Proteins for meat alternatives: new competition for soy and wheat

Steph M. Adams

Plant-based meat alternatives are not just for vegetarians and vegans anymore. Flexitarians—people who want to decrease their meat consumption for health and sustainability reasons—are also seeking substitutes. However, for this group tofu and seitan will not do; the 'meat' needs to look, taste, and feel like the real thing.

- **Soy and wheat products currently dominate the meat analog market, but the exploration of new protein sources abounds.**
- **Structural modifications have the potential to make new protein sources multi-functional, and thus more competitive with soy and wheat.**
- **Emerging extraction technologies could improve protein functionality, although extrusion still dominates the formulation of meat alternatives.**

"Meat mimicers are getting better and better, particularly as we use newer proteins from pulses like faba bean, lentil, mung bean and more," says Mac Orcutt, a food scientist with the plant protein and oil ingredient supplier, Bunge in St. Charles, Missouri, USA.

A growing consumer appetite for meat-like products (meat analogs, as they are called in the industry) sparked a recent innovation boom in the food science industry that according to analysts will more than double by 2030 (https://www.alliedmarketresearch.com/meat-substitute-market). This growth is fueling exploration beyond the meat alternative forebearers, soy and wheat, toward new protein sources that could offer healthier, more sustainable meat alternatives that do not sacrifice on taste.

Orcutt says, researchers are racing to capitalize on potential opportunities, but for now "soy protein is still king in plant-based meat."

BEYOND SOY AND WHEAT

In 2020, soy and wheat products accounted for over 75% of the meat alternative market. Although, new protein sources are gaining traction with successful products, like Beyond Meat's pea-protein based burger (https://tinyurl.com/mbubfup3) food manufacturers are hunting for other sources. The industry has good reasons for wanting to expand past these primary proteins—and just as many reasons why replacing them will be a challenge.

Both soy and wheat are among the eight most common food allergens. And a genetically modified status still clings to soybeans in the minds of some consumers. Moreover, soy crop expansion has been linked to impacts on forests and biodiversity in key producing countries. (Many companies like Bunge have made a public commitment to avoid deforestation.) For these reasons, consumers and producers want to explore other sustainable protein options.

Nevertheless, both soy and wheat proteins have unrivaled advantages. Both are outputs of industrial food and feed production mak-

ing them easily accessible. Soy protein has the added bonus of being nutritionally comparable to animal protein. Soy and wheat proteins are known entities; food scientists have decades of experience harnessing the meat-like functionalities of soy and wheat (and to a lesser extent, pea) protein. Newer protein sources are just beginning to be mapped in plant-based meat.

"We continue to enhance our understanding of which pulse proteins optimize texture in alternative meats, and are finding that some are great options versus soy, across various applications," says Tammy Lin Bratton, director of protein ingredients applications at Bunge.

Although suppliers have already added whole pulses or flours to their portfolios, the proteins are generally available as is. Measured against the functionalities that soy and wheat can provide, their attributes often fall short. For example, faba bean and lentil are considered promising proteins for meat analogs,. They compete with soy on the emulsion capacity that evokes juiciness and tenderness, but lack the gelation characteristics needed for a meat-like texture (https://doi.org/10.3390/foods10030600).

Yet, even the most popular plant proteins cannot be a direct substitute for animal protein. Additional ingredients must fill in the gaps when a plant protein reaches the limits of its functionality, sometimes adding a dozen or more components to a meat analog's formulation. Unrecognizable ingredients that imply overly processed, highly refined products make consumers wary. Binders, oils and fats, flavors, and colors—all essential components—look more appealing to consumers when they can be either achieved by plant-based proteins or derived from other plant elements.

MULTI-PURPOSE PROTEINS

Food scientists are researching how to modify proteins to make some of the extra ingredients unnecessary. "By modifying plant-based proteins using physical and biological technologies, we can make them have better functionality," says Maryam Nasrabadi, post-doctoral fellow at the University of Saskatchewan, Canada.

Myriad research projects have focused on protein modification methods for food applications. The diversity of projects stem from the unique characteristics of each protein source. Globular plant proteins exist as tertiary structures composed of sub-proteins: albumins, globulins, prolamins, and glutelins. The sub-protein combinations, or fractions, vary by plant. Even for a singular source, a number of conditions such as crop species, cultivar, or growing and harvesting conditions affect the types and distribution of its sub-proteins. In addition, these subunits have different chemical properties whose functionalities respond differently to modifications.

This divergence of effects means that scientists must consider their final product when performing modifications. Whole meat cuts remain the primary target.

Meat analog companies are not divulging all the technology they use to replicate whole meat cuts, but it must require altering a protein's solubility. Denatured proteins in an aqueous solution influence the emulsifying, foaming, and gelation properties necessary for these high-moisture food applications.

One of the common ways scientists alter the structure and function of plant-based proteins is thermally. Along with denaturing, heat treatments trigger chemical and enzymatic reactions that can add texture to whole cuts without needing

TABLE 1. Some protein techno-functional properties and their relationship with food sensory and physicochemical characteristics. Source: Almeida Sá, A.G., *et al.*, *Front Nutr, 9*, 2022.

Function	Physicochemical property	Sensory property	Examples	Products
Foaming	Hydrophilicity, hydrophobicity, air/water film formation	Mouthfeel, smoothness	Seed proteins	Dessert, ice cream, cakes, mousses
Emulsifying	Hydrophilicity, hydrophobicity, oil/water film formation	Mouthfeel, flavor, smoothness	Seed proteins	Meat analogs, soups, sauces, desserts, cakes, ice cream, salad dressings
Gelling	Thermal aggregation, water entrapment, protein matrix formation	Mouthfeel, texture, smoothness	Seed proteins	Desserts, meat analogs, and bakery products
Oil-holding	Hydrophobicity	Flavor, odor, smoothness	Seed proteins	Beverages, sauces, meat analogs, bakery products
Water-holding	Ionic hydration, H-bonding	Texture, consistency	Soybean and cereal proteins	Meat analogs, cakes, bakery products
Viscosity	H-bonding, hydrodynamic shape and size, water-binding	Taste, consistency, mouthfeel	Soybean	Soups, salad dressing, sauces, desserts
Elasticity	Hydrophobicity, disulfide crosslinking deformable gels	Texture, crispiness, chewiness	Gluten protein	Meat analogs, extruded and bakery products
Cohesion and adhesion	H-bonding, ionic-bonding	Chewiness, stickiness	Seed proteins	Meat analogs, pasta, extruded snacks, and bakery products

extra ingredients. Heat has the added benefit of inactivating trypsin inhibitors—believed to be antinutritional compounds—thus, improving a plant protein's digestibility and nutritional properties.

Researchers are also examining how to form multi-functional proteins by enhancing extraction. The wet fractionation method results in a highly-concentrated protein powder by using alkaline extraction followed by acid precipitation. The process must be conducted within selective pH and ionic strength ranges or a large fraction of the proteins can be damaged (https://doi.org/10.3390/foods10081967). Along with harsh chemicals, wet fractionation also involves an unsustainable amount of water and energy. Scientists are exploring pre-treatments techniques applied to the whole seed that might reduce resources while protecting the protein, improving yield, and doubling as a modifying technique (https://doi.org/10.1016/j.foodhyd.2021.106595).

EMERGING INNOVATIONS

Experiments show that exposing protein sources to perturbations such as high-pressure, ultrasound, or microwaves, eases extraction and could lead to lower chemical and water consumption. These treatments affect non-covalent bond structures, changing the proteins secondary and tertiary structures by disrupting hydrophobic and electrostatic bonds.

Technologies like this, that perform double-duty for extraction efficiency and protein function modification, are a boon for formulators trying to trim product ingredient lists. Though a systematic approach to determining the value of these treatments is needed, some studies have shown their promise as a means of altering a protein's techno-functional properties.

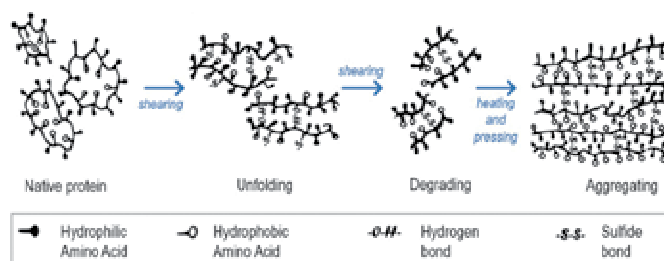

FIG. 1. A representation of the molecular-level changes that occur during extrusion. The process causes the protein to denature, unfold, and realign due to shear, heat, and pressure. The different types of protein bonds influence the final texture of the meat analog. Source: Zahari, I., *et al.*, *Foods, 9*, 6, 772, 2020.

High-pressure treatments, for example, are known to decrease protein allergenicity and inactivate antinutritional compounds, hence improving protein digestion. Other treatments have indicated usefulness in enhancing a protein's emulsifying and gelation qualities.

These technologies are currently being conducted at the laboratory scale and have not achieved industrial level application. Scientist still need to assess whether applying these technologies as a pretreatment before extraction truly reduces the water and energy requirements for the wet fractionation process. In addition, they have not yet determined if these pretreatments are even feasible or cost-effective at a large scale. Finally, pretreatments need to be evaluated in terms of a protein's final application. In other words, the question of how they can benefit protein extraction for use in meat analogs, as opposed to beverages, remains unanswered.

IN THE MEANTIME, EXTRUSION

While researchers pursue ways to maximize protein-based ingredients before they are processed, producers continue to discover what they can do with the biggest tool in the meat analog toolbox: extrusion.

During extrusion, high temperature, pressure, and mechanical shear from two screws rotating in the same direction cause the unfolding and realignment of protein molecules, creating meat-like textures and modifying a protein's properties (Fig.1). In addition, extrusion can use less refined proteins such as concentrates and flours (https://doi.org/10.3390/foods10030600).

Orcutt says that single-screw extrusion technology to produce meat substitutes has been around for decades, but the advent of twin screw extrusion "has given us the ability to add even more shear and more variation in shear to create better varieties of textured products."

For finer granule textured proteins that go into products like nuggets and patties, processors use low-moisture extrusion with mostly dry ingredients and water. Products with a muscle-like structure require high-moisture extrusion with more water and added oils and fats. Both types of extrusion can be performed on the same machine with some alterations and can be used as a pre-treatment for other protein modification methods.

Even with a growing cache of novel protein sources and technologies to manipulate how they function in a product, manufacturers admit they are still at a stage of mostly trial and error (https://tinyurl.com/yckvbwbt). Fava bean and lentil, as well as mung and canola, inherently possess a variety of functionalities. Research and development scientists have found that by combining one protein's penchant for solubility with another's for gelling they can mix and match proteins according to a given application. After adding in oils and fats, formulators say they are getting closer to creating a protein and fat matrix from plant-based sources that authentically mimics animal meat. Orcutt notes that "having a best-in-class range of proteins, oils, and fats from many botanical sources at Bunge maximizes the likelihood of being able to recreate the real meat experience from plants."

As the world's population grows and the need for sustainable food production becomes critical, meat analogs will have to be a mainstay among consumers. Formulators today must entice flexitarians with delicious tastes and textures that compel them to repurchase plant-based products. An added challenge that looms over them is keeping their products reasonably priced with a short ingredient list. If emerging technologies for plant protein modification can be developed commercially, it may become possible to find convincing soy- and wheat-free substitutes made from just a few components.

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