by Roger Clemens and Peter Pressman

Understanding Alternative Dietary Proteins

Numerous publications suggest compliance with plant-based dietary patterns may reduce the risk of noncommunicable diseases such as diabetes (Satija, Bhupathiraju, Rimm, et al. 2016), hypertension, and cardiovascular disease (Satija and Hu 2018). Plant-based diets have also been associated with improved intestinal health (Albenberg and Wu 2014), possibly mental health (although the evidence is controversial and inconsistent) (Lavallee, Zhang, Michalak, et al. 2019), and perhaps visual acuity (London and Beezhold 2015). From an environmental perspective, some speculate that adhering to a plant-based dietary pattern will enhance sustainability of food production (Sabaté and Soret 2014).

While regulatory agencies in the United States have not advanced a definition of "plant-based" dietary patterns, this was a topic of the 2015–2020 dietary guidelines and addressed by the 2010–2015 advisory committee. Despite the absence of a formal definition and specific recommendations, numerous plant-based products have emerged in the U.S. market that have challenged conventional naming of products with standards of identity (83 FR 49103). For example, what do you call plant-based "milk," "cultured milk," "yogurt," and "cheese"?

Plant-based foods have become more mainstream, and consumers are interested in alternative sources of dietary protein, such as those derived from plants (e.g., legumes, grains, nuts), algae, and even insects. Marketing data from Lux Research and Mintel indicate that many consumers now avoid animal protein due to perceived health, environmental, sustainability, ethics, and cost issues.

While the number of edible plant species appears to range from 7,000 to 30,000, humans consume fewer than 200 of these (Kuhnlein, Erasmus, and Spigelski 2009; Shelef, Weisberg, and Provenza 2017). The protein quantity and quality of these plants is quite variable. According to the Institute of Medicine (IOM), a complete protein contains all nine of the indispensable amino acids, without any mention of amino acid ratios or digestibility appropriate for growth and development of humans (IOM 2005). In addition, the IOM notes that proteins from plants, legumes, grains, nuts, seeds, and vegetables tend to be insufficient sources of one or more of the amino acids required for humans and therefore are considered "incomplete."

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These variations in amino acids from plants have been noted (Gardner, Hartle, Garrett, et al. 2019). While virtually all plants contain 20 amino acids, the proportions of these amino acids are quite variable, and these protein sources are typically limited in amino acids required for normal growth and development for humans. That is to say, plant-derived proteins typically contain a disproportion of essential or indispensable amino acids relative to animal-derived proteins. For example, the most common limiting amino acids are lysine and methionine, which are low in grains and legumes, respectively. In addition, plant-derived proteins have a lower digestibility than animal-derived proteins (Arentson-Lantz, Clairmont, Paddon-Jones, et al. 2015). Even the now popular dehulled hemp seed protein is low in lysine and marginal in tryptophan and leucine relative to the Food and Agriculture Organization (FAO) reference.

In an earlier publication out of France, the authors noted that the current protein consumption trend exceeds the estimated average requirement, and that the likelihood of amino acid insufficiency or protein inadequacy within that country is less than approximately 0.30% (De Gavelle, Huneau, Bianchi, et al. 2017). Several proposed protein consumption models indicate increases in the consumption of legumes, nuts, and seeds and a concomitant reduction in animal protein may address the apparent lysine inadequacy issue while reducing energy intake without compromising total protein intake.

A variety of animal and plant protein blends are currently on the market. Some of these blends, such as casein, whey, and fava bean proteins, may offer unique functional properties and may improve protein retention (Berrazaga, Mession, Laleg, et al. 2019). Algae-derived proteins, typically limited in tryptophan and lysine, have lower digestibility than animal proteins, yet may present higher digestibility than proteins derived from grains, legumes, fruits, and vegetables (Bleakley and Hayes 2017; Tibbetts, Milley, and Lall 2016). Data on the growing popularity of insect protein indicate an average digestibility range of 62%–98% and methionine, tryptophan, and lysine as limiting amino acids, and are often confounded by the presence of exoskeleton chitin, which is approximately 7% nitrogen (Churchward-Venne, Pinckaers, van Loon, et al. 2017).

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consider when developing plant-based protein products. From a production perspective, the basics of cost, purity, sensory quality, and even anti-nutritional factors must be well thought out. When working with these plant proteins, their structure (e.g., amino acid composition, globular or fibrous nature, secondary structures, surface properties, chemical reactive sites); their interactions with environmental factors (e.g., pH, salts, temperature, solvent dynamics); and processing factors (e.g., thermal versus nonthermal, pressure, shearing, enzymes, and interactions with other ingredients) must be carefully and systematically evaluated.

Along with these kinds of attributes, the product developer should also consider the functional properties of these plant-based and potentially sustainable proteins. Those properties include solubility, viscosity, emulsification, foaming, water binding, heat stability and gelation, cohesion and adhesion, and elasticity (Nadathur, Wanasundara, and Scanlin 2017).

The quality of protein remains an internationally contentious issue. Within the United States since 1990 with the passage of the Nutrition Labeling and Education Act, protein quality of all foods, except for infant formula, is assessed by PDCAAS (Protein Digestibility Corrected Amino Acid Score). Within Canada, protein quality is evaluated via the classic PER (Protein Efficiency Ratio), even in the absence of ANRC (Animal Nutrition Research Council) casein, which was the standard against which all protein quality was measured. Then there is the FAO, which now advances DIAAS (Digestible Indispensable Amino Acid Score) as the best approach to evaluate protein quality.

Finally, there is the standard Kjeldahl method to quantify protein (AOAC 991.20). In this case, the total nitrogen is multiplied by a conversion factor to calculate total protein, despite the errors by avoiding nonprotein nitrogen components, such as chitin, amino sugars, creatinine, and urea (Jones 1931; Mariotti, Tomé, and Mirand 2008). Nearly a decade ago, several alternatives to Kjeldahl were suggested by a team of protein experts with the U.S. Pharmacopeia (Moore, DeVries, Lipp, et al. 2010). Those methods included at least 10 contemporary analytical approaches that would provide a more realistic assessment of total protein. In a recent publication, several investigators suggested that the quality of dietary protein should be modernized (Katz, Doughty, Geagan, et al. 2019). This group suggested a protein quality matrix that includes PDCAAS, dietary recommendations, and environmental factors.

In the 2005 IOM report and related reports on dietary protein, the experts did not express any health concerns regarding protein consumption (IOM 2005). For example, several studies suggested "no significant association between protein intake and change in glomerular filtration rate in women with normal renal function" (Knight, Stampfer, Hankinson et al. 2003; Martin, Armstrong, and Rodriguez 2005). A few years later, analysis of multiple protein and health studies did not support a long-term association between the amount of animal or vegetable protein intake and change in normal renal function (Bernstein, Treyzon, and Li 2007). The consensus at this time appears to be that protein restriction may be an appropriate dietary intervention for those with existing kidney disease, but there is not any significant evidence for a detrimental effect of high protein intakes on kidney function in healthy persons after centuries of a high protein Western diet (Martin, Armstrong, and Rodriguez 2005; Devries, Sithamparapillai, Brimble, et al. 2018).

Three recent papers suggest high protein diets (≥1.2 g/kg/day) may improve body composition (Morales, Tinsley, and Gordon 2017), modulate postprandial mitochondrial protein synthesis among obese individuals (Beals, Mackenzie, van Vliet, et al. 2017), and mediate crosstalk among gut microflora and the host's immune system (Zhao, Zhang, Liu, et al. 2019).

In summary, consumer enthusiasm for health-promoting dietary modifications that are built around plant-based regimens are neither simple for an optimal protein delivery nor are they necessarily cost-effective for desired health outcomes. Perhaps the greatest challenge is directed to food scientists charged to develop these kinds of protein-laden products that are safe, nutritious, functional, accessible, affordable, and actually taste good. **FT**

References cited are available via hyperlinks in the digital version of this column.

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