

IDF Report

International Symposium Dietary Protein for Human Health

14-16 September, 2023 Utrecht, The Netherlands

Relevant links of the event:

- Programme, see [here](#)
- Abstracts of posters, see [here](#)

1. Introduction and general remarks

The International Symposium Dietary Protein for Human Health was held from 14 September to 16 September. The event was hosted by FAO, Riddet Institute, Wageningen University and IAEA, and it gathered around 300 delegates. IDF was represented by Anabel Mulet-Cabero. Some IDF experts also attended, Thom Huppertz (NL), Jan Geurts (NL), André Brodkorb (IE), Lotti Egger (CH), Reto Portmann (CH), Isabelle Neiderer (CA), Janice Giddens (US), Matthew Pikosky (US), Andrew Fletcher (NZ) (this is not an exhaustive list).

2. Summary of key messages

- Protein/amino acid (AA) recommendations were suggested by several speakers to be revised based on emerging data, with special considerations for vulnerable populations such as infants, older adults, pregnant women.
- Protein quality was highlighted for its importance to ensure the nutritional needs and make informed dietary choices. Protein quality can be defined as the ability of a food or ingredient to meet physiological indispensable AA requirements. Depends on the AA pattern and the proportion of the AAs that are digested and absorbed in the gut.
- Protein quality considered data on ileal digestibility (related to DIAAS) to overcome drawbacks of fecal digestibility (related to PDCAAS).
- New methodologies to measure AAs digestibility and availability, dual isotope technique. Great progress regarding in vitro digestion models to measure protein quality. To highlight the in vitro protein digestibility based on the static INFOGEST method, which is currently under ISO/IDF standardization. Validated in vitro methods are the future for routine acquisition of protein quality data (Paul Moughan).
- There is currently DIAAS data on 500 foods (including 100 foods from PROTEOS project). FAO plans to develop a Protein Digestibility Database to aid dialogue on the evaluation of protein quality and protein sufficiency in different populations. IDF is following the progress of the PROTEOS project and monitoring any developments made by FAO.
- Milk proteins were shown as high-quality sources whereas plant-based proteins were generally presented as having lower digestibility due to the food structure and presence of components that inhibit protein digestion.
- Protein transition to more plant-based, highlighting that it is not about animal or plant-based proteins but a balance to a more sustainable future. Important to ensure protein quality in that transition to more sustainable diets. The holistic approach of considering the proteins in diets and food systems was highlighted. Aspects such as protein quality in the context of climate change and geographical

differences and adding context to data were highlighted. The IDF Task Force on Protein from Protein Perspective is planning to work on a Bulletin about the valuable role of dairy proteins in the multidimensions of sustainable diets.

- Increased research on modelling approaches to understand food production/consumption impacts on health, environment and affordability was presented.
- Uncertainties on how the emerging knowledge on proteins can be translated into sustainable practical solutions that benefit society (regulation/policies).

3. Summary of the presentations

Session 1: Amino acid and protein requirements

Daniel Tomé, France – Protein, Protein Quality, Nutrition and Health

- Proteins are constituted of 20 amino acids (AAs) including 9 indispensable amino acids (IAAs)
- Protein requirements relate to the supply of metabolically available nitrogen and IAAs to balance nitrogen and AA losses, and to support body protein synthesis and maintain the body's protein pool. Need to provide protein every day and probably in every meal.
- Several health outcomes are associated with protein sufficiency, including growth, body weight, muscle mass and strength.
- Protein quality is defined by the capacity to provide an adequate quantity of nitrogen and of the 9 IAAs, limiting factors for protein synthesis.
- Protein metabolism affects body composition and many functions. There are several markers for measuring the need for AAs and proteins and protein quality.
- Reference values on IAA bioavailability of the different protein sources are required. Since 1970/80s, FAO/WHO/UN has had the priority to define the requirement for nitrogen (N) and IAAs as criteria for quality protein to support body protein synthesis. Protein requirement and recommended intake were determined by the nitrogen balance method in adults (FAO/WHO/UN, 2007). Re-evaluation of adults IAA requirements between 1985 and 2007 from nitrogen balance method to stable isotopes methods.
- AA scoring is the preferred approach to protein quality. It correlates with other approaches of protein quality (nitrogen retention, protein synthesis, physiological functions).
- The lower IAAs content of certain protein sources is at the origin of the risk of protein deficiency in certain diets. Protein quality matters when shifting towards plant-based diets. Lower IAA profile and digestibility in plant-based sources compared to animal source foods (Vliet et al 2015 J Nutr).
- Reduction in diet-associated greenhouse gas emissions involved a shift towards plant-based diets that leads to reduced IAA content.

Raj Elango, Canada - Determining amino acid requirements

- Body protein needs are for amino acids. Dietary AAs are considered as individual nutrients (FAO/WHO 2011)
- Current AA requirements are only determined in adults. The recommendations for AA intake are referred to as estimated average requirements (EAR) and recommended dietary allowance (RDA). The FAO/WHO recommendations are the same, referred to as "Average" and "Safe".
- The AA requirements have been measured using nitrogen balance and carbon oxidation methods.

- The indicator amino acid oxidation (IAAO) method is minimally invasive with single-day adaptation, oral stable isotope delivery and measurement of $^{13}\text{CO}_2$ in breath and urine.
- IAAO has been applied to vulnerable populations and disease.
- Children aged 6-10 years have similar AA requirements compared to adults (Mager, 2003). Therefore, factorial calculations are appropriate in 6-10 year children. However, special consideration on AA requirements is needed when certain health conditions. E.g., children with liver disease have around 40% increased BCAA requirements (Mager et al 2006).
- AAs requirements are not proportional, consideration for pregnancy/lactation (different stages) and elderly (between males and females), and diseases conditions. E.g., Leucine needs nearly double in elderly (Szwiega, 2021). Therefore, the impact of protein quality, with increased AA demands in vulnerable life stages should be assessed.
- There is a need to address how the shifting to more plant-based diets impacts individual AA requirements.
- Protein recommendations are based on FAO report 2007, and based on the emerging data sets and trends, there is a need for discussion on revising them.

Amélie Deglaire, France - Amino acid requirements for infants

- The current AA profile of human milk(HM) has been indicated by FAO 2007. Needs to be revised with more robust values in order to determine the AA pattern of the protein reference and guideline for infant milk formula (IMF).
- Emerging data for tryptophan (important for synthesis of neurotransmitter hormones) and true ileal digestibility.
- Improved knowledge of AA requirements. FAO, 2007 data (includes 3 studies) was compared with data from Zhang 2013 (includes 26 studies) and Charton 2023. Good correlation of IAA values between Zhang, 2013 and Charton 2023, and 22% higher than FAO (2007) values. It shows that several AAs in the profile of mature human milk had a higher content Zhang 2013. The calculation based on true protein makes a difference since there is a high content of non-protein nitrogen in human milk.
- Protein content is usually higher in IMF than HM and IAAs are usually lower in IMF.
- High true ileal digestibility in piglets of human milk (95% on average) except for Thr. However, when looking at the total nitrogen digestibility, HM digestibility was lower than the values considering AA nitrogen. This shows some digestibility and utilization of non-protein fraction by microbiota (Charton et al, 2023).

Lisette De Groot, The Netherlands - Protein recommendations for adults/older adults

- Minimum 0.8 g/kg body weight for adults.
- Currently the same recommendation is for older adults, but is this adequate for their maintenance and healthy aging? There is emerging data suggesting the need to reevaluate the protein RDA of 0.8 g/kg BW for older adults. Most likely more future evidence for higher levels.
- Geriatrics: at least 1g/kg for vulnerable/hospitalized/sarcopenic older adults.
- New challenge: older people are also influenced by the protein transition and its impact on requirements and recommendations in older adults needs to be considered.

- The need to address how the shifting to more plant-based diets impacts individual AA requirements was highlighted.

Dan Moore, Canada - Requirements for endurance exercise and sports

- Endurance exercise increases daily protein requirements. Approximately 1.8 g/kg/d of protein maximized whole body protein synthesis during recovery in trained athletes. BCAAs, primarily Leu, are the main limiting AAs in endurance athletes' diets.
- Female athletes are under-represented in sport science research.
- Consuming adequate energy generally covers protein needs.
- Balanced meal protein ingestion is metabolically efficient. Regularly spaced (3-5 hours) containing 0.3-0.5 g proteins/kg.
- Moderate protein mixed meals optimized muscle remodeling.
- Food matrix effects may influence anabolic potential of dietary protein, e.g., protein synthesis was better with whole egg than egg white when in lower optimal meal protein intake.

Marco Mensink, The Netherlands - Protein, amino acids and type 2 diabetes

- There is no evidence that the usual protein intake for most individuals needs to be modified for people with diabetes.
- Replacement of animal protein with sources of plant protein could improve A1C, FPG and fasting insulin.
- In healthy individuals consuming high animal-protein non-restricted diet, is associated with insulin resistance and type 2 diabetes, and should not be recommended (from observational studies).
- In metabolically compromised individuals, high-protein diets might be helpful as a dietary strategy to improve body composition and glycemic control.

Mick Deutz, US - Amino acid requirements in critical care

- ICU patients have strongly modified specific AA and protein breakdown pathways.
- The sicker the ICU patients, the lower the overall net protein breakdown and the higher the breakdown of structural proteins (myofibrillar/collagen)
- Higher protein dosing (more than 2.2 g/kg day) in ICU patients did not provide health benefits but it seems that might harm with acute renal failure.

Claire Gaudichon, France - Amino acid scoring patterns for protein quality scores

- AA composition is the main determinant of AA scores. It can be determined for many foods using standardized analytical methods
- The way to quantify the protein content in the food has a great impact on the chemical score. The factor N x 6.25 (internationally recommended) penalizes the score for all foods. Calculating the scores using both 6.25 and a specific factor is of interest.
- The FAO reference patterns for AA scoring have evolved from 1991 to 2013, in relationship with AA requirements (1985, 2007). The pattern used (age range) has a major impact on the score.
- PDCAAS (1991) and DIAAS (2013) have refined the chemical score with digestibility component. Whereas a practical solution has been proposed for PDCAAS, methodological complexity appears

for DIAAS. However, this boosted this area of research and many DIAAS data have been produced on various food since 2013.

- As AA scores summarise protein quality in a single number, they are practical but not perfect. although well correlated to PER, some discrepancies exist due to differences in the concepts.
- Complementary concepts and methodological developments by many teams allow for good explanatory capacities of the quality of protein in human diets.

Session 2: Amino acid digestibility and availability

Suzanne Hodgkinson, New Zealand - Amino acid digestibility/availability definitions and conventional oro-ileal determination in humans

- Protein quality can be defined as the ability of a food or ingredient to meet physiological essential (indispensable) AA requirements. Depends on the AA pattern (related to the human AA requirements) and the proportion or concentration of the AAs that are digested and absorbed in the gut.
- Digestibility (disappearance of AAs from the gastrointestinal gut) gives an estimation of the availability of those AAs.
- Traditional methods involved fecal digestibility but microbes are present in the large intestine (large amounts of AAs in feces are of microbiological origin). In terms of protein metabolism, AA absorption is complete by the end of the small intestine. This is why we talk about digesta collected from the terminal ileum, ileal digestibility.
- Naso-ileal intubation and use of ileostomised participants allow direct determination of ileal digestibility in humans. While the methods rely on different assumptions, the results obtained with them both do not differ.
- They are appropriate for use for some experimental work and validation work, but not suitable for routine digestibility measurement.

Hans Stein, US - Animal models for determining amino acid digestibility

- Protein value is determined by the digestible concentration of the first limiting AA.
- Each IAA is treated as an individual nutrient.
- Pigs and rats can be used as models for humans, but pigs correlate better with humans than rats.
- There is good repeatability of DIAAS within and among laboratories.
- Animal models allow for rapid generation of DIAAS values.

Anura Kurpad, India - Dual-isotope method for determining true ileal amino acid digestibility in humans

- Dual isotope method constitutes an alternative to measure ileal digestibility in humans.
- Deuterium labeled test protein is compared with a ¹³ Carbon labelled reference protein whose digestibility is known. The ratio of IAA enrichment (plasma meal) between each protein is an index of digestibility.
- There is the need for application of a correction factor for transamination loss of deuterium.

Glenda Courtney-Martin, Canada - IAAO estimation of amino acid availability in humans

- Slope ratio assay is the most common assay used in bioavailability studies. It measures the amount of test protein relative to a reference protein to provide an equivalent response. It uses growth as endpoint. It measures the capacity of the protein to provide a specific limiting amino acid to support growth.
- The indicator amino acid oxidation method (IAAO) can be combined with the slope ratio assay since it is sensitive to the level of the most limiting AA in the diet. Since there are no AA stores, IAAs are either incorporated into protein or oxidized. When the test amino acid is below the requirements all other IAAs are oxidized. The indicator oxidation is inversely related to protein synthesis.
- Combined IAAO slope ratio method. Strengths: non-invasive, measures bioavailability, validated in animals, applicable for the limiting AA of concern. Limitations: high cost, one amino acid can be studied at a time and only for indispensable AA. It is useful in developing reference tables of the availability of AAs in major food proteins and assessing processing conditions.

Maria Xipsiti, FAO - Developments in protein quality evaluation: a policy perspective

- FAO is the lead agency supporting countries in this area of work.
- Timeline FAO Expert meetings in protein quality evaluation (more recent)
 - Protein Quality Evaluation Report of the Joint FAO/WHO Expert Consultation, 1991.
 - Dietary protein quality evaluation in human nutrition. Report of and FAO Expert consultation, 2013.
 - Research approaches methods for evaluating the protein quality of human foods. Report of FAO expert, 2014.
 - Protein quality assessment in follow-up formula for young children and ready to use therapeutic foods, Report of the Expert working group FAO, 2018.
 - Joint IAEA-FAO Technical meeting on the development of a protein database and the way forward for reviewing protein requirements, 2022.
- FAO, with funding provided by the Government of Canada, has recently initiated a project in collaboration with IAEA to inform the future development of a protein digestibility database. The technical meeting reviewed and updated evidence and related methods on protein requirements and protein quality assessment and designed a framework for the development of a Protein Digestibility Database to aid dialogue on the evaluation of protein quality and protein sufficiency in different populations.
- The objective of the protein digestibility database is to provide fully accessible, robust database on ileal digestibility of protein and individual AA composition in human foods to determine protein quality using the appropriate scoring method. Practical steps for the establishment of database:
 - Scientific advisory/management group. Set up a standardised process, establish a template to call for published data on protein digestibility, publish call for data and agree on database aspects.
 - Need to raise funds to make the database a reality.
- Importance of defining accurately the amount and quality of protein required to meet human needs and describe appropriately the protein supply by foods and diets.

Session3: In vitro amino acid digestibility and availability

Andre Brodkorb, Ireland - Historical overview of in vitro protein/amino acid digestion

- The in vitro methods can be classified into three classes:
 - Static methods. They are simple, low cost and provide good reproducibility. However, there is no simulation of gastric emptying or absorption, the physical processes are difficult to mimic, pHs are generally fixed.
 - Semi-dynamic/dynamic methods. Overcome limitation of the fixed pH, simulation of emptying. You can do kinetics studies. some devices provide absorption simulation. However, they are more complex and require different instruments. the dynamic models are expensive devices.
 - In silico methods. They are cheap and animal-free methods but they are still under development.

Isidra Recio, Spain - Current advances (Europe) for in vitro protein digestibility

- In vivo protein and AA digestibility is the gold standard.
- There is a need for fast, simple, in vitro methods for reduction of animal trials, that can serve as screening tool for new/modified formulas.
- With in vitro methods, it is impossible to simulate the complexity of in vivo digestion and absorption.
- It is important to reach a consensus on a vitro protocol to validate with in vivo data.
- Promising results based on the INFOGEST protocol to determine DIAAS. Good comparability in vivo/in vitro with 7 PROTEOS substrates. Standardization of the method for dairy products ongoing within IDF/ISO.

Jim House, Canada - Current advances (North America) in vitro protein digestibility

- Protein content claims must be substantiated.
 - In the US, the basis of the claim is protein quantity and quality. The methodology used is PDCAAS, considering the score of 5.0 – 9.9 g as a good source and 10.0 g or above as an excellent source.
 - In Canada, the basis of the claim is protein quantity and quality. The methodology used is PER, considering the score of 20 – 39.9 g as a good source and 40 g or above as an excellent source.
 - In the EU and UK, the basis of the claim is protein quantity. They express protein content relative to energy content. The criteria of 12 – 19.9% of energy is considered as source of protein and 20% of energy and above is considered as a high protein source.
 - In Australia and New Zealand, the basis of the claim is protein quantity. They express protein content relative to serving. The criteria of 10 g of protein is considered as good source.
- The current methods for measuring digestibility for claims rely on the use of animal models. In vivo methods are not practical to measure sources of variability, e.g., processing factors. Also, there are challenges when data is not available for new or alternative proteins.
- The in vitro methods constitute an option. However, they require additional validation against in vivo studies and need for standardization approaches and inter laboratory validation studies.

- Apart from static INFOGEST method, the ASAP quality score method (from Megazyme) and pH drop/pH stat method have been used (aiming to assess PDCAAS values). There is an ongoing collaborative study to validate a pH drop/pH stat method for determining protein digestibility.
- Alternative approaches to animal models need validation and will require regulatory approval.

Paul Singh, US - Advances in the design of physical models to study food digestion in the gastrointestinal tract

- Static in vitro models fail to mimic fluid flow and mechanical forces present in the gastrointestinal tract.
- Dynamic gastric models offer an improved representation of the shape and functions of a human stomach for food digestion research (e.g., Human Gastric Simulator, Dynamic Gastric Model).
- Test procedures are needed to standardise forces created in the dynamic systems
- Ring trials should be considered for the different systems used in various research laboratories.

Session 4: Bringing amino acid requirements and bioavailability together to describe protein quality

Bob Wolfe, New Zealand/US - Describing protein quality an overview

- IAAs are the predominant active components of dietary protein.
- Dietary guidelines do not take adequate account of IAA content of dietary proteins.
- Reliance on low-quality proteins generally requires greater energy intake to reach IAA goals.
- DIAAS can quantify protein quantity in terms of meeting RDAs for IAAs.

Phil Atherton, United Kingdom - Protein, protein quality and the role of leucine in protein metabolism

- AA derivatives from dietary protein, typically stimulates muscle protein synthesis (MPS) for periods of 2-3 hrs.
- The rate of aminoacidemia is not a key facet of MPS response when fed IAA.
- Leucine alone is sufficient to stimulate MPS in humans due to its unique signaling properties.
- Activity modulates receptiveness of MPS to dietary AAs.
- Muscle is again receptive to re-stimulation of MPS around 4 hours after feeding.

Luc van Loon, The Netherlands - Determinants of post-prandial muscle protein synthesis

- The postprandial stimulation of muscle protein synthesis is strongly determined by the protein digestion and AA absorption kinetics as well as the AA composition of the ingested protein(s).
- The bioavailability of a protein and its capacity to stimulate postprandial muscle synthesis depend on many factors, which include: amount of protein, duration of the postprandial assessment period, food composition, processing and treatment, age, health and lifestyle.

Mark Manary, US - Protein quality malnutrition

- Children who are malnourished frequently have two special conditions that require more dietary AAs, rapid tissue accretion and acute infection.
- Physiologic status of malnourished children must be accounted for when determining AA requirements.

- Growth and recovery rates among wasted children correlated with protein quality of supplementary foods.
- When trying to deliver similar quantities of absorbed AAs, about 1.5x more vegetable proteins is required in the diet.

Don Layman, US - Impacts of protein quality and distribution on body composition

- Leucine has metabolic roles and requirements beyond minimum RDA
- Leucine is a dietary signal triggering recovery from short-term catabolic conditions
- The first meal after overnight fast is most sensitive to protein distribution
- Quantity and distribution of dietary AAs affect muscle mass and body composition.

Malcolm Watford, US - Specific physiological effects of amino acids: A case for using availability measures for individual amino acids

- AAs are not simply required for protein synthesis but have alternative roles and functions in the body; may have antioxidant properties, many are neurotransmitters, important for signal molecules, and novel functions are continuing to be discovered. (Wu G, 2010, Adv Nutr).
- Dietary methionine restriction increases longevity and healthspan (Fang, 2022 Annu.Rev. Nutr)

Jess Fanzo, US - Protein, protein quality – public health and environmental aspects – unintended consequences of consuming high-quality protein

- EAT-Lancet report showed inequalities (Willett, 2019the Lancet)
- Animal source foods are very low in low/middle income countries and they are top sources of commonly lack nutrients (Ortenzi, 2021)
- Energy-intensive lifestyles and dietary choices of those living in high-income countries are significant anthropogenic contributors to climate change. Animal-sourced foods are a more significant contributor.
- Use land in a more structured way. 77% of the agricultural land is used by livestock contributing to 18% global calorie supply in contrast to 23% of agricultural land used by crop contributing to 82% of the global calorie supply.
- Livestock and particularly beef seems to be a major cause of deforestation (Pendrill 2019)

Paul Moughan, New Zealand - Review of progress in describing dietary protein quality and DIAAS – 10 years on

- DIAAS is a measure of delivery of the first limiting AA relative to a requirement.
- Much progress has been made on developing a less invasive isotope-based method in human. The dual isotope method gives rise to true ileal AA digestibility values with application to DIAAS. It may be applied to human in different physiological/health states to provide specific data.
- Much progress has been made in generating ileal AA digestibility data for a whole range of foods. There is a validation of growing pig as model for adult human (Hodgkinson, 2020 Journal of Nutrition) and current data for around 500 foods (including 100 foods in PROTEOS project).
- DIAAS is currently the most accurate means of routinely describing protein quality for stand-alone foods. DIAAS values are not additive for meals/diets. However, the true ileal AA digestibility values

are mathematically additive, and food digestible AA intakes should be used directly to determine how a meal/dietary pattern meets specific AA requirements.

- There is scope to improve the accuracy of DIAAS
 - Need accurate individual IAA requirements and more information on AA patterns.
 - Do dispensable AA levels affect protein utilization in practice?
 - Effects of processing on protein quality. True ileal digestibility is sensitive to processing.
 - Use of specific nitrogen:protein conversion factors in calculation DIAAS but food systems need to be consistent.
 - Need to correlate DIAAS across a broad range of foods, with and metabolic/health outcomes, e.g., muscle and body/protein synthesis.
 - In vitro ileal AA digestibility. There is a need for a validated in vitro method to generate routine data.
- There is a need to review DIAAS in relation to cut-off regulations for food claims of FAO 2013 recommendation for regulations (claims). Need to develop a published set of guidelines as to how DIAAS should be applied.
- Food labelling should include digestible IAA values.
- Meals, dietary patterns, personalized meal plans are best assessed using food intakes, AA contents and AA digestibility coefficients.

Session 5: World food protein – towards a sustainable, healthy supply

Barbara Burlingame, New Zealand - Global food sustainability – the UN 2030 agenda and beyond

- UN's 2023 agenda. All the SDG have direct or indirect relationship with protein, particularly, SDG2 (end hunger).
- The protein gap. In 1949, the report of the first joint FAO/WHO Expert Committee in Nutrition stated that "protein deficiency was the most serious and widespread dietary deficiency in the world". There have been several publications on protein requirements since then. In 1974, there was a great controversy by the publication of "The Great Protein Fiasco" by McLaren highlighting that the protein gap theory "one of the greatest errors committed in the name of nutrition science". And that debate on protein still continues.
- World dietary protein supply, animal source almost 33 g/cap/day in 2018/2020. Africa has still less dietary supply than the global average, in contrast to other regions such as Europe and Oceania. The latter has not been an issue during any of the past years. It is an equity issue. Animal products are lower in low-income countries. There is an imbalance in dietary protein by income.
- FAOSTAT will launch the "Food and Diet domain" with statistics on food and nutrients from supply utilization accounts, household consumption and expenditures surveys.
- Sustainability is one of the dimensions of food security. E.g., the Mediterranean diet pyramid has shifted consumption of meats from daily to weekly consumption. There is a third dimension representing environmental impact. Aspects of frugality and biodiversity are also included.

Andrew Fletcher, New Zealand - Food protein – a global nutrient context

- Sustainable food systems are food systems that ensure food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition

of future generations are not compromised (HLPE, 2014). Nutrition should come first, if a food system does not deliver nutrition will fail in its primary duty.

- The DELTA Model, tool that explores different scenarios and how the food system could respond in terms of food production and the nutrient needs of the global population. Uses the production data from FAO to start off, food composition and bioavailability data.
- Key conclusion is that protein is not the problem. Considering an even distribution, the world already produces enough protein for nutritional needs. The protein supply would need to increase 25% to accommodate the increase in population in 2050. Also, considering that in 2050 the population of seniors would increase with possible higher protein needs, the higher targets of protein would be met by increasing 6% protein supply.
- When assessing supply against target intake, protein comes in 12th of the 29 nutrients to consider. There are other nutrients under more stress, calcium, Vit E, Vit A, Zinc and Iron are the top 5 critical nutrients identified. However, this assumes that all the food sources are equally shared. Considering the population growth and inequality, 88% of calcium would be needed to close the gap in 2050.
- Assessing the inequality inter-country based on average per capita supply, there are around 600 million people who do not receive sufficient bioavailable proteins to meet their needs. We need to produce 1% more bioavailable protein to close the protein supply gap.
- We need to consider what other nutrients are supplied by protein-rich foods, to address the deficiency of other nutrients.

Alice Stanton, Ireland - How much meat and dairy should we eat? The importance of transparent evidence based health metrics

- Scientist, policy-makers and all involved in the food system should be wary of reports, guidelines that ignore the protections against nutritional deficiencies and chronic diseases afforded by animal-sourced foods. It is shown that average national diets low in animal-source foods do not meet needs for essential micronutrients (Nordhagen,2020 GAIN discussion paper), and animal-source foods are the top sources of commonly lacking nutrients. there is an inverse relationship between childhood stunting and annual meat, milk and seafood consumption.
- We need diets that include environmental considerations. The Planetary Health Diet proposed halving animal-source foods, stating that it meets all nutritional requirements for adults and children greater than 2 years (Willett 2019). But it is shown that the diet will cause micronutrient shortfalls.
- The Global Burden Disease (GBD) analyses (2017 and 2019) underestimated the benefits of milk/dairy since it was only referred to protection against colorectal cancer. It has been shown that the consumption of dairy reduces total mortality and heart attacks and strokes.
- The death attributed to red meat consumption increased 36-fold in the GBD 2019 analysis. However, this has not been shown in the medical literature. The analysis has not been corrected, which continues to facilitate high impact, misleading, publications.
- Excess red meat (more than 4 portions or 500g/week) may be associated with (5-15%) increases in colon cancer. Insufficient red meat consumption (less than two portions per week) is associated with large increases in anemia, stunted childhood growth and cognition, osteoporosis and sarcopenia.
- The majority of the world's population is not eating enough dairy nor omega 3 – PUFA rich foods.

- Consumption of nutrient -rich animal sourced foods, in appropriate evidence-based quantities, should continue to be included in national and international guidelines for a healthy, balanced diet.

Sylvia Chungchunlam, New Zealand - Food protein sources – the affordability dimension

- Sustainable diets need to be sparing of natural resources and the environment, culturally acceptable, nutrient adequate and affordable.
- The environmental sustainability of foods has been largely examined, which has led to plant-based diets. However, the impact of societal, nutritional content, and monetary cost of such diets have been less considered.
- Use of linear programming for diet optimization on how to choose a mixture of foods to meet nutrient intake requirements at least cost. The method has been applied in US, New Zealand, Africa and South East Asia. For example, in the US, the price for animal-based foods drop out to give a plant-only modelled diet would range 2 - 11.5 times baseline market prices of animal foods (Chungchunlam, 2020 Nature Foods).
- Animal proteins included in the least-cost nutritionally adequate modelled diets.
- Nutrient bioavailability needs to be considered in the discussion of sustainable nutrient -adequate affordable diets.
- Using bioavailable proteins leads to different conclusions about food proteins, with animal proteins having superior protein quality.

Hanna Tuomisto, Finland - Environmental sustainability of alternative protein sources.

- Alternative proteins generally have lower environmental impacts compared to livestock proteins in product-level assessments, but energy consumption for some products may be high.
- Many of the technologies are still under development and the environmental assessment have high uncertainty.
- The nutritional properties of the products are important to consider in the environmental assessments. Meal and diet level assessments are better suited than product level assessments.
- Need to move towards multisectorial integrated assessment methods and global level modelling.

Tamsin Blaxter, United Kingdom – Achieving a balance between plant and animal sourced foods plant or animal versus plant and animal

- The global food system is in the midst of multiple crises and there are arguments that livestock are the cause and others about being part of the solution. Many arguments about food production and consumption can be drawn into the plant vs. animal debate. Trying to reduce everything to a single question with a single answer is often a dead end. Different geographies may favor different answers and not all of this is about evidence since there are also values differences.
- All foods have wide ranges of environmental performance/impacts. All of the environmental impacts vary by species, systems and geographical context. Also, the debate does not necessarily need to be animal vs. plant but in terms of systems, e.g., extensive vs intensive.
- The environmental impacts such as GHG emissions associated with different foods change according to the functional unit used, which is largely dependent on the value you have for foods.

- With the current global food system, average impacts are highest for ruminant meat, lowest for plant-based food, intermediate for poultry and eggs.
- Reducing animal-source food consumption in wealthy countries would have environmental benefits.
- Primarily plant based diets have both health benefits and drawbacks compared with diets with higher animal source foods consumption, but the balance is highly dependent on socioeconomic factors.

Hannah van Zanten, The Netherlands - The ratio between plant- and animal-based proteins in circular food systems

- How can we feed a grown population with enough healthy food while respecting the boundaries of our planet using circularity principles? Using circularity can strengthen sustainability of the global food system (van Zanten 2023 Nature Food)
- The principles of circularity are the respect of planet boundaries, production of enough food for everyone, avoid waste and if cannot be avoided it, that we use it in a most efficient way.
- Feeding animals with only the leftover streams of the food systems, we can produce between 9 and 23 g of protein per person per day. If replaced by plant-based proteins, we would need more arable land (Van Zanten, 2018 Global Change Biology)
- National dietary guidelines based on health and environment but incompatible with circular food principles (Frehner, 2022 The Lancet Planetary Health)
- If you feed animals with waste - products that we cannot or do not want to eat - you can significantly reduce the environmental impact of livestock farming. However, this depends on how you design the food system, having a holistic approach. The Circular Food System (CiFoS) model takes different parameters trying to minimize the environmental impacts (land use, greenhouse gas emissions, water use, phosphorus use, and nitrogen use) on a global scale while still meeting human nutritional needs.

Future Food: Industry/Regulatory/Geographical Perspectives (A Workshop)

Nuria Moreno, Belgium - Are current regulations and standards fit for innovative protein ingredient development?

- A transformation of food system does not only require technology but also changes in the values, regulations, markets and governance that surround the food systems.
- EU has started that transformation with the Farm to Fork strategy, which includes a shift to healthy, sustainable diets moving to a more plant-based diet, ensuring sustainable food production and investing in research and innovation. A framework for a sustainable food system is expected this year.
- The current regulatory framework (EU) may sometimes hinder the protein transition and delay access to market to protein innovations. Big debate on product denominations on plant-based foods as alternatives to meat and dairy. Important to ensure that there is an opportunity for new products while the consumer is not misled.
- At the international level, Codex is looking into the so-called new foods, and how they should be regulated, standardized.

- Regulatory procedures to market take time and are costly. Important for producers to know the regulation, requirements for application. For market approval, safety is the most important. In the case of market penetration, aspects such as protein quantity and quality become more relevant.
- There is global variability in regulations. E.g., for protein nutritional claims, in the US PDCAAS protein quality is required for protein content claims while in the EU protein quantity is sufficient to make protein content claims.
- PDCAAS is the adopted method for protein quality determination, which has been seen to have a more physiologically relevant digestibility. How would this method be regulated? In general, the methods need to be more accessible, practical and established before they can be applied into regulations or standards.
- Evolving food regulations require collaboration among stakeholders in the agri-food chain.

Patricia Williamson, US – Plant proteins and their future role in feeding the world.

- If we want to have a more sustainable move towards plant-based products into diets, we need to consider better ways. E.g., make countries have adjustments for digestibility in labelling, labeling for foods should consider if the regulatory conditions are meaningful and purposeful for the consumer.
- Plant-protein ingredients are under continuous improvement to meet consumer needs and customer demands.
- Processed foods can utilize ingredients to improve nutritional profiles. The processing is done taking into account shelf life, functionality, safety and nutritional value.
- Innovation in a diversity of protein sources can meet the needs of a growing world population.

Rolf Bos, The Netherlands – Animal proteins and their future role in feeding the world.

- Animal source protein is part of the solution.
- It is a challenge to balance all the factors of a sustainable diet. It is even more challenging for consumers, and the cost is the main factor for them.
- The characteristics of a sustainable diet should be context-specific, but challenging to achieve.
- Aspects to consider ensuring diet quality in this transition:
 - Nutritional differences of plant-based products are not clear to consumers
 - Maintain optimal diet in the aging population. Consumers are not aware of the specific requirements of life stages.
- A responsible protein transition requires more data on IAA requirements of different target groups and investment in determining the long-term health effects of new plant-based products.

Beatrice Trotin, France - The future of flexitarian diets, implications for plant and animal proteins

- Current dietary patterns in Western countries are dominated by animal proteins, with a ratio plant to animal protein 30/70.
- The ideal future sustainable pattern of Planetary Health Diet would represent a total shift of proteins sources, with a ratio of plant to animal proteins 70/30.
- Flexitarianism is recognized as the more acceptable first step for the shift toward more sustainable diets in Western countries.

- To begin the shift towards such diets, rebalance between key staple food categories (meat reduction, increase in whole grains, fruits and vegetable) are required. Dairy can be maintained in flexitarian diets, with a shift between product types, more milk and less cheese. This was shown in a linear programming French study (Gazan, 2022), with the aim to reduce 30% GHG emission, fulfillment of 32 nutrients.
- There is a need for more data (dietary intakes) and studies on consumer behaviour change to characterize the gradual shift towards sustainable diets, adapted to the different cultures and populations.

Ken Maleta, Malawi - Future sustainable global food production: An African perspective.

- Food systems are context specific. Africa being as diverse as it is both ecologically and economically, it is a challenge to give a common view.
- Africa is in the second or third nutrition transition where they are subsisting on production systems that are very small end holdings, which makes them very prone to climatic shocks. Consuming what they produced and process, therefore diet quality is an issue.
- The key issue for the region is the low intake of protein and also low intake of fruits and vegetables. Most people of the region are very poor and cannot afford nutrient dense, high-quality protein sources.
- Another food driver is education. Most of the population has limited education such as the concept of nutrients. There are a handful of countries with food-based dietary guidelines.
- What is driving the food transformation in Africa? (1) Economic transformation, GDP per capita is growing at 4%, (2) growth of population with opportunity to more efficient production, (3) urbanization, the food preferences sifted to ready to eat meals which generate additional industries but it has the concern of fragile developments, pollution as well as potentially lead to non-communicable diseases, (4) globalization and large food producers, which provides wider range of foods, while it is a source of income and economic growth it is putting pressure on local producers.
- Some threats to the region: (1) climate change, (2) lack of adoption/investment of biotechnology, (3) lack of data to drive evidence-based policy decisions.
- The issues for the African region are the gaps in the plate, gap of protein, vegetables and fruits, everything that we need to do in the region has to be in relation to increasing production and making it affordable for people to consume meeting nutritional requirements. It is not about plant vs. animal, for the region, it is about both.

Subbanna Ayyappan, India - Future sustainable global food production: An Asian perspective

- The Asian food production has many strengths (e.g., diverse natural resources, wide climate diversity, large and diverse domestic market) and weaknesses (e.g., low input use efficiency, inadequate credit support, storage and transportation, weak agro-based industries).
- Some aspects are changing and improving such as agri-diversification and integration of food production systems, genome edited crops for climate smart food systems, producer support programs, enabling access and affordability to innovations through partnerships