PLANT MEAT: CARNIVORE NO MORE

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Part 2

Texture and color are considered the Holy Grail when it comes to using plant-protein ingredients to mimic meat. It is a fine art to duplicate the textural subtleties such as chewiness, fibrosity, and flakiness of the meat or fish. Proprietary innovative manufacturing and formulation technologies have become available and are now increasingly used for animal-protein replacement.

Flavor and Aroma is Key

Other major differences are the flavors and aromas of meat, which is especially true for beef. When beef is cooked, literally hundreds of different aroma compounds come through and together create the ultimate taste humans prefer, which is the golden standard for comparison and quality reference. Undoubtedly, flavor and texture of meat is hard to replicate. This is, by far, the highest hurdle for the meat alternative products to climb.

Plant protein ingredients, as well as support additives such as konjac –a fibrous root vegetable with a rubbery texture/consistence- can be modified for varying degrees of textural density to meet consumers' expectations.

Undoubtedly, vegetarians and vegans alike want burgers, and until recently, they were willing to eat over-seasoned and under-hydrated cardboard-like textures. However, those days are gone. Now there are a few vastly-improved meat-free burgers like the Beyond Meat, Moving Mountains, and the Impossible burger that are getting much closer to the real thing.

Meat flavors develop at different rates just like fat, connective tissue, and meat cook. Subsequently, the caramelization reaction of carbohydrates creates hundreds of flavor compounds during heating. This is a very difficult problem to solve for the vegetarian burger formulators. However, let us pause for a moment and recognize that true vegetarians and perhaps flexitarians, have debased their flavor and eating sensations. Quite a few perhaps do not know or have forgotten what an actual pure beef burger tastes like.

Even when plant protein-formulated meat equivalent products reach a high degree of flavor, aroma, and texture equivalency with the real McCoy, one major component is still missing from the burger attributes: blood. Of course, there is no real blood in raw meat but rather a combination of myoglobin and some extracellular water that creates the reddish-looking meat juices.

The mission of the entrepreneurial-driven meat analog companies is to improve human health, positively impact climate change, conserve natural resources, as well as improve animal welfare. The new plant-based meat substitutes are strikingly similar in taste and texture to animal protein and have an aura free from bioengineered foods.

Consumers at Turning Point

It is a definite sign of the times that even very traditional German meat companies are now entering the market for meat substitutes. Trends seem to indicate that meat alternatives sales in affluent markets are developing at the expense of meat: Meat analog sales are expected to pick up continuing momentum and register double-digit growth patterns, whereas meat sales in some affluent countries like Germany are on a slight decline.

The plant-based meat alternatives are a category that is outpacing growth in the broader packaged foods sector. Strangely, most of the sales growth of plant-based meat products does not come from vegetarians but rather from the millennial consumers (born 1982-2004) and their children who facilitate a long-term habitual change in consumption patterns.

Global Perspective

Despite the steady increase in global meat consumption averaging plus 3 percent each year, there is a collective push by entrepreneurial companies and capital venturists to shake up the meat supply chain, citing environmental and health concerns over intensive factory farming of animals. For example, Impossible Foods has received funding and support from Bill Gates-owned company Cascade Ventures, Google Ventures, Temasek Singapore and Khosla Ventures. It is remarkable that Venture Capital funds increasingly focus on investing in alternative proteins.

Expanding into the fast growing plant-based proteins market is a strategic growth platform, which supports the commitment to become part of the journey for food sustainability. The overriding reason is that animal protein is the most vulnerable and resource-intense part of the world's food supply with an immense use of land and water, pollution and antibiotic abuse to keep animals "healthy", and hormones to accelerate growth.

A possible future scenario for innovative technologies is in blending structured plant protein with a portion of animal meat or cultured meat, formulated to create wholesome and good-tasting foods. These products can be termed "hybrid foods". It is clear that innovative extruded structured plant protein products have reached a high degree of technology, which enables a successful duplication of authentic organoleptic meat properties.

Soy: A Missed Opportunity

It remains a mystery why the rather conservative US soy protein industry had a lackluster attitude about the necessity of product innovations to further advance the market. Instead, they took the easy way forward and carried on using dated technology extruding defatted soy flour - limiting its applications due to flavor constraints - and continued maximizing inclusion levels which clearly did not impress consumers. Even though consumers showed a strong dislike due to negative perceptions and flavor associations, the soy protein industry did little or nothing to make the necessary changes to improve acceptance levels. The large soy companies are now facing a new landscape in which they are no longer considered a pioneer but have become followers in a market they once dominated.

Alternative Meat

Computational science application is increasingly successful in determining values of plant species, such as those present in soy, wheat, corn and rice, as well as finding combinations to create nutritive and great tasting sustainable sources of protein and other bioactive phyto-compounds.

An example of an emerging ecologically-sustainable food source is the Jackfruit tree. The Jackfruit tree is indigenous to Southeast Asia and can be considered a highly neglected food source. The fruit is low in protein but high in dietary fiber that, when cooked, uniquely mimics the fibrous texture and appearance of (pork) meat. The fruit needs minimal processing and can be crumbled, shredded, minced or pulled when heated. Jackfruit trees grow in the wild and the fruit needs to be harvested before it ripens. This

plant-based whole fruit is non-GMO and another food choice high in dietary fiber, low in sugar and hypoallergenic.

Combining the virtues of plant protein and technology has unlocked the secret to create near-perfect replicas of muscle meat. These meat analog foods are formulated using plant proteins derived from wheat, soy and pea using a structuring process that uniquely creates and mimics meat-like alignment and fibrosity. This technology breaks away from the typical, outdated extrusion processes of meat substitutes –such as the rather old-fashioned textured TVP soy flour- which often lacks the fibrous texture moisture retention and has poor flavor. Traditional textured soy flour is considered merely as filler without real textural improvement.

However, premium extruded structured plant protein can successfully replace lean meat. The modern technology of structured plant protein is a great technology and its success is mainly determined by the composition and formula percentage, as well as the mechanical and thermal process to create a fibrous appearance that will duplicate the organoleptic properties of meat. In fact, the journey from tofu or "meat from the field" - to extruded structured meat analog ingredients has taken more than 2,300 years.

Structured plant protein foods have a lot of advantages: no cholesterol, no transfats or saturated fat, and are made of plant proteins free from antibiotics and hormones that are so typical for lean meat. Premium plant-based meat analog foods are products that look like real meat or meat products when cooked and can be pulled into shreds, or appear as minced or crumbled, or used as part component of an emulsified vegan sausage like a hotdog and bologna.

Perception is Reality

To gain acceptance from mainstream consumers, the meat alternative should ideally be just as a convenient, tasteful, and ultimately even cheaper than the animal meat protein product. Over time, "plant meat" products are expected to be cheaper than animal-harvested meat products.

In principle, structured "plant meat" is a manipulation of plant protein and other minor ingredients to perfectly mimic the texture, appearance, consistency and nutritional approximation of cooked meat. Today "plant meat" foods are priced higher than average supermarket beef and chicken, but less than premium varieties like cooked, free-range chicken.

At a molecular level, everything from an animal's lean and fat tissue can be replicated using plant fractions instead. For example, the "plant fat" can be replicated by using several methods and one specific technology is to structure coconut oil with extruded plant protein and pea protein or potato protein to entrap the fat. When heated on a grill, the plant fat begins to melt, very similar to beef fat.

Impossible: A that Bleeds

The unlikely has become a reality: the engineering of a plant-based burger that smells, tastes, looks and even feels like ground beef. These formulated products will sizzle and brown on the grill in a similar way as the animal-derived meat pattie.

The essence of meat is the compound called heme. In blood, the heme is present as hemoglobin, while in meat muscle it is called myoglobin. It is striking that the leghemoglobin present in the roots of soy and alfalfa and the myoglobin in meat both share similar 3-D structures known as an alpha helical globin fold, which centers at the heme.

Leghemoglobin –the star ingredient of the Impossible Burger- is a protein found in nodules attached to the roots of nitrogen-fixing plants such as soy, that is similar to myoglobin and hemoglobin generally recognized as safe (GRAS). It is made using genetically-engineered yeast –the DNA of which has been retooled to produce the color that is strikingly similar to blood. In the future, leghemoglobin will likely be considered a color additive in some other potential plant-based meat applications.

The molecule of heme is identical to the myoglobin that is in an animal or in human blood for that matter. Heme is essential for all forms of life in humans, animals and plants. In organoleptic sense, heme creates the (metallic) flavor in the raw and cooked products. During the cooking process, heme typically interacts with some of the ingredients like amino acids, sugars and vitamins, creating a "meaty caramelized and roasted aroma".

Impossible Food's name to fame has been the creation of "plant blood". This ingredient makes a meat-free burger that not only look and taste like beef, but also bleeds like the beloved all-time American favorite. US restaurants now serve these plant meat burgers that originated from the world's technology hub Silicon Valley, California. The Impossible Burger production capacity will be ramped up quickly now that the 8000m2 manufacturing facility in Oakland, California, is in full production, and initially aiming for about 450,000 kilos 'plant meat" a month, or the equivalent of some 6.2 million plant-based burgers a month.

There is no doubt that the Impossible Burger is getting closer to simulating the typical beef burger. In its raw state, the burger looks a bit reddish and somewhat artificially manufactured with slightly more finely-grained appearance. When cooked in a skillet pan with some oil, it immediately begins to sizzle and some of the coconut oil emulsion oozes out. After a little while, the pattie starts to brown upwards from the bottom and begins releasing some of the "plant blood" juices. When the pattie is flipped, a brown crust appears and it is striking to see that the burger has really firmed up like a beef pattie. (As a side note, coconut oil is known for its unique fatty acid profile and is rich in medium chain triglycerides and lauric acid.)

To simulate "beef fat", coconut oil and functional plant protein ingredients –i.e. potato protein and or soy protein- are typically used. Such a combination provides the sizzle during cooking and the mouthfeel of fat while eating. (Sizzling is the fat leaking out when a certain grill temperature is reached and allows crust and flavor/aroma development.) It is noteworthy, that the cooking time and temperature are slightly less than that of a traditional burger.

Not only animals have hemoglobin, but also other nitrogen-fixing plants such as soy, clovers, or alfalfa -which captures nitrogen- can be used to create leghemoglobin (a heme protein). This is done by using specific soy DNA that is inserted or infused it into a modulated or genetically-engineered yeast strain. It is well known that yeast is the modern workhorse of cellular biotechnology and increasingly used in a plethora of foods and beverages like alcohol, animal-free rennet for cheese processing, pharmaceuticals, and modification of many types of protein ingredients. These modulated yeasts also play an important role to make "plant blood" by means of fermentation.

The trick is to use yeast and fungi to create plant-based heme compounds that truly simulate the typical beef juices. Heme is an iron-containing molecule that is present not only at high concentrations in animal lean muscle, but also in legumes like the roots of the soybean and alfalfa. To recreate meat hemoglobin, oxygen is brought in contact with iron. The result is a red compound that is exactly what separates "red meat" like beef and "white meat" like chicken and, to a lesser degree, also pork.

The roots of some legumes like the soy plant and alfalfa have nitrogen-fixing properties. Using cellular biotechnology, specific single-cell yeast strains have the ability to make plant blood, also termed leghemoglobin. A rather traditional fermentation process is used to complete the production of the purified heme in which most of the yeast is removed. It can be debated that this method of heme technology skirts the process of genetically-modified organisms, and it remains to be seen how the natural food aficionados react when they have the option of purchasing these types of plant meat foods.

Although the "Impossible Burger" is entirely made of plant components, it can still be considered a product of cellular agriculture. The heme that gives the Impossible Burger its distinctive bloody appearance and taste is produced by taking the soybean gene that encodes the heme protein and transferring it to yeast. When cooked on a grill, the hemen gets transformed into an explosion of organoleptic preferences.

Impossible Food's strength centers around a technology that leverages molecular engineering to create "bleeding" plant-formulated burgers to greatly enhance the replication of the color and flavor. It is only a matter of time before these technologies have totally disrupted the traditional meat companies, including the fast-food restaurants like McDonald's and Burger King. For now, the burger chain White Castle has rolled out the plant-based Impossible Burger in all their 377 restaurants across the US and Impossible Food is expected to go retail in 2019.

Impossible Burger Ingredient Line-Up

- Water
- Extruded Pea Protein
- Coconut Oil
- Potato Protein
- Natural Flavors
- Leghemoglobin
- Yeast Extract
- Sodium Chloride
- Isolated Soy Protein
- Konjac Gum
- Xanthan Gum
- Vitamin B1, B2, B12.
- Zinc

Beyond Meat Burger Ingredient Line-Up

- Water
- Extruded Pea Protein Isolate
- Expeller-Pressed Canola Oil
- Refined Coconut Oil
- Bamboo Cellulose
- Methylcellulose
- Potato Starch
- Natural Flavor
- Maltodextrin
- Yeast Extract
- Salt
- Sunflower Oil
- Vegetable Glycerin
- Dried Yeast
- Gum Arabic
- Citrus Extract
- Ascorbic Acid
- Beet Juice Extract
- Acetic Acid
- Succinic Acid
- Modified Food Starch
- Annetto

Perception Is Reality

Most of the growth in the alternative meat segment comes from both the younger affluent millennial consumers and the baby boomers who proactively seek out foods that fit their lifestyle. These lifestyle reasons can be manifold -be it healthy, ethical, or simply distinctive eating experiences, feel-good, and the preference for natural and recognizable ingredients which often translates to the desire to eat less farm-raised muscle meat. The substitution of meat proteins with plant proteins is spreading, though it is fair to say that the global world market is still minuscule as a percentage.

It is too early to tell if the success rate of this pathway will be able to replicate all the benefits of animal protein using the most traditional methods. When farm-raised animals convert energy-dense, micronutrient-poor crops such as grains into micronutrient-dense foods like milk, eggs, and meat, the food production will reach an enhanced capacity to meet the micronutrient requirements of the population.

There is little doubt that finding a true alternative to meat for the general public is, by far, the biggest obstacle to tackle. After all, eating meat is deeply embedded in emotional, cultural, religious, and psychological associations. But, just as text messaging and emails have changed the way people communicate, society will change over time and adhere to a new identity of the food they eat.

Plant Protein Taste Considerations

Plant proteins tend to taste bitter, a clear disadvantage when compared to animal proteins present in meat, eggs and dairy. Flavors are frequently used to mask the bitter note of the plant protein ingredients.

The texture, bite, chew, and the right level of juiciness are created to assemble the right balance of the various plant protein properties. The organoleptic, and performance properties of plant proteins, need to be cleverly orchestrated. Wheat gluten is normally used to give the burger structure, firmness, chew and some protein lamination (fibrosity), while potato protein is ideally suitable to hold water and transition from a softer uncooked state, to a more defined solid state when cooked. The potato protein is absorbed at the fat:water interphase, and plant fats, like deflavored coconut fat, canola oil and rice oil are suitable emulsion carriers.

Color Tuning

For plant-based meat products, color is an increasingly important purchase driver. In marketing lingo, the Instagrammability of a food product is a trend that is mainly driven by Millennials and Gen Z. As such, the food should be photogenic –visually exciting, appetizing, and instantly perceived as natural. Yet, at the same time, the terms "natural" and "clean" are often interpreted differently by the industry and the consumers. The latter group wants to understand what is in their food, preferably with no, or very minimal chemical alternation.

Compared to animal protein foods, plant proteins can be problematic in masking both strong colors and off-flavors. Color is probably one of the most organoleptic variables in food's appeal. Plant-based meat manufacturers have become creative in finding ways to mimic the color in meat alternatives.

Plant-based botanical, and/or vegetable extracts include beetroot, saffron, red radish, lycopene, and sandalwood extract. These selective color pigments, extracted from fruits, vegetables and botanicals, are a way forward to deliver vibrant colored plant-based foods in a more natural and cleaner way. In addition, some of these color extracts like beetroot, lycopene, and turmeric are increasingly recognized for health benefits.

Each and every one of the color additives selected have their own efficiency, and these variables also depend on whether the plant meat product is sold "raw" or "cooked". When cooked, a typical brownish color is required. Caramelized sugar and/or malt will achieve the desired appearance.

Most of these coloring-support ingredients face some particular challenges such as heat stability and pH sensitivity. For example, lycopene can be an effective solution for plant meat products in which heat instability is at play.

Umami: Going Forward with Mushrooms

Meat consumption is expected to rise sharply, especially in developing countries. This is mainly due to improved living standards, including a higher financial status and improved health. There are also unsettling environmental and health consequences to consider. These include loss of biodiversity, higher greenhouse gas emissions, water pollution and deforestation. However, it is futile to expect that meat consumption will decline, though it will perhaps be possible to reduce the growth curves with a concerted effort.

The inclusion level of structured extruded plant proteins in hydrated form, ranges from 100 percent meat-free to approximately 20 percent. A typical pattie formula includes a stable fat and water emulsion that acts as a carrier, to which hydrated structured plant protein ingredients are added. A novel idea is also to include stabilized cheese curd and probably rice curd for more meat-free options.

The use of mushrooms in blended burgers, other ground meat and poultry products may allow for a significant reduction of sodium and fat. Mushrooms contribute to the creation of a desired umami flavor because of the presence of glutamate. Mushrooms can be added to the blend as pre-blanched, or as a powdered concentrated natural glutamate ingredient. At a usage level of 0.3 to 1.0 percent, the powdered ingredient provides the much sought-after umami flavor, allowing up to 50 percent salt reduction. Any mushroom variety will deliver value: white button, portabella, and shiitake boost umami flavor, while enhancing texture and moisture management in both hybrid and plant-based formulas.

Beef, and or plant-meat products blended with a significant portion of mushrooms are now en vogue and have become a regular offering in food service and food markets. Besides the sustainability attributes of mushrooms, like carbon footprint reduction, anti-inflammatory and antioxidant properties, they are an ideal vehicle to lower the cost for both premium beef of "plant meat" formulated products. The "beef-mushroom" burger is not something that has been concocted in the 2018s. In 1994, the writer of this article developed for McDonald's Indonesia a "low-cost" burger sandwich, using mushroom stems to add texture, chew, flavor and favorable price points.

Analog or Hybrid

Innovative structuring technology is now available using plant-based protein ingredients that are dried immediately after extrusion. These products are hydrated before use at prices significantly cheaper than meat. This form of extrusion is growing at a much greater speed than high-moisture processing. For now, a few entrepreneurial-driven companies that sell meat-mimicking food to affluent consumers, mainly use high moisture extrusion.

Extruded structured plant protein fibers and chunks will increasingly cut into lean meat formulations to either enhance or replace significant amounts of expensive meat sources. Most probably, beef and tuna foods will be the first to develop into "fusion" or hybrid meat products or even become animal-free altogether. Beef, salmon, and tuna are expensive muscle foods. Structured plant protein will not only deliver cost-savings but also contribute to a more efficient and economical use of transitional protein sources. Although chicken is a relatively cheap source of muscle protein, there are dynamics to infuse chicken food with structured plant protein ingredients in a wide range of hybrid chicken products, like those appearing on menu boards of the world's largest fast food companies.

Plant Meat Production

The structured protein ingredients can be extruded in many different shapes, sizes, and colors like nuggets, pellets, mince, flakes, and fibers. These products are often formulated using two main components: soy protein and wheat gluten. These two components have covalent disulfide bonds and non-covalent interactions, creating a typical configuration also known as lamella. These lamellas look like fine sheets of material held closely together with hydration fluid in between.

The composition of the extrusion formula largely determines the physical appearance and organoleptic attributes of the structured protein. Both fiber structure and laminar properties (cross-linking and a reformed expandable structure) play important roles, and are an integral part of the end product's characteristics.

Plant protein ingredients open up in the extrusion barrel to interact with the other formula components such as wheat gluten, potato starch, and plant fibers. Functional plant fibers like those extracted from rice and fruit can be considered support ingredients, and low inclusion levels may be part of the formula. These (water-insoluble) fibers typically act as a "dispersing phase", somewhat interrupting the nucleation of the melt, and create a kind of diagonal expansion showing a zigzag pattern. Nucleation (aggregation/sticking together) is often found to be sensitive to impurities in the thermodynamic phase of the formula system.

Gluten can be considered a main ingredient for creating lamination of the extruded structured plant protein, whereas, soy or pea protein supports the creation of the longitudinal formation of the fibers that mimic cooked meat fibrosity and appearance. Changing the wheat and soy or pea protein ratio can modify the structure of a textured rehydrated plant protein particle. This is especially important to create elasticity and stress relaxation properties, duplicating the structure of muscle, thus, closely mimicking cooked meat.

Specifically, the breaking of the chemical bond in the proteins –disulfide bonds- is essential for the protein molecules to realign and link into longer chains, a process very similar to polymerization. The continuous flow of the protein dough and the subsequent breaking of the disulfide bonds can create extensive stress on the metal composition of the barrel lining, and should be monitored.

The reassembling of the disulfide bonds causes the much sought-after properties to resemble mimic meat-like properties. The conditioned dough has a typical processing temperature of 120°C – 130°C which finally reaches the die mounted at the end of the long barrel. The simultaneous shearing and cooling in the end-compartment boost lamination and cross-linking. The product is cut and shaped exactly at the point of pass-through at the die.

The combination of added moisture, heat, shear, and pressure in the extruder barrel creates gelatinization of the starch and denaturation of the plant proteins. This builds a viscoelastic mass that flows and allows alignment as well as cross-linking, then immediately expands into the required shape and structure when finally escaping the die.

Besides the important role of soy protein and wheat gluten, there are a few secondary-support functional ingredients used to improve not only organoleptic quality but also water-holding or water retention. For the latter, stabilized rice bran or rice fiber can be used at an inclusion level of up to 2 percent to improve the speed of hydration and water retention.

Flavor and Color

Extruded structured meat analog particles still have an overhang of distinct soy, pea or wheat flavor. The freshly extruded granules or chunks can only be seen as an intermediate product that still needs flavoring through marinade diffusion. Depending on the specific properties of the structured meat analog fibers, the water hydration ranges from 2 to 4 parts. These levels of hydration are typical and analytically provide the same protein values as lean meat.

For the use of typical chicken or beef flavors, certain amino acids –the key component of sodium glutamate- can be used to create the much-heralded umami flavor, one of only five that the tongue can perceive. The hydration or marinating is usually done in large stainless vacuum tumblers that allow flavors, such as hydrolyzed plant proteins, yeast extracts, and seasoning/spices, to diffuse into the structured plant protein membranes.

To simulate cooked beef color, both caramel and malt can be used as a component of the plant meat. New technologies have been developed to include stable heat and color forms of hydrolyzed protein flavors. The inclusion level of these natural flavors is less than 1.0 percent and allows for the by-passing of flavor addition and diffusion when the final product is assembled in the processing plant

Noteworthy is the addition of minute amounts of titanium dioxide, often used to camouflage the grey color of the soy protein into something more appealing to create the typical cooked chicken breast look.

High Moisture Extrusion

Premium (high moisture) structured plant protein foods have taken a page from Apple founder Steve Job's credo that "People don't know what they want until you show it to them." Some of the world-famous Silicon Valley entrepreneurs are now investing in companies that use radically different approaches to create a more sustainable food supply chain by primarily focusing on providing alternatives to animal protein.

Market research in consumer attitudes and expectations can be tricky and misleading. The cold fact is that "you can't ask your customers to tell you what to do next. They simply don't know, until it is shown to them." (James Dyson, WSJ December 9, 2017). These words from James Dyson echo the words of Steve Jobs.

High moisture extrusion (HME) can be described as a system in which a blend of plant proteins, starches and processing aids are moved into a pre-conditioner where water and oil are added. This mixture is then moved into co-rotating and intermeshing steel augers, where specific steam heat, pressure, and shear conditions alter the protein structure, including the influence of chemical expansion properties of the support additives. This mechanical process very quickly creates a dough-like paste while pushing it forward into the long barrel for transformation into a laminated and fibrous or fibrated meat-like product.

Innovative extrusion technology allows conversion of plant protein to animal protein characteristics like meat properties. It requires quite a bit of knowledge about protein interaction and extrusion expertise to perfectly match the organoleptic properties of cooked meat.

High moisture extrusion technology generates products to have the taste and mouthfeel of genuine muscle meat, without the need for rehydration. These types of plant meat foods are perfectly suitable for "heat & eat" consumption.

The product specifications of high moisture meat analog products are typically similar to harvested meat: 70-75 percent water, 15-20 percent protein, and 2-5 percent fat.

For now, the downside of high moisture extrusion, is its rather high consumer prices. Retail prices are typically higher than its meat equivalent. Only affluent consumers can afford these high prices. Eventually, prices need to come down to be competitive with animal protein. The future starts today and an entirely new plant protein platform will emerge, changing the landscape forever.

Moving Ahead

To immediately reduce meat consumption, the way forward should be to choose a path where lean meat is blended or infused with structured plant protein extrudates that ingeniously mimic beef, chicken or tuna by infusing hydrated structured or fibrated plant protein ingredients or particles with a portion of lean meat. World-famous franchised restaurants have successfully introduced this concept by using this technology to offer affordable chicken patties, burgers, breakfast links, pizza toppings, and spaghetti meat sauce while maintaining nutritional value.

Existing formulated-meat products will likely undergo conceptual changes. For example, coextruded dumplings, hot dogs, hors d'oeuvres, pizza pepperoni, and burgers will continually evolve until they are no longer perceived primarily as a meat product. For example, KFC (UK) is testing chicken-like vegetarian options and planning to launch in 2019. The vegetarian chicken substitute initiative is based on how the main fast food restaurants have started to respond to the growing demand for meat-replacement products, which is another clear sign how breathtaking fast the plant-based meat sector is moving.

The same is true for hand-held "pocket" foods. This category has expanded into a wide array of products for people who have little time or desire to sit down for a meal. Hand-held wrapped foods originated in the Orient, where they were known as "lumpia" or spring rolls. Today, these products come in many varieties - from tortillas to a growing selection of mix-and-match foods - based on ethnic preferences, flavor, and taste.

Wrapped or handheld foods may be considered as the beginning of the demise of meat as the main focal point of a meal, and will slowly be transplanted by food-on-the-go. Here, meat is "hidden" in wrapped fillings and stuffing, which serves as a characterizing ingredient with significantly less emphasis on the species - whether beef, poultry or fish.

With the growing popularity of plant-based meat foods, this category is expected to skyrocket. The latter is also true for the sales of fish substitutes –including sushi, often considered the last frontier that people will give up. It will be interesting to see how the Good Catch "fishless" products are accepted when introduced later this year. The potential of "fake-fish" has been underestimated, but consumers are starting to recognize the negatives of commercial fishing practices and the mercury levels present in fish as vegetarian foods become more mainstreamed.

Some may bemoan the change, but the new concept of formulated meat foods as tasty and convenient ingredients will not only accelerate consumer demand, but also serve as a catalyst for modern applications with the real use of plant protein as the chosen protein for a new line of products. Hence, providing sustainable, affordable, environment-friendly, nutritive, and tasty convenience foods.

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