FIS: 503 PRODUCTION OF OTHER MARINE PRODUCTS (2 UNITS)

PROCESSING AND PRESERVATION OF MARINE PRODUCTS

INTRODUCTION

Food Processing and Preservation, branch of manufacturing that transforms raw animal, vegetable, or marine materials into tasty, nutritious, and safe food products. The industry has its roots in ancient times, as humans have always needed to obtain food and store a portion for later use. Prehistoric humans may have dried fruits in the sun and stored meat in cold areas, such as caves. The modern food processing and preservation industry was born in 1809, when French chef and inventor Nicolas Appert, searching for a better way to provide food for Napoleon's army, devised a method for sterilizing food in tightly sealed glass bottles. Today a wide variety of methods are available to maintain and enhance the appearance and taste of food. Food processing and preservation methods also create products that are convenient for consumers, such as products that are ready to eat or require minimal preparation and cooking. Combining these methods with modern distribution networks makes seasonal crops available year-round in grocery stores all over the world.

PROCESSING AND PRESERVATION METHODS

Food processing encompasses all the steps that food goes through from the time it is harvested to the time it arrives on supermarket shelves. At simplest, processing may involve only picking, sorting, and washing fruits and vegetables before they are sent to market. Some processing methods convert raw materials into a different form or change the nature of the product, as in the manufacture of sugar from sugar beets, oil from corn or olives, or cheese from milk. Processing may also involve an extremely complex set of techniques and ingredients to create ready-to-eat convenience foods. Food preservation refers specifically to the processing techniques that are used to keep food from spoiling. Spoilage is any change that makes food unfit for consumption, and includes chemical and physical changes such as bruising and browning; infestation by insects or other pests; or growth of microorganisms, such as bacteria, yeast, and molds. Some food preservation techniques destroy enzymes, proteins that are present in all raw foods, which are responsible for the chemical and physical changes that naturally occur after harvesting. Food preservation techniques also help eliminate the moisture or temperature conditions that are favorable for the growth of microorganisms. As they multiply and grow, microorganisms are capable of causing food-borne illness. They also break down foods, producing unpleasant changes in taste, texture, and appearance changes that we recognize as spoilage. Although people have known about spoilage and some preservation methods to prevent it for centuries, it was only in 1857 that French chemist Louis Pasteur demonstrated the role of microorganisms in the process.

1. Curing

Curing is one of the oldest forms of food preservation. It is used to preserve meat and fish, yielding common products such as bacon, ham, frankfurters, and corned beef. Curing involves adding some combination of salt, sugar, spices, vinegar, or sodium nitrite to animal foods.

Smoking, a flavoring technique and preservation method, is another ancient technique that is commonly used with curing. Smoking involves cooking meat or fish very slowly over a low wood fire. Curing and smoking preserve food by binding or removing water so that it is not available for the growth of microorganisms. These methods impart a distinctive color and flavor to food and, in some cases, eliminate the need for refrigeration. Some studies, however, show that curing agents such as sodium nitrite may combine with other chemicals to form cancer-causing nitrosamines. In addition, cured products tend to be very salty, and the sodium in salty foods has been linked to hypertension, also known as high blood pressure. Smoked meats and fish may contain toxic and even carcinogenic compounds that they absorb from wood smoke.

2. Drying

Cultures throughout the world have used drying to preserve food, probably since prehistoric times when people learned that dried foods—for example, fruits left out in the sun—remain wholesome for long periods. In modern times, the dried foods industry greatly expanded after World War II (1939-1945) but remains restricted to certain foods, including milk, soup, eggs, fruits, yeast, some meats, and instant coffee, that are particularly suited to the process. Three basic methods of drying are used today: sun drying, a traditional method in which foods dry naturally in the sun; hot air drying, in which foods are exposed to a blast of hot air; and freeze-drying, in which frozen food is placed in a vacuum chamber to draw out the water. Removing the water preserves food because microorganisms need water to grow and food enzymes cannot work without a watery environment. Removing the water also decreases the weight and volume of foods, thereby reducing transportation and storage costs. However, dried foods may be less convenient for consumers because most must be rehydrated before consumption. In addition, most dried foods only reabsorb about two-thirds of their original water content, leaving the rehydrated product with a tougher, chewier texture than the original. Some scientists and consumer groups have raised concerns about the sulfites commonly added to fruits before drying to prevent browning. These chemicals may cause severe allergic reactions in people with asthma or other people sensitive to the chemicals.

In freeze-drying, frozen food is placed in a special vacuum cabinet. There, water escapes from the food by sublimation, a process in which ice changes from a solid directly to a vapor without first becoming a liquid. Freeze-dried foods retain their original flavor, texture, and nutrients upon rehydration but must be packaged in moisture-proof, hermetically sealed containers. Freeze-drying is an expensive process used for such products as instant coffee, dried soup mixes, strawberries, mushrooms, and shrimp. Flash freezing is a process of supercooling foods to temperatures of -195°C (-320°F) through the use of liquid nitrogen. The process reduces cellular deterioration and increases retained moisture so that foods are tastier when they are unfrozen.

3. Canning

Canning is used to preserve a wide variety of foods, including soups, sauces, fruits, vegetables, juices, meats, fish, and some dairy products. Canning preserves food by heating it in airtight, vacuum-sealed containers. The can is filled with food, and air is pumped out of the space remaining at the top of the can to form a vacuum. The container is sealed, heated in a cooker called a retort, and then cooled to prevent overcooking of the food inside. This process removes oxygen, destroys enzymes involved in food spoilage, and kills most microorganisms that may be present in the food. Canned foods are popular because they are already partially prepared and cooked, can be stored without refrigeration for long periods, and are generally low in cost.

However, because of the high temperatures required for sterilization, canning affects the color, texture, flavor, and nutrient content of foods. Fat-soluble vitamins and minerals are barely affected by heat processing, but water-soluble vitamins, especially thiamine, riboflavin, and vitamin C, can leach into canning or cooking water that may later be thrown away during preparation. Up to half of the original content of water-soluble vitamins in a canned product can be lost in this way. Rapid, high-temperature processes generally conserve nutrient content best, as every 4.4° C (18° F) rise in processing temperature yields approximately a ten-fold increase in microbial destruction, with littleadditional nutrient loss.

4. **Additives**

Food additives are chemicals that are added to food in small amounts. Direct additives are added deliberately during processing to make food look and taste better, maintain or improve nutritive value, maintain freshness, and help in processing or preparation. Some additives help preserve food by preventing or slowing chemical changes and the growth of microorganisms in food. As many as 3,000 substances are approved by the Food and Drug Administration (FDA) for use as direct additives. An additional 10,000 substances are present in foods as indirect additives. These substances enter food incidentally during handling or from processing equipment or packaging.
Food additives have been used for thousands of years. The salts and other chemicals used in curing are additives, and before the advent of canning and mechanical refrigeration, chemical additives were the only means of preservation available. Additives were not limited to use as preservatives, however. People in ancient Rome added certain chemicals to wine and cooked vegetables to improve the color of these foods. Other examples of additives that have been used since ancient times include yeast and baking powder used as leavening in baked goods.
Advances in the knowledge of chemistry have greatly expanded the number of additives that are used in foods. Such recent additions to the ranks of food additives include artificial sweeteners, such as aspartame and saccharin; fat replacements, such as simplest; and colors, such as FD&C yellow No. 5, which is used in beverages, ice cream, cereals, and other foods.
The development of new chemical additives has also played an enormous role in the growth of convenience foods. Additives that help ensure the quality of convenience foods include anti-caking agents, such as calcium silicate and magnesium stearate, to prevent lumps in dry mixes; humectants, such as glycerol, propylene glycol, and sorbitol, to help retain moisture in breads and cakes; emulsifiers, such as egg yolk, lecithin, and monoglycerides, which bind oil and water to improve the uniformity and smoothness of foods; and stabilizers and thickeners, such as guar gum, carrageenan, and gelatin. As the use of food additives has grown, so has public concern about the type and amount of these additives and their potential to cause cancer or other illnesses in human beings. Some studies have suggested that saccharin, nitrites, and other additives may cause cancer, but these results remain controversial. At the same time, some additives may actually provide a health benefit. For example, the vitamins used to fortify foods such as bread and milk are additives.

5. **Freezing and Refrigeration**

Low-temperature storage as a preservation method probably began when prehistoric humans stored meat and other foods in ice caves. However, mechanical refrigeration and large-scale freezing are relatively recent innovations. Mechanical refrigeration was pioneered by American inventor John Gorrie in 1842, but a mechanical refrigeration system suitable for widespread commercial use was not developed until the 1870s. American inventor Clarence Birdseye developed procedures, equipment, and packaging for quick-freezing in the 1920s and in 1953 frozen TV dinners were introduced by C. A. Swanson and Sons. Storage at low temperature slows many of the enzymatic reactions involved in spoilage and reduces the growth rate of microorganisms (though it does not kill them). To minimize microbial growth, refrigerators should be kept at 0° to 4° C (32° to 40° F) and freezers at or below 0° C (32° F). Refrigeration is advantageous because it does not cause chemical or physical changes to food. Freezing allows foods to be stored for longer periods than refrigeration because it inhibits enzyme activity and microbial growth to a greater degree. The greatest disadvantage of freezing is that the water in food expands and forms ice crystals. The ice crystal formation disrupts the structure of plant and animal cells, giving frozen food a softer texture after thawing. Newer technologies in which freezing occurs more rapidly help minimize this problem: Faster freezing, such as flash freezing, means that smaller ice crystals form, resulting in less damage to cells. Foods that should be refrigerated include meats, fish, eggs, milk, some fruits, and some vegetables. Many of these foods can also be frozen. Frozen produce is often high in quality and can rival the flavor of fresh. In many cases, produce frozen and stored under proper conditions contains more nutrients than produce picked unripened and allowed to mature during transportation. Briefly cooking vegetables in boiling water before freezing, a process known as blanching, inactivates enzymes altogether and reduces discoloration and nutrient loss.

6. Controlled Atmosphere Storage

Fruits and vegetables are sometimes stored in sealed warehouses where temperature and humidity are closely controlled, and perhaps most importantly, the composition of gases in the atmosphere is altered to minimize spoilage. Usually, the concentration of oxygen is reduced, the concentration of carbon dioxide is increased, and ethylene, a gas naturally produced by plants that accelerates ripening, is removed from the atmosphere. This controlled environment helps slow the enzymatic reactions that eventually lead to decomposition and decay, and may increase the time that produce can be stored by several months. Ripening rooms, in which ethylene gas is added to the atmosphere, also help produce higher quality fruits and vegetables. This technology enables produce to be picked before it is ripe, for easier handling, and then ripened quickly and uniformly under controlled conditions.

7. Aseptic Packaging

Aseptic packaging is now commonly used for packaging milk and juice. Like canning, aseptic packaging involves heat sterilization of food, but unlike canning, the package and food are sterilized separately. Food can be sterilized more rapidly and at lower temperatures in aseptic packaging than in canning, allowing the food to retain more nutrients and better flavor. Containers are sterilized with hydrogen peroxide rather than with heat, permitting the use of plastic bags and foil-lined cartons, which would be destroyed by heat sterilization. These containers cost less than the metal and glass containers used in canning and also weigh less, reducing transport costs. Aseptically packaged foods will keep without refrigeration for long periods of time, perhaps even years. They are growing in popularity because of their low cost, good taste and nutrition, and convenience.

8. Irradiation

Irradiation is a process in which food is passed through a chamber where it is exposed to gamma rays or X rays. These high-energy rays are strong enough to break chemical bonds, destroy cell walls and cell membranes, and break down deoxyribonucleic acid (DNA), the substance that carries genetic information in all cells. Irradiation kills most bacteria, molds, and insects that may contaminate food. Irradiation also delays the ripening of fruits and sprouting of vegetables, permitting produce to be stored for longer periods of time. Because irradiation involves minimal heating, it has very little effect on the taste, texture, and nutritive value of food. The FDA first approved irradiation for use on wheat and wheat flour in 1963, and later approved its use on white potatoes, spices, pork, some fresh produce (onions, tomatoes, mushrooms, and strawberries), and poultry. In 1997, in response to several food-borne illness outbreaks and increasing public concern over the safety of the food supply, irradiation was approved for use on poultry products. In 1999, irradiation was approved to curb pathogens in raw meats including ground beef, steaks, and pork chops. Irradiation is also used to preserve some meals eaten by astronauts during long-term space missions. Some consumer groups have raised concerns that irradiation might cause the formation of toxic compounds in food. Because of these and other concerns, only a limited amount of irradiated food has been sold in the United States.

9. Fermentation

Fermentation is a chemical reaction carried out by many types of microorganisms to obtain energy. In fermentation, microorganisms break down complex organic compounds into simpler substances. Although chemical changes and microbial growth usually mean food spoilage, in some cases fermentation is desirable and microorganisms are actually added to foods. For example, in the production of beer, wine, and other alcoholic beverages, yeasts convert sugar into ethyl alcohol and carbon dioxide. In the making of yogurt and cheese, bacteria convert lactose, a sugar found in milk, to lactic acid. Alcohol, acids, and other compounds produced in fermentation act as preservatives, inhibiting further microbial growth. In addition to its use with alcoholic beverages, cheese, and yogurt, fermentation is used to produce yeast bread, soy sauce, cucumber pickles, sauerkraut, and other products.

10. Pasteurization

Pasteurization involves heating foods to a certain temperature for a specific time to kill harmful microorganisms. Milk, wine, beer, and fruit juices are all routinely pasteurized. Milk, for example, is usually heated to 63° C (145° F) for 30 minutes. Ultra-High Temperature (UHT) pasteurization, a relatively new technique, is used to sterilize foods for aseptic packaging. In UHT pasteurization, foods are heated to 138° C (280° F) for 2 to 4 seconds, allowing the food to retain more nutrients and better flavor.

11. Genetic Engineering

Genetic engineering is aimed at improving the food supply even before harvest or slaughter by improving yields, increasing disease resistance, and enhancing the nutritional qualities of various foods. Broadly speaking, genetic engineering refers to any deliberate alteration of an organism’s DNA. Genetic manipulation has been practiced for thousands of years, ever since humans began selectively breeding plants and animals to create more nutritious, better tasting foods. In the past two decades, genetic engineering has become increasingly powerful as scientific advances have enabled the direct alteration of genetic material through the use of recombinant DNA. Genes have been cut and pasted from one species to another, yielding, for example, disease-resistant squash and rice, frost-resistant potatoes and strawberries, and tomatoes that ripen—and therefore spoil—more slowly. However, genetic engineering is controversial, as some critics argue that its possible environmental impact has not been sufficiently studied.

FOOD PACKAGING

Regardless of the processing or preservation method used, proper packaging of food is essential to make sure the food remains wholesome during its journey from processor to consumer. Packaging contains food and makes it easier to handle, and protects it from environmental conditions, such as temperature extremes, during transport. It locks out microorganisms and chemicals that could contaminate the food, and helps prevent physical and chemical changes and maintain the nutritional qualities of food. For example, milk is often stored in opaque containers to prevent vitamins from being destroyed by light.

Both the type of food and the processing method used affect the choice of packaging. For example, since oxygen makes fats go rancid, oils are packaged in containers that are impermeable to oxygen. On the other hand, oxygen-permeable plastic wraps allow fruits and vegetables to “breathe” and ensure that meats will maintain a vibrant red color. Metal and glass containers have traditionally been used in canning because these materials can withstand the high temperatures and changes in pressure that are involved in this processing method. The development of metal cans in the early 1800s represented the birth of the modern packaging industry.

The first British patent for a tin-plated steel container was issued in 1810 to British inventor Peter Durand. Canned foods were produced for the British armed forces in 1812 and offered commercially to the public two years later. Today, food cans are made of steel with various coatings to resist corrosion. Beverage cans are made of aluminum because it is lightweight and easy to manufacture. In addition to metal, glass is often used for packaging heat-sterilized foods. Glass is impermeable to oxygen and water and does not change the flavor of food. Another advantage of glass is that it is transparent, enabling the consumer to see the product inside. However, glass is not impact-resistant and is relatively heavy.

Plastic, by contrast, is lightweight and unbreakable, and it has become an extremely common material for use in food packaging. Most plastics used in food packaging are heat resistant so that they can go through high temperature sterilization processes. Plastic is made into a wide variety of shapes, including bottles, jars, trays, and tubs, as well as thin films that are used as bags and wraps. By itself, paper is not frequently used in packaging, except for certain dry foods, such as flour and sugar. When paper is coated with plastic or other materials to make it stronger and impermeable to water, it can be more widely used. Paperboard is often used for cartons, and plastic-coated paperboard for packaging frozen foods. Cartons and containers for shipping are usually made of corrugated cardboard. In recent years, environmental concerns have influenced food packaging. Scientists are working to develop packaging that is recyclable, biodegradable, or more compact so that it will use less landfill space, as well as to eliminate unnecessary packaging. Programs to recycle glass and aluminum beverage containers have been started all over the country. Plastic beverage bottles can be recycled as clothing or other products in addition to food containers. Aseptic packaging and several other new methods are compact and use a minimal amount of materials.

FOOD DISTRIBUTION

After food is processed and packaged, it enters an extensive distribution network that brings food products from the manufacturer to various retail outlets across the country and even around the world. Modern, high speed methods of transportation—trucks, trains, and planes—and reliable methods of environmental control—especially refrigeration—enable even perishable food to be transported great distances. Distribution networks help satisfy consumer demand for variety, making available, even in remote areas, foods that are not locally grown or processed. In fact, although food distribution is all but invisible to the average consumer, it plays a vital role in ensuring the availability of even the most basic foodstuffs. The now-famous bread lines and bare supermarket shelves shown in images of the former Soviet Union were brought about not so much by inadequate food production as by the lack of an efficient distribution network to bring the food to the consumer. Some large grocery store chains have the resources to buy food products directly from processors, transport the products, and store them in warehouses until they are needed at the store. However, for independent grocery stores and other small retailers, food wholesalers fulfill these roles. One type of wholesaler is a cooperative wholesaler, which is owned by the retailers that buy from them and usually sells only to these member-owners. In contrast, voluntary wholesalers are public companies that sell to any retailers without having membership requirements. Some food is sold directly to a retail store without going through a wholesaler first. This is common for foods such as bread and dairy products that must be delivered fresh every day or every few days. Smaller manufacturers often use food brokers as agents to arrange for their products to be shipped to retailers or warehouses. Through these various distribution channels, food makes its way to food retailers, such as restaurants, fast food outlets, supermarkets, convenience stores, specialty shops, drug stores, and some department stores.

Supermarkets are the predominant type of food retailer in the United States. They arose during the Great Depression (1930s) as a way of providing cheaper food products to consumers. The main cost-cutting measure was to have customers select products off the store shelves rather than having a clerk fill a client’s order. In addition, these early supermarkets were located on the outskirts of town where land was cheaper. Since the first supermarket opened in Queens, New York, in 1930, the concept has spread throughout the world.

GOVERNMENT MONITORING AND REGULATION

For hundreds of years, governments have had an interest in regulating food processing to ensure the safety and wholesomeness of the foods consumed by their citizens. The earliest known food law was written in Japan in AD 702. In Britain, the first Pure Food Laws were enacted during the 1860s to combat adulteration, the secret use of additives to stretch wholesome foods with cheaper, non nutritious (and sometimes dangerous) ingredients. This practice became common during the Middle Ages (5th century to 15th century), when cities began to grow and urban populations no longer got their food directly from the farm, creating an opportunity for deception by middlemen. Today, several United States government agencies carry out inspections and enforce a comprehensive system of regulations governing food processing, packaging, and distribution.

Among the first regulations in the United States for protecting the food supply was the Meat Inspection Act of 1906. It was inspired in part by the 1906 novel The Jungle by Upton Sinclair, which described unsanitary conditions in Chicago stockyards. The Meat Inspection Act required inspection of cattle, hogs, sheep, and goats intended for interstate commerce, as well as the monitoring of slaughter and processing procedures. When poultry became more popular during the 1950s, a similar law, the Poultry Products Inspection Act of 1957, subjected poultry producers to the same scrutiny.

Today the Food Safety and Inspection Service, a part of the U.S. Department of Agriculture

(USDA), carries out inspections of meat and poultry processing. Animals are inspected by USDA veterinarians before they are slaughtered to eliminate animals with disease from the food supply. This phase of inspection includes blood tests of randomly selected animals from each flock to make sure residues of antibiotics or pesticides, if present in the animals' blood, do not exceed acceptable levels. Animals are also inspected after slaughter for disease or contamination of carcasses, and processing procedures, recipes, and labels on products are also monitored. Meat and poultry inspections follow a method known as Hazard Analysis Critical Control Points (HACCP), which was developed during the 1960s by the National Aeronautics and Space Administration (NASA) to ensure that foods produced for astronauts were safe. HACCP involves a thorough analysis of the steps of processing to determine which steps involve the greatest risk of contamination. Monitoring and inspection then focus on those critical points. The FDA is responsible for monitoring and inspecting most all other food products. The FDA enforces the Food, Drug, and Cosmetic Act of 1938, which prohibits the shipping of adulterated or mislabeled products in interstate commerce. FDA inspectors visit food processing plants and warehouses to monitor all phases of processing, packaging, and distribution. Samples of food products are analyzed by FDA chemists to ensure the foods are wholesome and unadulterated and do not contain harmful substances, such as levels of pesticides above the limits set by the Environmental Protection Agency (EPA). In 1958, amendments to the Food, Drug, and Cosmetic Act gave the FDA authority to regulate the use of additives in foods. The Delaney Clause, which was part of those amendments, prohibits approval of additives that cause cancer in human or animal tests. Some people have criticized this clause for being too inflexible, because some studies show very small increases in cancer risk and some studies that show a risk of cancer in animals may not be relevant to humans. Since 1969, the FDA has set standards for inspection of retail food stores, restaurants, and cafeterias, although local health departments are responsible for carrying out those inspections. Package labels are also regulated by the federal government. What began as an effort to make sure that labels were accurate has now expanded to require labels that provide more information to increasingly healthconscious consumers. The 1938 Food, Drug, and Cosmetic Act prohibited mislabeling of food. In 1964 the Truth in Labeling Act required the package label to provide an accurate description of the weight, volume, or count of the package contents, a description of the contents, and the name and address of the manufacturer.

The Nutrition Labeling and Education Act of 1990 required that all packages include a label, headed "Nutrition Facts." This label must list the serving size and number of servings per package, and detail the food's content of various nutrients (including carbohydrates, proteins, fats, vitamins, and minerals). These labels help people compare different food choices and select those that fit their diet (see Human Nutrition).

In 2004 the U.S. Congress enacted the Food Allergen Labeling and Consumer Protection Act. The law went into effect in January 2006. It requires food manufacturers to clearly label ingredients in their products that are derived from the eight major food allergens: crustacean shellfish, eggs, fish, milk, peanuts, soybeans, tree nuts, and wheat. These eight food groups account for 90 percent of food allergy cases in the United States. Under the law, food labels must contain a box near the ingredients list that specifies the food allergens in the product. Within the ingredients list, the common name for a food allergen must be provided next to the scientific or technical name. See also Allergy.

DEEP SEA AND SHORE FARMING OF SOME PRODUCTS

The world's ever-growing population is eating more and more fish and the oceans can't keep up. Fishing has depleted wild stocks of tuna, swordfish, cod and many other species.

A school of fish raised in a deep-sea Kona Blue fish farm off the coast of Hawaii.

Some scientists say the answer is a massive growth of fish farming — a so-called "blue revolution" to help feed the planet. So far, fish farming has occurred on land or in protected harbors. But some see a future with large-scale off-shore fish farms in waters hundreds or thousands of feet deep.

One of the first companies venturing off-shore is Hawaii-based Kona Blue. It is raising fish in giant, netted cages off the coast of Hawaii, submerged in waters some 200 feet deep. Some scientists say that farming in such deep waters can avoid environmental concerns raised by fish farms close to shore. If you get too many caged fish in a harbor, the fecal matter will pollute it. But offshore at the Kona Blue site, powerful ocean currents constantly flush so much water through the farm that Kona Blue reports it can't detect any change in nutrient levels up-current versus down-current of the farm.

A big challenge, of course, for off-shore aquaculture is designing a fish farm that can survive the open ocean. Anyone who read the book or saw the movie *The Perfect Storm* got a sense of the forces that are unleashed on the ocean's surface.

The trick has been to sink the giant cages down well below the surface of the water and tie them to a series of anchors using high-strength polymer ropes. The only things exposed above water are several large metal feed buoys. One experimental fish farm off the coast of New England has survived several northeasters with 40-foot waves and high winds.

A Kona Blue worker checks on the 'farm': This giant, 80-foot-tall netted cage is used to house fish submerged in waters off the coast of Hawaii that are about 200 feet deep. Courtesy Kona Blue

Fish farms have been a boon to fish lovers around the world. About 30 percent of the seafood eaten in the United States this year will come from so-called "aquaculture" farms, most of them in Asia.

But fish-farming operations, which traditionally operate near the shore, have raised environmental concerns. According to one study, a fish farm with 200,000 salmon releases nutrients and fecal matter roughly equivalent to the raw sewage from 20,000 to 60,000 people.

Kona Blue's Neil Sims says inshore farming has become much cleaner in recent years. And he and other scientists say farming far offshore — in waters hundreds of feet deep, with strong currents — goes a long way toward diluting any waste, making it a very appropriate place for large-scale aquaculture.

Some environmentalists, though, are still concerned about the environmental controls in new federal legislation that would set up a regulatory framework for open-ocean aquaculture. Rebecca Goldburg of Environmental Defense, an advocacy group, worries that, in its current form, the legislation leaves too much environmental regulation up to the discretion of the National Oceanic and Atmospheric Administration (NOAA).

Goldburg worries this could leave the door open for irresponsible deep-water aquaculture that might create pollution problems, perhaps similar to those seen from large-scale industrial hog-farming on land. (Hog farms have been linked to groundwater pollution, not to mention olfactory unpleasantness.) For example, a big enough fish farm in the Gulf of Mexico, where waters are already nitrogen-saturated, could cause problems.

Escapes present another area of concern. When the fatter, slower farmed salmon get loose, they can breed with threatened species of wild salmon. Goldburg says that's like breeding dogs and wolves. It pollutes the wild gene pool with much slower and dumber wild salmon that have trouble surviving and making it back up river to spawn.

That said, even Goldburg says that Neil Sims and the other top scientists and executives at Kona Blue are being environmentally responsible. The Kona Blue team is monitoring the sea water around their farm, and the company says it has found no discernable environmental impact. Goldburg notes that the company is also farming a species native to the area, and is not genetically altering or selectively breeding the fish in any way. So any escapes that occur won't affect the surrounding wild species of fish.

There is one other potential problem. Right now, carnivorous fin fish such as salmon are fed a fish-meal made with wild-caught feed fish such as herring. Goldburg says it takes about three pounds of feed fish to raise one pound of salmon on a farm. She says that's not exactly a "sustainable" model, since farming fish relies on catching so many wild fish out of the oceans.

But Kona Blue's Sims says big strides have been made in replacing some of the fish in the fish meal with vegetable products. He expects the percentage of wild-caught fish in fish meal will fall sharply in years to come. And he's hopeful that more of the fish feed can be made with fish byproducts: heads, tails and trimmings which would otherwise go to waste.