Food Industry Watch

Future Foods

August 2010

Engineered Foods Will Offer Benefits to Nutrition, Health, & the Environment

Watch List

- Over the next few years, food professionals expect new products to emphasize "clean" labeling with natural ingredients and healthy attributes.
- Opposition to GM foods may give way when second-generation GM products, with benefits consumers value highly, reach markets in the US, Europe, and developing world.
- Nanotechnology is creating a new kind of food additive: Targeted nutriceuticals in molecule-size packages.
- In 2010, the FDA is finalizing its guidance for manufacturers on use of nanoparticles in food. The EU is updating its law on novel foods to deal with nanotechnology.
- Meat, milk, and other products from cloned cattle, swine, and goats were approved for the US in 2008. Clone-derived meat may claim a premium niche, comparable to Certified Angus Beef, based on genetically assured characteristics.
- The Enviropig, a Yorkshire breed genetically modified for less-polluting manure, has been approved for limited production in Canada and is under review by the FDA.

Related Reports

- Animal Cloning in the Food Supply
- Functional Foods
- Nanotechnology & Food Production

Key Takeaways

- Industry leaders believe that consumers are label-conscious and looking for natural ingredients, authentic flavors, and health-supporting characteristics in foods.
- Demand for functional foods, which offer added nutrients or health benefits, may open the door for engineered foods. However, the example of golden rice illustrates that consumer acceptance can be complicated.
- The regulatory environment for novel foods is relatively open in the US and more difficult in Europe. Pending new guidelines, food products with nanotechnology are reviewed on a case-by-case basis.
- Nanoparticles offer novel ways to deliver enhanced nutrition, quality, and safety. More research is needed to understand their equally novel potential for unintended effects.
- The FDA has found no evidence that foods derived from cloned animals pose additional risk. Opponents argue that the high failure rate in the SCNT cloning process points to potentially hazardous DNA errors.
- Lab-grown meat is technically feasible but awaits investment. Benefits include reduced use of land and animals. An alternative approach to future meat production is GM animals like the Enviropig, which could make mega-farms less polluting.

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Executive Summary

The most important factor shaping near-term food innovation is consumer demand for natural, healthy ingredients. Marketers and technologists are focused on authentic flavors, especially from ethnic cuisines (innovative example: Mushroom-flavored chips developed by PepsiCo for Russia, where mushroom hunting is nostalgic). Strong sales growth in functional foods — which feature special ingredients or additives for nutrition and health — is expected to continue and may create opportunities for GM and nanotech products.

Second-generation GM crops are genetically modified to add or improve characteristics valued by consumers (first-generation products emphasized weed control, valued by producers). Surveys using auction methodology find that consumers are willing to pay for genetically modified foods with "anti-cancer" or "heart healthy" attributes. However, acceptance may be complicated by other factors, as seen in a study of issues relating to golden rice, a cultivar designed to remediate vitamin A deficiency.

Nanotechnology is the assembly of customized molecules that are one to 100 billionths of a meter in one or more dimensions. Nanoparticles are used already in food packaging to provide a better barrier against oxygen, moisture, and light. Used as food additives, nanoparticles can encapsulate nutrients for time-release in the gut or mask undesirable flavors, such as the fish oil in an Australian brand of bread enriched with omega-3 fatty acids. Future "smart" applications include packaging that turns color when food decays and vitamins that sense where they are needed.

Nanoparticles exhibit unusual properties because of their size but also because of their disproportionately large surface area. Forces such as surface tension, molecular attraction, and electrical charge exert strong effects. Along with the novel benefits, there could be novel pathways to toxicity, including overdoses, impurities, and invasion of tissues that larger particles cannot reach. The FDA and EU are in the process of setting guidelines.

Emerging alternatives in meat production include clones, GM animals, and lab-grown products. Cloning involves high initial costs, but clone descendants may find a premium-quality niche based on guaranteed genetics. Approved in the US since 2008, clone products will face review as novel foods in Canada and the EU. High rates of deformity and ill health raise questions about DNA errors in the SCNT cloning process.

Lab-grown meat is far from actual production but technically feasible. Initial products would mimic ground beef or chicken nuggets, with benefits in less land use, less pollution, and less cruelty to animals. Closer to market is the Enviropig, a Yorkshire breed genetically modified for better digestion of phosphorus and less-polluting manure. GM animals could reduce the threat to water tables from megafarms but would still involve raising large numbers of animals in confined conditions.

Market Readiness for Engineered Foods

Consumers Looking for Natural, Authentic, Healthy

Our ability to engineer foods is far ahead of our willingness to eat engineered foods. By consensus in the food industry, consumers today are label-conscious and looking for natural ingredients. In a 2008 survey for Perfumer & Flavorist, four of five respondents identified "flavors from natural ingredients" as the most important trend for the next five years ("New opportunities…," 2008). As a FritoLay vice-president put it: "Consumers want to recognize the ingredients on their label and they don't want to see a lot of them" ("Savory flavor," 2008).

The desire for authentic flavors is a related trend, with the industry drawing on ethnic cuisines for product innovation. In snack foods, for example, PepsiCo has developed chaat-flavored chips for India and mushroom-flavored chips for Russia — a turnaround from its previous strategy of globalizing flavors like nacho cheese or sour cream and onion (Barroso, 2009). This new type of product demands technical precision in recreating local, emotionally resonant flavor experiences (mushroom hunting is a family memory for many Russians). Food technologists use advanced laboratory processes (gas chromatography/mass spectrometry, high-pressure liquid chromatography, scanning electron microscopy) to identify sequences of chemical events that contribute to a sensory experience, as with PepsiCo's lime-flavored chips for Mexico, which begin with the scent of lime, then offer a citrus taste, followed by fried potato flavor, and finish with a citrus note "leading to the next bite." New foods derived from ethnic cuisine will likely migrate to other countries as marketers follow the flow of populations.

A third trend is healthy ingredients. Products featuring special ingredients or additives for nutrition and health are called functional foods, a category predicted to continue sales growth at a rate near 5 percent per year ("New opportunities…," 2008). As health-conscious consumers look for foods and beverages that address concerns about obesity, heart disease, and diabetes, they may look favorably on engineered products that reduce fat, increase antioxidants, and add key nutrients — with ingredients from genetically modified organisms (GMOs) or from nanotechnology.

Second-Generation GM Foods

The advent of genetically modified (GM) crops in the 1990s met with strong resistance in Europe, leading to EU laws that govern any future introduction of novel foods. A second generation of GM crops has come under development since then, many with characteristics valued by consumers (first-generation products emphasized weed control, valued by producers). Examples of consumer-oriented GM products include cooking oil with reduced fatty acids, fruits with increased antioxidants, potatoes with higher protein, produce that doesn't spoil as fast, and wheat without gluten. Grains, fruits, and vegetables with genes inserted for resistance to insects and disease allow reduced use of pesticides, another health-related benefit valued by consumers.

Surveys using auction methodology find that consumers in Canada and the US prefer conventional foods to either GM or organic but are willing to buy GM foods and also willing to pay more when GM foods offer "anti-cancer" or "heart healthy" benefits. European consumers tend to be against GM foods in principle but express some willingness to buy when asked specifically about GM tomatoes with added vitamins, longer shelf life, or environmental benefits (Larue et al., 2004). An experiment using roadside fruit stands in five European countries found opposition to GM foods was soft among consumers making actual purchases. Given a three-way choice of organic, conventional, or genetically modified/spray-free fruit, nearly half chose organic with conventional coming in second and GM averaging 21 percent. When the GM fruit was priced 15 percent lower than the others, it became the number one choice except in France and the UK (Knight et al., 2007). These findings were consistent with a Eurobarometer poll showing half of consumers would probably buy a GM product if it offered less pesticide residue.

In developing nations, attitudes toward GM crops are more favorable, as drought tolerance and disease resistance are seen as directly beneficial to consumers. China has made a substantial investment in GM rice and other crops, along with a program for public education (Stone, 2008). In India, where researchers are working on GM varieties of cabbage, potatoes, rice, and tomatoes, more than 90 percent of respondents say they would consider GM food if it used less pesticide (McCluskey et al., 2007). Even so, there are concerns about the safety of untraditional foods, and other factors may influence consumer perceptions, as illustrated by the case of golden rice.

Golden rice is a cultivar genetically modified to produce beta-carotene, a precursor to vitamin A. According to World Bank estimates, deaths of children under six in some areas could be reduced 23 percent with supplemental vitamin A (Egana, 2003). Still, there is controversy over golden rice, beginning with its golden color (from beta-carotene). Polished white rice is prestigious and widely preferred, so consumers may perceive golden rice as being for poor people and avoid it. Another objection notes that absorption of vitamin A requires dietary fat, which may be deficient. Suspicions of corporate greed are are also a background issue as the broken promises of the Green Revolution of the 1960s, which increased agricultural productivity but did not end hunger in the developing world, remain fresh.

Nanoparticles as Food Additives

Range of Applications

Nanotechnology is the assembly of customized molecules that are one to 100 billionths of a meter in one or more dimensions. Nanoparticles can take various shapes — spheres, tubes, discs — and are made from various materials, including carbon, silver, milk protein, and chitosan (a seafood byproduct). For example, nanocochleates (named for snails with spiral shells) self-assemble when calcium ions are added to a lipid from soybeans, resulting in a rolled-up container that can protect a vitamin or other micronutrient from breaking down during storage (Chaudry et al., 2008). Molecular-scale tinkering can attach a water-soluble component to a fat-soluble vitamin (or vice versa), so nutrients can be effectively dissolved in water or any food medium.

Used as a delivery system, encapsulating nanoparticles can time-release nutrients in the intestines for more efficient absorption into the bloodstream. Time-release can also be applied to flavor sequencing or to masking flavors, as in an Australian bread with omega-3 fatty acids but no fishy taste.

As additives in themselves, nanoparticles can be designed to enhance color, texture, and freshness in foods. Lycopene, a synthetic form of the carotene in tomatoes, is available today in the US and Europe as a color additive and antioxidant. Because of their extensive surface area relative to overall size, nanoparticles are able to impart a creamy texture, so ice cream with reduced fat can still have the appropriate mouthfeel. Mars Inc. has patented a spray coating of silicon dioxide, magnesium oxide, and titanium dioxide that maintains a freshness seal even if the product is flexed.

Food packaging is another significant area for nanotechnology. Silver, magnesium oxide, and zinc oxide nanoparticles are all effective antimicrobials and likely to see wide use in food containers. Nanosilicates extend shelf life, keeping moisture in and oxygen out. Thanks to nylon nanoparticles that repel odors, beer can now be sold in plastic bottles.

Farther into the future, smart applications will introduce improved safety, more sophisticated targeting, and even consumer interactivity. Traceability can be built into future foods as nanotechnology becomes more widespread. Particles called quantum dots will be incorporated into packaging that changes color in the presence of decay gases. For better targeting of nutrients, nanoparticles may include a chemical nanosensor, detecting where a nutrient is needed and releasing it accordingly. Perhaps the ultimate nanoproduct is a beverage that will be colorless and flavorless when the consumer brings it home. By choosing settings on the microwave, the consumer selects colors and flavors that release at specified frequencies.

Identifying the Risks

Nanoparticles behave in sometimes surprising ways, with characteristics not seen in the same materials at a larger scale. Nanoparticles make materials stronger, more conductive, and catalytically more efficient, because they pack more structure into the same volume of space. Little is known about nanoparticle interactions in the digestive system — with acids, enzymes, and other food ingredients. In a study of rats, carbon nanoparticles given orally were eliminated in feces but ended up in the liver when injected to the bloodstream (Das et al., 2009).

Because nanoparticles reach the bloodstream and deep tissues more easily, research is needed to define the potential for overdoses and accidental intake of impurities, such as manufacturing byproducts, pesticides, or antimicrobial metals from containers. Early studies indicate chemically stable metals are safe but reactive metals are toxic to cells and can disrupt DNA replication. There is evidence that nanoparticle surfaces with a positive electrical charge are more toxic than negatively charged surfaces and that neutral surfaces are the most biocompatible (Ligeng et al., 2010). Nanoparticles that slip through cell walls can increase production of free radicals and cause oxidative damage (Chaudry at al., 2008).

Regulations in Transition

In the US, the policy of the Food and Drug Administration is to review nano-scale ingredients on a case by case basis. No additional approval is required for ingredients generally regarded as safe (GRAS). Lycopene, for example, is viewed as the synthetic equivalent of tomato carotene, which is GRAS. In cases where particle size changes the nature of an ingredient, the burden is on the manufacturer to show that it is not harmful. The FDA is expected to issue nanotechnology guidelines for manufacturers in 2010.

The European Food Safety Authority (EFSA) also follows a policy of case by case review, with only a few nanoadditives approved so far. The European Parliament is drafting an update to its law on novel foods to cover nanotechnology products. EFSA's Scientific Committee emphasizes that limited information about nanoparticles makes it difficult to assess specific products (European Food Safety Authority, 2009). A British government report pointedly calls on industry to be more transparent about details of new nanoparticles, reflecting greater skepticism in Europe toward industry on the subject of engineered foods (House of Lords, 2010).

Strange Meat

Future of Cloning

Emerging alternatives in meat production include cloned animals, GM animals, and lab-grown products. Cloned cattle, swine, and goats were declared safe for use as food by the FDA in January 2008. To provide a period of transition, the US Department of Agriculture (USDA) asked producers to observe a voluntary moratorium on clone-derived foods, expected to last three to five years. In Europe, EFSA also affirmed the food safety of healthy clones, but clone-derived products will have to undergo an approval process under the EU novel foods law. The 2010 draft update to that law at first included a provision for foods from clone descendants, but the provision was deleted in committee. Cloning will likely be addressed in separate legislation. In Canada, clone-derived foods will be subject to premarket approval under its novel foods law.

There are only a few hundred clones among the tens of millions of cattle in the US. Because of high initial costs, clones will be used mostly as breeding animals. Products from clones or clone descendants do not require special labeling, and it is likely that small amounts have already entered the US food supply. When the USDA moratorium ends, meat from clone descendants could be marketed as a premium product, along the same lines as Certified Angus Beef. Industry proponents say clones bred for efficient meat production could be part of the solution to future needs for a greatly increased food supply.

Opponents maintain that cloning is not just an additional method for selective breeding, comparable to in vitro fertilization. They point to the low rate of cloning success, with only 6 percent of implanted embryos surviving to become healthy adults (Riddle, 2007). The reason for the high failure rate is that the standard process for cloning — called somatic cell nuclear transfer (SCNT) — involves genetic reprogramming. When the nucleus from the donor cell is implanted in an egg, it has to revert from being a specialist (typically a skin cell) and express the full complement of genetic instructions for bones, nerves, organs, and so on. High error rates in clone DNA, evidenced by deformities and ill health, pose a "subtle hazard" to the food supply, according to opponents. Animals that appear healthy may have compromised immune systems and so spread pathogens in manure as well as food. As fertilizer, manure would spread to crops, and slaughter byproducts in feed would affect other livestock.

Cloning advocates report that the SCNT success rate has risen to 10 to 15 percent (Plume, 2009).

Enviropig: On Its Way to Market

Genetic modification represents a more targeted approach, compared to cloning. The targeted characteristic of the Enviropig, which may soon become the first GM animal approved for food use, is not succulence or flavor but a production attribute — manure that is less polluting. Ordinary pig manure contains high levels of phosphorus. Runoff from farms enters waterways, causing algal blooms and oxygenless dead zones. On megafarms, manure lagoons pose a continual threat to water tables. Since 1999, the University of Guelph has been testing successive generations of Enviropig, a Yorkshire breed modified for improved digestion of phosphorus.

To create the Enviropig, researchers inserted a new gene into pig DNA that enables production of phytase, an enzyme that breaks down phosphorus. The gene came from the bacterium Escherichia coli. To ensure the new gene was effective, Enviropig also received a segment of mouse DNA that promotes replication. The modified genome has been successfully passed on to new generations of Enviropigs, whose manure contains 30 to 65 percent less phosphorus. Applications to assess the safety of Enviropigs for human food and animal feed are under review in the US and Canada.

Lab-Grown Meat

Lab-grown meat, also called in vitro meat, is far from actual production but technically feasible. The methodology comes from tissue engineering, a field with primarily medical applications. The reasons for attempting it on an industrial scale are ethical and environmental. Megafarms subject large numbers of animals to debilitating confinement, and accumulation of their waste threatens rivers and water tables. Health professionals view megafarms as potential sources of epidemic disease among animals and humans. Worldwide, the raising of livestock uses up fossil fuels and land resources inefficiently, with every kilogram of beef requiring seven kilograms of grain for feed (Datar & Betti, 2010).

In vitro meat would be produced in a form resembling ground beef or chicken nuggets. Using starter cells from animal muscle, the meat would be grown in sheets on collagen beds or a beaded matrix. The sheets would be bathed in nutrients (possibly a mushroom extract) and would have to be induced periodically to stretch or contract, encouraging growth and preventing atrophy. When "done," the sheet would be rolled up, cooked, and packaged like hamburger.

The metabolism of muscle cells in a live animal is managed by homeostatic processes. Replicating those processes on an industrial scale, delivering nourishment and carrying away waste, is a primary technical challenge for in vitro meat. Advocates recognize that public acceptance of in vitro meat as food is an even greater challenge.

Opinion polls show that consumers feel greater reservations about food from engineered animals than from engineered crops (Larue at al., 2004).

Related Entities

- Advisory Committee on Novel Foods and Processes (ACNFP) — United Kingdom
- European Food Safety Authority (EFSA)
- Food and Drug Administration (FDA)
- Food Inspection Canada
- Food Standards Agency (FSA) — United Kingdom
- Health Canada
- Institute of Food Technologists (IFT)
- New Harvest
- Rutgers Food Innovation Center
- US Department of Agriculture (USDA)

Acronyms

GMO: Genetically Modified Organism

GRAS: Generally Recognized as Safe

SCNT: Somatic Cell Nuclear Transfer (primary method of cloning)

SLN: Solid Lipid Nanoparticle

SWCNT: Single-walled Carbon Nanotube

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