Perfecting Plant-based Protein

State-of-the-art formulation and ingredient science in plant-based protein alternatives are helping manufacturers grow this dynamic product category

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While plant-based meat alternatives are nothing new, their fast-growing popularity is. And as consumers face retailer rationing and out-of-stocks on various meat products as a result of the global COVID-19 pandemic, the category has seen many responding to the crisis with a greater openness to a variety of meat analogues. In a recent consumer survey published by Datassentials¹ (Where’s the Meat, May 2020), 47% of consumers say they will eat more plant-based meat alternatives, a sentiment shared by a higher proportion of respondents in the Gen Z (62%) and Millennials (56%) demographic cohorts.

Success has been a long time coming. The first meatless burger appeared in the 1930s², but not until 2014 did U.S. sales of meat alternatives reach $620 million. Now, what was a $5.5 billion global market in 2019 is expected to exceed $8 billion by 2025, according to Global Market Insights. Growth in meat substitutes was +3.5% YOY globally in 2019 overall, with the Food Service segment growing +3.2% and Retail increasing by +4.3%.

Meat substitutes take many forms: patties, links, crumbles, nuggets, meatballs and more. They may be grain-based, single-cell proteins such as fungi or algae, soy-based or vegetable/plant-based proteins. They may be chilled, frozen, and even canned. Rapid growth in this category is driving rapid innovation and ever-greater variety.

Growing pains

Until recently, most plant-based protein products were sold in a frozen state, since their relatively slower sales meant more time on the shelf before purchase. Now they are moving faster and manufacturers are increasingly interested in creating ready-to-eat and ready-to-cook varieties. Many meat analogues are shipped frozen to the store, where they are slacked and sold as fresh.

But moving beyond frozen formats brings new preservation challenges in terms of safety, shelf life, and spoilage, particularly given the increasing complexity of today’s distribution networks. Solving those challenges is crucial for even long-established consumer brands, but

1 DATASSENTIAL, COVID-19 report 18: Where’s the Meat?, 05.13.2020
2 soyinfocenter.com/books/179
for plant-based protein products — about which many consumers’ minds are not made up — getting freshness right in terms of safety, taste, texture, aroma and appearance is a make-or-break proposition.

**Composition and microbial threats**

Meat analogues are complex combinations of dozens of ingredients, and the range of raw materials being used in them is wide and varied; oilseeds (including soy), peas, mushrooms, chickpeas, peppers, tapioca, wheat and nutritional yeasts are among those most commonly used in meat analogues.

Building products from multiple varieties of vegetable matter can introduce an equally varied array of bacteria from the field into the manufacturing process. On the other hand, the bacterial threats in these products tend to be similar to those that occur in cooked processed meats: *Listeria monocytogenes*, *Clostridium botulinum*, *E. coli* and *Salmonella*. Globally, lists of the top five most prevalent spoilage organisms in standard processed meats and in plant-based protein food products both include *Lactobacillus sakei* and *Leuconostoc carnosum*.

Microorganisms don’t discriminate based on the protein source. What matters are key metrics such as the water activity, moisture level, and pH that are much alike in plant and animal proteins. However, plant-based protein sources typically have higher pH values than meat protein, making finished products more susceptible to microbial outgrowth and pathogenic threats such as *Listeria monocytogenes*.

Fortunately, solutions developed for and proven in meat applications are also proving to be similarly efficacious in plant-based protein products.

Corbion has characterized numerous plant-based protein products in order to model the shelf life and *Listeria* control performance of specific ingredients. The company’s research has shown that many solutions originally created for meat applications demonstrate value and efficacy in plant-based protein products, addressing multiple factors that affect food safety and freshness (shelf life). Although *Listeria monocytogenes* is a pathogen of concern in alternative proteins, as it is in animal protein, it can be effectively controlled by use of liquid or powdered vinegar ingredient solutions. Similarly, acetate is extremely efficacious at inhibiting the outgrowth of *Listeria monocytogenes* whether the protein source is from wheat, peas or turkey, for instance, and lactate is highly useful in controlling spoilage bacteria in both plant and animal proteins.
Controlling freshness and safety factors

An analysis of leading commercial plant-based protein products shows that many products have pH and water activity that increase susceptibility to microbial outgrowth. Testing by Corbion has found finished products with a pH as high as 7.5. Such increased pH values create an environment more conducive to both spoilage and pathogenic microorganisms, particularly when marketing a refrigerated product.

However, the pH of the finished product may be adjusted to a more advantageous level (approximately 6.5) without adversely affecting the flavor of the product by including an organic acid antimicrobial, such as a refined lactic acid ingredient, in the formulation. This acidification creates an environment in which bacterial outgrowth can be effectively inhibited.

As in meat applications, the use of a lactate ingredient serves to lower water activity in plant-based products, thereby inhibiting spoilage organisms such as lactic acid bacteria (LAB). A microbial cell in solution with more solutes outside than inside will lose water through its membrane to the high-solute concentration, shrinking the cell and losing nutrients essential for cell growth and division.

Through this mechanism, lactate helps control both spoilage organisms and *Listeria monocytogenes*. Acetate acts similarly and is effective at a lower dosage compared to lactate, but may have a greater impact on flavor in the finished product. Blending the two has shown excellent results. Corbion tested a highly concentrated blend of potassium lactate and potassium acetate in a vegetarian chicken nugget, resulting in shelf life extension of more than 85% by suppressing the growth of LAB.

The company also conducted shelf life studies to examine the effects of adding a proprietary blend of liquid vinegar and natural flavor at 1.5% to a vegetarian chicken nugget with reduced sodium content. The blend inhibited the growth of LAB, extending product shelf life at 4°C from 15 days (control) to 25 days, as shown in Fig. 1.

![Figure 1: Lactic Acid bacteria counts in a vegetarian chicken nugget](image-url)

**Figure 1:** Lactic Acid bacteria counts in a vegetarian chicken nugget

- **Control**
- **1.5% Verdad N16**
Corbion also tested a vinegar solution at just 0.5% in the same plant-based protein product under the same conditions. Results of the study showed effective control of LAB for more than 26 days, as seen in Fig. 2.

In addition to inhibiting spoilage bacteria in these meat analogues, both the vinegar-based solutions and the lactate/diacetate blend provide outstanding control of *Listeria* and other pathogens.

**The effect of pH on texture**

One of the central challenges involved in creating plant-based meat analogues is achieving texture that convincingly mimics that of whole-muscle meats. But the ability to maintain pH in an optimal range can help manufacturers achieve structure in the product that is comparable to its animal protein counterpart. In dough-based plant protein applications, a lactate ingredient can be used to effectively lower the product’s pH, thereby shortening the formulation’s gluten network and resulting in a dough that is less sticky and has a tighter, firmer, more meat-like texture in the final product.

This effect can be seen in Fig. 3, which depicts doughs prepared for use in a vegetarian burger product. The control in the top image has a visibly stretchy, sticky texture, whereas the dough in the center, which includes a proprietary blend of potassium lactate and potassium acetate at 1.3 percent, has a texture similar to ground meat due to the breakdown of the mixture’s gluten network.

A vinegar additive can function similarly to create a firmer dough. The dough shown in the bottom image, which contains a blend of vinegar and natural flavor at 1.5 percent, also has a firmer texture resembling ground meat compared to the control.
Sodium reduction and flavor enhancement

Selecting the right antimicrobial solution is particularly critical when sodium reduction is among the manufacturer’s formulation goals. In addition to affecting product flavor, decreasing salt content boosts water activity — making microbial control more difficult — and reduces the solubilization and extraction of proteins, which can adversely affect product texture.

When combined with an effective, clean-label antimicrobial such as vinegar, specific natural flavors can enhance flavor and compensate for saltiness otherwise lost when reducing sodium levels. In the case of the proprietary vinegar/natural flavor blend tested by Corbion (Fig. 1), pH and water activity are optimized to deliver control of microbial outgrowth and to preserve desirable texture, while enhancing salty flavor. Sensory tests which compared this solution to a control with 1% and a control with salt reduced to 0.3% demonstrated the ability of the ingredient solution to offset the reduction of sodium from an organoleptic standpoint. (See Fig. 4.)

Well-chosen organic acids can play a key role in helping to give plant-based protein foods a meat-like taste, which is essential when creating products that convincingly mimic traditional animal protein foods. Lactic acid, for example, is an important contributor to meaty flavors and is, in fact, naturally present in meat products and extracts.

Lactic acid or sodium lactate powders can be highly effective in enhancing broth-like or meaty flavors, often without any accompanying decrease in pH.

Nutrition enhancement opportunities

Although the amount of protein a plant-based meat substitute can deliver is the prime nutritional focus for most consumers, these products have the advantage of greater flexibility in formulation than any animal protein. Hence, they present manufacturers with
opportunities to offer enhanced nutritive value and diversity compared to conventional meat products. For example, ingredient solutions can provide calcium fortification through the inclusion of calcium lactate, calcium gluconate, or a combination of the two, delivering as much as 14 percent calcium. These solutions offer good to excellent levels of solubility, as well as calcium bioavailability equal to that of milk.

Mineral fortification of plant-based proteins gives producers a way to provide an added incentive for consumers to choose their products as a healthy, viable alternative to traditional meats. In addition to calcium, meat substitutes can also supplement consumers’ nutritional intake with other minerals such as magnesium, potassium and zinc.

**Managing formulation complexity**

Formulating plant-based meat alternatives is complicated, given the diversity of components involved. But effective preservation can be achieved with access to a broad ingredient solutions portfolio and expert knowledge of how those solutions perform in specific food systems.

Consumers judge freshness based on multiple attributes. The best way to get all those attributes right in a particular product with a particular composition may involve a vinegar-based solution, or a lactate/acetate blend, or an ingredient with strong antioxidant properties...or some combination of these.

Despite the dynamic nature of this fast-growing category, manufacturers can leverage extensive knowledge and experience in preservation that is highly transferable from traditional meat applications. Ingredient specialists expert in tackling formulation challenges in a wide variety of applications often can back their solutions with data from microbial studies and predictive modelling tools that help manufacturers speed their product development and testing processes, saving both time and R&D costs.

Given that acceptance of any plant-based meat analogue is in large part dependent on delivering a sensory experience similar to its animal protein counterpart, product formulation is of the utmost importance. Fortunately, the expertise and ingredient solutions that can help manufacturers achieve that end have been proven well in advance of the dramatic growth we are now witnessing in this category.

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88% of respondents say plant-based alternative proteins met their expectations.

Of that 88 percent, 91% will continue to purchase plant-based alternative proteins instead of or in addition to traditional meat and seafood proteins.
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Background information:
Corbion is the global market leader in lactic acid and its derivatives, and a leading supplier of emulsifiers, functional enzyme blends, minerals, vitamins, and algae ingredients. We use our unique expertise in fermentation and other processes to deliver sustainable solutions for the preservation of food and food production, health, and our planet. For over 100 years, we have been uncompromising in our commitment to safety, quality, innovation and performance. Drawing on our deep application and product knowledge, we work side-by-side with customers to make our cutting-edge technologies work for them. Our solutions help differentiate products in markets such as food, home & personal care, animal nutrition, pharmaceuticals, medical devices, and bioplastics. In 2019, Corbion generated annual sales of € 976.4 million and had a workforce of 2,138 FTE. Corbion is listed on Euronext Amsterdam. For more information: www.corbion.com