

Periodic Graphics

A collaboration between C&EN and
Andy Brunning, author of the popular
graphics blog *Compound Interest*

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online

To see more of
Brunning's work, go to
compoundchem.com.
To see all of C&EN's
Periodic Graphics,
visit [cenm.ag/
periodicgraphics](http://cenm.ag/periodicgraphics).

The chemistry of plant-based meat



Many consumers have developed a taste for plant-based meat alternatives in the past decade. Here we look at what these alternatives are made from and how chemistry is used to improve their appearance and flavor.



Sources

Manufacturers can use various plant proteins to make plant-based meat alternatives; soy protein and pea protein are the two most commonly used.



Legumes

Examples: soybeans, peas



Cereals and grains

Examples: wheat, rice, oats



Nuts and seeds

Example: almonds



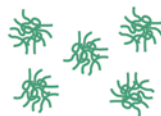
Fungi

Example: mycoprotein

Manufacturers usually process plant proteins into flours or concentrates before mixing them with other ingredients to make meat alternatives.

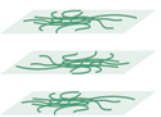
Structure and color

To make a meat-like structure, manufacturers usually use high-moisture extrusion. This process causes plant proteins to unfold, aggregate, and cross-link, producing a layered and fibrous structure like that of real meat.



Plant proteins

Mixing with water, heating, extrusion, cooling



Fibrous structure

Manufacturers add plant extracts such as those from beets or purple carrots to improve the color of plant-based meat alternatives. Some manufacturers even add heme produced from genetically engineered yeast to make plant-based meat appear to bleed like real meat.



Beets

Color: betanin pigments



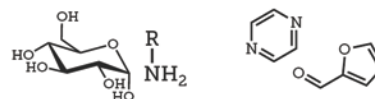
Purple carrots

Color: anthocyanin pigments

Flavor and texture

In meat, the Maillard reaction produces key flavor compounds. Manufacturers add yeast extract or hydrolyzed plant proteins to plant-based meat to give it the amino acids and sugars needed to produce similar flavor compounds.

The Maillard reaction



Sugars and amino groups react

More reactions form flavor compounds

R = rest of amino acid molecule

To replicate the mouthfeel that animal fats lend to meat, manufacturers use a blend of liquid plant oils and solid fats from tropical fruits. Carbohydrate polymers from plants improve the thickness and consistency of the product.



Liquid oils

Examples: Sunflower oil, canola oil



Solid fats

Examples: Coconuts, cocoa beans

Manufacturers mask plant protein off-flavors with spices and herbs. They also add minerals and vitamins to compensate for deficiencies relative to real meat.