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This review describes the composition of milk protein and shows how it relates to its quality, which evidence suggests is higher than previously thought.

A publication for health professionals

Milk protein:

New insights into quality and function

Milk protein includes whey and casein as the major fractions and also numerous minor bioactive peptides and essential and non-essential amino acids. The traditional anabolic functions of protein remain important, but recent research has also identified additional metabolic and neutraceutical roles of the biologically active peptides of milk protein. At present, the quality of milk protein is based on its constituent amino acids – something largely underestimated for animal-derived foods by common assessment methods. The quality of milk protein is higher than previously believed.

The composition of milk protein

Milk is an important source of protein in the human diet. The protein in milk includes whey, which represents the soluble fraction, and casein, which represents a less soluble fraction. Whey makes up about 20% (w/w) of milk protein and is rich in branched-chain amino acids (leucine, isoleucine and valine). Casein has a higher proportion of histidine, methionine and phenylalanine and constitutes about 80% (w/w) of milk protein.[1,2] Milk also contains bioactive peptide components with unique functions. The functions of some milk proteins are listed in Table 1.

Amino acids are the building blocks of protein and are traditionally classified as essential or non-essential. The essential amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) must be provided by the diet and are therefore said to be indispensable. The others (cysteine, tyrosine, glycine, arginine, glutamine, proline, asparagine, glutamic acid, alanine and serine) can be produced in the body and are therefore called dispensable. The first six in this latter list (cysteine, tyrosine, glycine, arginine, glutamine, proline) plus taurine may become essential under special conditions. The biological value of a food protein is determined by the extent to which its profile of essential amino acids satisfies the body's needs.

Table 1
Concentration and function of selected cow's milk proteins[3,4]

Protein	Concentration (g/L)	Functions
Total caseins	26.0	Mineral transport (Ca^{2+}, PO_4^{3-} Fe^{2+}, Zn^{2+}, Cu^{2+}); precursors of bioactive peptides
α-Casein	13.0	
β-Casein	9.3	
κ-Casein	3.3	
Total whey proteins	6.3	
β-Lactoglobulin	3.2	Retinol carrier; binding of fatty acids; possible antioxidant
α-Lactalbumin	1.2	Lactose production; calcium transport; immunomodulator; anticarcinogen
Immunoglobulins (A, M and G)	0.7	Immune response
Alanine (amino acid)	0.4	Nitrogen transport in blood
Lactoferrin	0.1	Antimicrobial action; antioxidant; immunomodulator; iron absorption; anticarcinogen
Lactoperoxidase	0.3	Antimicrobial action
Lysozyme	0.0004	Antimicrobial action; synergistic actions with immunoglobulins and lactoferrin
Miscellaneous others	0.8	
Proteose peptone	1.2	
Glycomacropeptides	1.2	Antiviral action; bifidogenic action

Table 2
Methods to evaluate protein quality[2,5,6,9,11]

Method	Description and comments
Nitrogen balance	Measurement of the difference between nitrogen intake and losses. Nitrogen retention efficiency and nitrogen efficiency for growth can also be included.
Biological value ('true' and 'relative')	Utilisation of absorbed essential and non-essential dietary amino acids
Protein efficiency ratio ('estimated' and 'maximum')	The ratio compares the growth response of young rats, fed a marginal amount of test protein, with that of control rats, fed a similar amount of casein
Amino acid score (AAS)	The content of the first limiting amino acid in a test protein (mg/g) is divided by that of the corresponding amino acid in a reference protein (mg/g). An amino acid scoring pattern is age-specific.[12] It is obtained by dividing essential amino acid requirements by minimum requirements of high-quality proteins. Three amino acid scoring patterns have been published: 0.5 years, 1–2 years, and >18 years. It is clear that minimum requirements do not necessarily represent optimum nutrition, beyond nitrogen balance and growth.[9] Millward[13] published an adapted amino acid scoring pattern for infants, children, adolescents and adults, taking amino acids requirements and safe protein intakes into consideration.
Protein digestibility corrected amino acid score (PDCAAS)	The PDCAAS is derived from a comparison of the first limiting amino acid in the protein under investigation to the corresponding amino acid concentration in a reference amino acid pattern, corrected for faecal nitrogen digestibility. Formula: AAS x true nitrogen digestibility (%)
Digestible indispensable amino acid score (DIAAS)	The ratio of the amount (mg) of digestible indispensable amino acid in 1 g of dietary protein to the amount (mg) of the same indispensable amino acid in 1 g of a reference protein, expressed as a percentage.[6,14]

Milk protein quality

Proteins differ in their composition and indispensable amino acid content, and with regard to the physico-chemical properties of their food matrix.[5] Generally speaking, protein quality refers to the ability of a food protein to meet the metabolic demand of the (human) body for amino acids and nitrogen.[2,6] Factors such as the age, health status and energy intake of the person consuming the food also affect the functional protein quality,[7] although various criteria and markers can be used to define dietary protein requirements.

In addition to the composition of a food protein, physiological criteria such as digestibility and bioavailability are core concepts that should be used when describing protein quality.[2]

- Protein **digestibility** refers to the progressive proteolytic processing of proteins to release amino acids as food travels from the mouth to the small intestine (ileal digestibility) or when it has reached the anus (faecal digestibility).[2] Protein digestibility can be differentiated as 'apparent', 'corrected', *in vitro* or *in vivo*.
- **Bioavailability** of an amino acid is the proportion of consumed protein that is absorbed in a chemical form for it to be used by the human body. This utilisation can be influenced by food processing (e.g. Maillard reactions due to heat treatment, which affect lysine bioavailability; spray drying, extrusion, irradiation, fermentation) or by antinutritional factors (e.g. enzyme inhibitors, lectins, tannins), and the interaction between these compounds and processing.[2,8,9]

Digestibility and bioavailability can be inter-related and specific processes during manufacturing may affect the various protein fractions to varying extent. For example, Barbé et al.[10] described gelation through acidification or renneting differentially affecting the kinetics of milk protein digestion and amino acid availability.

Table 2 summarises some methods used in the assessment of protein quality.

Because of its relative simplicity and direct relationship with the human requirements for growth and tissue repair, the protein digestibility corrected amino acid score (PDCAAS) is widely used and, despite some limitations, remains the preferred reference measure of international regulatory authorities (World Health Organization/Food and Agriculture Association/United Nations University). Briefly, these limitations include the following:

- The truncation rule of the PDCAAS states that the biological value may not exceed 1. This means that proteins with additional essential amino acids (i.e. beyond those in the reference amino acid pattern) do not get due credit.[6,9,15] To correct this, so-called supplementation power (SP) values have been published. These values are based on the power of the protein to balance diets that are deficient in limiting amino acids (i.e. lysine in cereals, sulfur amino acids in legumes, threonine in some cereals, and tryptophan in maize). In the case of milk powder, the SP values for lysine, sulfur amino acids, threonine and tryptophane are 1.46, 1.22, 1.30 and 1.54, respectively.[9] These values indicate that milk protein has the power to supply the limiting amino acids from plant-based proteins.
- Amino acid availability is not accounted for.[9,15]
- Antinutritional factors in plant-food protein sources are not taken into account.[8,9]

In practice this means that proteins of high biological value, for example milk protein, are of even better quality than the original (uncorrected) PDCAAS method suggests. It has been recommended that a new expert consultation panel re-examines protein quality assessment methods. The DIAAS may address some of the limitations, but international consensus is still outstanding.

Functions of milk protein

Milk protein has numerous functions. All classic functions ascribed to proteins as a group also apply to dairy protein. This refers to the provision of amino acids for protein turnover (i.e. anabolism and catabolism in health and disease throughout the life cycle, and as part of biological catalysts, plasma and membrane transport, movement, structure, protein folding, immunity, growth and differentiation[16]).

In addition to some of the unique functions of milk protein fractions listed in Table 1, McGregor and Poppitt[17] have described numerous roles of milk protein in metabolic health, including decreased prevalences of hypertension, dyslipidaemia and mild hyperglycaemia. In the case of the effect of dairy on cardiometabolic risk factors, Pal and Radavelli-Bagatini[18] focused on the whey component and specifically highlighted the potential role of leucine in this regard. Dairy protein may indirectly aid weight management through its effect on satiety and body composition, and seems to function synergistically with physical activity.[12,17,18] Dairy protein intakes are also considered when risk factors for non-communicable diseases such as osteoporosis and bone health are assessed.[19] The biologically active components of dairy have been labelled 'neutraceuticals',[4] resulting in milk and dairy being classified as functional foods.[20]

Tomé[5] suggested that the unique response of specific target tissues (e.g. bone, muscle) and hormones (e.g. insulin, IGF1) to a particular protein be taken into account when determining protein quality. As new research reveals more functions for protein and amino acids in the regulation of body composition and bone health, gastrointestinal function and bacterial flora, glucose homeostasis, cell signalling and satiety, researchers and practitioners need to integrate this in the interpretation and planning of diets.[7] It follows that protein quality and functions have become intricately linked. This has direct implications for nutrition planning for specific consumer groups or situations, such as for infants, sports nutrition, nutrition during pregnancy and for older adults.

Implications for protein requirements

The official definition of protein requirement refers to it being 'the lowest level of dietary protein intake that will balance the losses of nitrogen from the body and thus maintain the body's protein mass in persons at energy balance with modest levels of physical activity'.[12,21] New evidence challenges scientists to rethink this definition. The requirements for protein depend on numerous factors, and practical intake recommendations for populations and individuals should take additional factors into account, such as affordability and acceptability of specific foods. The following points are pertinent food for thought:

- At decreasing protein quality, the percentage of energy needed from protein to meet the requirements increases.[21] This implies that more protein must be consumed to meet amino acid requirements when the bioavailability is lower.[22] Similarly, quality-adjusted protein–energy ratios have been proposed for the recommended protein and amino acid intakes.[23]
- For children, essential amino acid requirements per gram of protein (a measure of protein quality) are now considered to be higher than indicated in previous international recommendations.[21] However, current protein intake recommendations still reflect the minimum and are based on ideal conditions, whereas the reality is that children (in developing countries) are potentially subject to repeated infections, chronic energy deficiency, poor sanitation and psychological stress.[21,24]
- Cow's milk protein is key in the treatment of severe acute malnutrition (SAM). Adding dairy protein improves protein quality, which makes it possible to reduce total protein content of a product or diet used in the treatment of SAM.[25,26] Using dairy protein in the treatment of SAM has metabolic advantages,[14,26] including improving linear growth without excess body fat gain[27,28] and muscle mass and functional test scores.[29] By using less soy and cereal in the treatment of SAM, the antinutritional effects of plant-based proteins are reduced.[8] However, the increased cost of using dairy protein should not limit the number of potential beneficiaries, and the ability to tolerate lactose may require consideration in this vulnerable group.[26,30]
- Current recommendations do not yet consider the newly described metabolic and neutraceutical functions of protein related to proteogenic and non-proteogenic pathways.[14,17]

Conclusion

The importance of the protein content of milk has been known for centuries. This is appreciated now more than ever, as current evidence shows that the quality of milk protein is higher than previously acknowledged and functions of dairy protein beyond the provision of amino acids and organic nitrogen are described. The South African food-based dietary guideline 'Have milk, maas or yoghurt every day'[31] is a step towards harnessing the full benefit of dairy protein.

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