[26].

Plant-based protein source amino acid profiles attained from commercially available protein isolates (concentrated protein fractions)[27].

Egg amino acid profile attained from raw egg proteins[24].

The importance of lysine

Lysine contributes to the maintenance and growth of muscle and is one of the most limited essential amino acids available in a plant-derived diet[28,29]. In developing countries, where poverty exists and animal protein intake is limited, **lysine deficiency can lead to fatigue, nausea, poor concentration and irritability, and long term it can cause growth inhibition, anaemia, hair loss and issues with fertility**[30,31]. It is also important to note that when protein quality is sub-optimal or limited in some way, a larger food volume is required to meet the RDI, which subsequently means higher caloric energy intake. This can be problematic for groups with low or loss of appetite or early satiety (e.g. the elderly or those with swallowing difficulties [dysphagia])[24].

Bioavailability

There are two common internationally recognised methods to measure protein digestibility and absorbability:

- **Digestible and Indispensable Amino Acid Score (DIAAS).** DIAAS is the protein quality ranking method recommended by the Food and Agriculture Organisation (FAO) of the United Nations and provides a score of >100 as the highest measure of protein quality being considered "excellent" quality[32-35]. A score of 75-99 is considered a "good" source of protein and a score of <75 will not have a claim attached to protein quality[32-35]. This method focusses on the digestibility and absorption of mainly essential amino acids such as valine, isoleucine, leucine, and lysine in the small intestine[33].

- **Protein Digestibility-Corrected Amino Acid Score (PDCAAS).** PDCAAS is the most common method of assessing protein digestibility and is represented by a chemical score that ranges between 0 and 1.0. A score of 1.0 means that all essential amino acids are present in amounts that meet minimum requirements for the estimated average requirements for tissue growth and maintenance[35,36].

The DIAAS and PDCAAS scores of commonly eaten protein foods are listed below. This suggests foods that score well on both analysis methods are the easiest dietary protein sources to digest and absorb when consumed.

Protein source	DIAAS	PDCAAS
Cow's milk (whole milk)[38]	114	1.0
Egg (Hard boiled) [38]	113	1.0
Lean beef (raw)[37]	111	1.0
Chicken breast[39]	72	1.0
Cooked kidney beans[39]	59	0.65
Soy protein isolate[38]	98	0.90
Cooked rice[38]	59	0.62
Cooked peas[38]	58	0.60
Wheat[37]	40.2	0.46

The cooking method of beef can affect the DIAAS. A New Zealand study, using the pig model for adult humans, found the DIAAS was greater for raw, boiled, and pan-fried beef than for roasted and grilled beef. However, the high DIAAS range across all cooking conditions confirms that beef is a high-quality protein source[40].

Whilst animal proteins score higher for both DIAAS and PDCAAS, it is recognised that whole food proteins are more than just their constituent amino acids. They also contain other non-protein nutritive components such as vitamins, minerals, and for plant-based protein, fibre (missing in animal-based proteins), so it is important to include a range of proteins from both animal and plant sources in a diet.

WHY RED MEAT?

- Lean red meat, such as New Zealand pasture-fed beef and lamb, is a **high-quality and nutrient dense source of protein.** It is complete in essential amino acids and scores among the highest of common protein foods for digestibility and absorption on both DIAAS and PDCAAS protein analysis methods.

- Lean red meat is **light on calories** yet protein and nutrient dense. For example, when comparing 100g of cooked lean rump steak to 100g of cooked lentils, one would need to eat approximately four times the amount of lentils (or one can of lentils) and over twice the amount of calories (442kcal) to get the same amount of protein as the rump steak[9]. Combining meat with pulses (e.g. a lentil and mince cottage pie) is a good way to get more protein and a range of nutrients (e.g. fibre).

- Lean red meat is **packed full of other essential micronutrients such as vitamins and minerals essential for a healthy and balanced diet.** Red meat is a good source of vitamin B_{12}, bioavailable iron and zinc while also being a source of other minerals and vitamins such as selenium, B vitamins and vitamin D[47-49].

The best beef & lentil cottage pie can be found at recipes.co.nz

PROTEIN, ENVIRONMENT AND GLOBAL HEALTH

Although plant proteins serve an important purpose for global protein supply, recent studies have shown that a radical reduction of animal-based proteins may be problematic[42]. The transition from animal proteins to plant-derived proteins has been proposed to tackle the global warming crisis[43,44]. This notion mainly comes from the identification that lower greenhouse gas emissions (GHGE) per calorie are emitted with plant-based diets, over diets including animal products. However, as one recent study has shown when you look beyond calories alone and take into account protein quality (GHGE per total amino acids), the opposite pattern was found with lower GHGE from meals inclusive of animal products compared to strictly plant-based meals[45]. This suggests eating high-quality protein sources could have lower GHGE when compared to plant-based protein foods needed for the same amount of amino acids.

Soya is the only complete plant-based protein available, therefore the suggestion for a complete shift towards plant-based protein diets could lead to a global deficiency in certain essential amino acids, such as lysine[44].

Protein sources that can supply lysine in adequate amounts are mainly animal-based products, and therefore an extreme reduction of these products could have a detrimental effect on global nutritional status[42]. To optimise the nutritional adequacy of future generations, moderate amounts of high-quality protein sources, such as New Zealand pasture-fed beef and lamb along with other animal and plant proteins, should be considered as part of a healthy, varied and well-balanced diet.

The environmental impact of food has become of greater interest in the quest to encourage foods that meet human health needs with the lightest environmental footprint. **Since 1990, the New Zealand sheep and beef sector have made significant environmental changes to optimise agricultural productivity and reduce GHGE by 30%[41]. This progress is working towards a sector goal of being carbon neutral by 2050.** Through collective efforts from farmers, government, consumers and food industry partners, such as Beef + Lamb New Zealand, more environmentally conscious farming strategies have been identified and adopted. *For more information on environmental impacts and sustainability of sheep and beef farming visit:* https://www.beeflambnz.co.nz/sustainability

KEY MESSAGES FOR HEALTH PROFESSIONALS

- **Protein is an essential nutrient required at every age and stage. It is particularly important for pregnant and breastfeeding women, growing children and teenagers, athletes and older adults.**
- **All age groups should aim to incorporate some protein at all meals and snacks to help meet nutritional and energy requirements.**
- **Lean red meat is high-protein quality, protein dense, nutrient rich and calorie light. As per Ministry of Health Eating and Activity Guidelines, between 350-500g cooked, lean red meat can be enjoyed each week[13], or in other words, about 3 times per week as part of a varied, balanced and healthy diet.**
- **Not all protein sources have the same quality. Animal sourced proteins are a:**
  - **High-quality protein source that provide the full array of essential amino acids and other important nutrients, such as bioavailable iron, vitamin B_{12} and zinc.**
  - **Top scorer for protein digestibility and absorbability.**
  - **Richer source of protein per gram compared to plant protein sources, meaning you don't need to eat as much.**
- **For people who choose to avoid eating animal sourced foods, consider supporting them with meal planning to combine a range of plant foods. Dietary advice input from a Registered Nutritionist or Registered Dietitian may be beneficial.**

REFERENCES

1. N.V. Bhagavan & Chung-Eun, Ha. (2015). *Essentials of Medical Biochemistry* (2nd edition). Academic Press: Massachusetts.
2. National Health and Medical Research Council and Ministry of Health. (2006). *Nutrient Reference Values for Australia and New Zealand.* Canberra, ACT.
3. Herring, C., Bazer, F., Johnson, G. & Wu, G. (2018). *Impacts of maternal dietary protein intake on fetal survival, growth, and development. Experimental Biology and Medicine*, 243(6), 525-533.
4. Rizzoli, R., Biver, E., Bonjour, J.P., Coxman, V., Goltzman, D., Kanis, J. A., Lappe, J., Rejnmark, L., Sahni, S., Weaver, C. & Weiler, H. (2018). *Benefits and safety of dietary protein for bone health—an expert consensus paper endorsed by the European Society for Clinical and Economical Aspects of Osteoporororosis, Osteoarthritis, and Musculoskeletal Diseases and by the International Osteoporosis Foundation.* Osteoporos Int. 29:1933–1948.
5. Perez-Cornago, A., van Baak, M., Saris, W., Martínez, J. & Astrup, A. (2014). *The role of protein and carbohydrates for long-term weight control: Lessons from the Diogenes Trial.* Current Nutrition Reports, 3(4), 379-386.
6. Astrup, A., Raben, A. & Geiker, N. (2014). *The role of higher protein diets in weight control and obesity-related comorbidities. International Journal of Obesity,* 39(5), 721-726.
7. Liu, L., Ikeda, K., Sullivan, D.H., Ling, W. & Yamori Y. (2002). *Epidemiological evidence of the association between dietary protein intake and blood pressure: A meta-analysis of published data.* Hypertens Res, 25, 689 –695.
8. Kjeldsen, S. (2018). *Hypertension and cardiovascular risk: General aspects. Pharmacological Research*, 129, 95-99.
9. *Plant and Food Research and Ministry of Health.* (2018). *The Concise New Zealand Food Composition Tables. 12th Edition.* Wellington: New Zealand.
10. *National Heart Foundation of New Zealand. Red and poultry: position statement.* Auckland; October 2020.
11. University of Otago and Ministry of Health (2011). *A Focus on Nutrition: Key findings of the 2008/9 New Zealand Adult Nutrition Survey.* Wellington: New Zealand.
12. Elango, R. & Ball, R. (2016). *Protein and amino acid requirements during pregnancy. Advances in Nutrition*, 7(4), 839-844.
13. Ministry of Health. 2020. *Eating and Activity Guidelines for New Zealand Adults: Updated 2020.* Wellington: Ministry of Health.
14. Ministry of Health. (2012). *Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2–18 years): A background paper.* Partial revision February 2015. Wellington: New Zealand.
15. Ministry of Health. (2008). *Food and Nutrition Guidelines for Healthy Infants and Toddlers (Aged 0–2): A background paper (4th Ed).* Wellington: Ministry of Health.
16. Sport New Zealand. (2019). *Active NZ 2018 Participation Report.* Wellington: New Zealand.
17. Bosse, J. & Dixon, B. (2012). *Dietary protein to maximize resistance training: A review and examination of protein spread and change theories. Journal of the International Society of Sports Nutrition,* 9(1).
18. Phillips, S. & Van Loon, L. (2011). *Dietary protein for athletes: From requirements to optimum adaptation. Journal of Sports Sciences,* 29(1), 29-38.
19. Beasley, J., Shikany, J. & Thomson, C. (2013). *The role of dietary protein intake in the prevention of sarcopenia of aging. Nutrition in Clinical Practice,* 28(6), 684-690.
20. Montero-Fernández, N., Serra-Rexach, J.A. (2013). *Role of exercise on sarcopenia in the elderly.* Eur J Phys Rehab Med, 49(1), 131-143.
21. Bauer, J., Biolo, G., Cederholm, T. (2013). *Evidence-based recommendations for optimal dietary protein intake in older people: A position paper from the PROT-AGE study group.* J Am Med Dir Assoc, 4(8), 542-559.
22. Hall, N. & Schönfeldt, H. (2013). *Total nitrogen vs. amino-acid profile as indicator of protein content of beef. Food Chemistry,* 140(3), 608-612.
23. FAO Expert Consultation. (2013). *Dietary protein quality evaluation in human nutrition* (ISBN. 978-92-5-107417-6). Food and Agriculture Organisation of the United Nations Rome.
24. WHO Technical Report Series. (2007). *Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint WHO/ FAO/UNU Expert Consultation.* (ISBN. 92 4 120935 6).
25. Kalman, D. (2014). *Amino acid composition of an organic brown rice protein concentrate and isolate compared to soy and whey concentrates and isolates.* Foods, 3(3), 394-402.
26. Purchas, R., W. & Wilkinson, B. W.P. (2013). *The concentration of selected nutrients in New Zealand beef and lamb cuts and offal. 2nd edition.* Massey University Institute of Food, Nutrition and Human Health.
27. Gorissen, S., Crombag, J., Senden, J., Waterval, W., Bierau, J., Verdijk, L. & van Loon, L. (2018). *Protein content and amino acid composition of commercially available plant-based protein isolates.* Amino Acids, 50(12), 1685-1695.
28. Baker, H.B. (2007). *Lysine, arginine, and related amino acids: An introduction to the sixth amino acid assessment workshop.* J.Nutr, 137, 1599-1601.
29. Rutherfurd, S. M., Bains, K., Moughan, P.J. (2012). *Available lysine and digestible amino acid contents of proteinaceous foods of India.* British Journal of Nutrition, 108, S59-S68.
30. Rushton, D.H. (2002). *Nutritional factors and hair loss, Clinical and Experimental Dermatology.* 27(5), 396-404.
31. Ghosh, S., Smriga, M., Vuvor, F., Suri, D., Mohammed, H., Armah, S.M. & Scrimshaw, N.S. (2010). *Effect of lysine supplementation on health and morbidity in subjects belonging to poor peri-urban households in Accra, Ghana.* The American Journal of Clinical Nutrition, 92(4), 928–39.
32. Huang, S., Wang, L., Sivendiran, T. & Bohrer, B. (2017). *Amino acid concentration of high protein food products and an overview of the current methods used to determine protein quality. Critical Reviews in Food Science and Nutrition,* 58(15), 2673-2678.
33. Burd, N.A., McKenna, C.F., Salvador, A.F., Paulussen, K.J.M. & Moore, D.R. (2019). *Dietary protein quantity, quality, and exercise are key to healthy living: A muscle-centric perspective across the lifespan.* Front. Nutr. 6 (83).
34. Wolfe, R., Rutherfurd, S., Kim, I. & Moughan, P. (2016). *Protein quality as determined by the Digestible Indispensable Amino Acid Score: Evaluation of factors underlying the calculation. Nutrition Reviews,* 74(9), 584-599.
35. Mathai, J., Liu, Y. & Stein, H. (2017). *Values for Digestible Indispensable Amino Acid Scores (DIAAS) for some dairy and plant proteins may better describe protein quality than values calculated using the concept for Protein Digestibility-Corrected Amino Acid Scores (PDCAAS).* British Journal of Nutrition, 117(4), 490-499.
36. Schaafsma, G. (2012). *Advantages and limitations of the protein digestibility-corrected amino acid score (PDCAAS) as a method for evaluating protein quality in human diets. Britis*h Journal of Nutrition, 108(2), 333-336.
37. Ertl, P., Knaus, W. & Sollitsh, W. (2016). *An approach to including protein quality when assessing the net contribution of livestock to human food supply.* Animal, 10 (11), 1883-1889.
38. Philips, S.M. (2017). *Current concepts and unresolved questions in dietary protein requirements and supplements in adults.* Front Nutr. 4 (13), 404-409.
39. Rutherfurd, S.M., Fanning, A.C., Miller, B.J., Moughan, P.J. (2015) *Protein Digestibility-Corrected Amino Acid Scores and Digestible Indispensable Amino Acid Scores Differentially*
40. Hodgkinson, S.M., Montoya, C.A., Scholten, P. T., Rutherfurd, S.M., & Moughan, P.J. (2018). *Cooking conditions affect the true ileal digestible amino acid content and Digestible Indispensable Amino Acid Score (DIAAS) of bovine meat as determined in pigs.* J. Nutr,148(10), 1564–1569.
41. Beef and Lamb New Zealand. (2018). *Environment strategy and implementation plan 2018-2022.* Retrieved from https://beeflambnz.com/sites/default/files/levies/files/Env-strategy-Imp-plan.pdf (accessed May 2020).
42. Leinonen, I., Iannetta, P., Rees, R., Russell, W., Watson, C. & Barnes, A. (2019). *Lysine supply is a critical factor in achieving sustainable global protein economy. Frontiers in Sustainable Food Systems,* 3(27), 1-11.
43. *Intergovernmental Panel on Climate Change (IPCC). (2018). Global Warming of 1.5 °C.* Retrieved from https://www.ipcc.ch/sr15/ (accessed May 2020).
44. Murphy, S.P. & Allen, L.H. (2003). *Nutritional importance of animal source foods.* J Nutr, 133, 3932-3935.
45. Park, G., Kim, J., Lee, M., Yun, J. & Park, K. (2020). *Comparing greenhouse gas emissions and nutritional values based on Korean suggested meal plans and modified vegan meal plans.* Journal of Animal Science and Technology, 62(1), 64-73.
46. Ferreira, R. R., Varisi, V. A., Meinhardt, L. W., Lea, P. J., & Azevedo, R. A. (2005). *Are high-lysine cereal crops still a challenge?* Braz. J. Med. Biol. Res. 38, 985–994.
47. Wyness, L. (2015). *The role of red meat in the diet: Nutrition and health benefits.* Proceedings of the Nutrition Society, 75(3), 227-232.
48. Derbyshire, E. (2017). *Associations between red meat intakes and the micronutrient intake and status of UK females: A secondary analysis of the UK National Diet and Nutrition Survey.* Nutrients, 9(7), 768.
49. Benstoem, C., Goetzenich, A., Kraemer, S., Borosch, S., Manzanares, W., Hardy, G. & Stoppe, C. (2015). *Selenium and its supplementation in cardiovascular disease—What do we know? Nutrients,* 7(5), 3094-3118.

Acknowledgements to the following for the development and review of this document:

Daniel Bahg – Student Dietitian, University of Auckland
Dr. Andrea Braakhuis, University of Auckland

BEEF + LAMB
NEW ZEALAND

/nzbeeflamb @beeflambnz /beeflambnz

For more information and great protein-rich nutritious recipes and meal ideas, visit recipes.co.nz

Feburary 2021