Environmental Health Perspectives
Vol. 86, pp. 229–232, 1990

Influence of Food-Environment Interactions on Health in the Twenty-First Century

by Owen Fennema*

The quality and safety of foods are affected by the environment, and the quality and safety of the environment are, in turn, affected by foods and food processing. To explore these interrelationships, as they might exist in the twenty-first century, one must speculate regarding future changes in foods and food processing.

Several trends in food processing seem likely to predominate into the twenty-first century, and they will be, for the most part, evolutionary in nature and of low consumer visibility. These trends are greater use of foods marketed in a refrigerated state, greater use of irradiation and combination processes, greater automation and optimization of processes, and greater use of biotechnology. It is also reasonable to assume that food products of the following types will increase in importance, namely, those that are convenient (includes eating away from home), those that are tailored to specific dietary needs, those containing chemically modified components such as altered proteins and carbohydrates, and fabricated foods. If these trends in foods and food processes prevail then concern must be directed to the following areas: Microbiological concerns—refrigerated foods; food service operations; new or altered procedures for processing, handling and storing foods; and new foods or food formulations; attention must be given both to controlling known pathogens as well as newly perceived pathogens. Chemical concerns—toxicants occurring naturally in foods; contaminants; chemicals developing in foods during processing, handling and storage; chemicals used in fabricated foods; and chemicals of newly perceived importance, especially those having adverse, covert effects. Several of these chemical concerns are influenced in seriousness by composition of the food environment.

Introduction

Important interrelations exist between food safety, quality of the environment, and health. Quality of the environment influences the quality and safety of foods through contact with air, water, and soil. In turn, quality of the environment is influenced by waste discharges from plants that process foods or manufacture equipment; firms that store, transport, or facilitate the marketing of foods (e.g., those making paper for newspaper ads); by packaging materials and chemicals from the food industry; and waste discharges from food-service facilities and homes. This two-way interchange between the environment and food means that the improper disposal of unused food and food-related wastes can produce an unhealthful environment. An unhealthful environment can render food unwholesome. These interrelationships are important now, and they will become more important in the future as population density increases and accompanying agricultural and industrial activities intensify.

*Department of Food Science, University of Wisconsin, Madison, WI 53715.

The task here is to identify changes in foods and food processing that will likely occur into the twenty-first century, with special attention given to anticipated interrelations—both good and bad—among food quality, environmental quality, and health.

No matter how skilled, one cannot provide reliable, highly specific assessments of the changes that will take place in foods and food processing during the next 20 years. The best that can be done is to identify major factors that will influence these changes and, based on these factors, provide educated speculation as to likely major trends in products and processes. Having done this, one can then identify likely areas of concern and opportunity.

Future Trends

Major factors that will influence changes in the types of food and food processes during the next 20 years are listed in Table 1. These will not be elaborated on since they have been discussed adequately elsewhere (*1*). Based on these factors, several trends in food processing seem likely to persist or emerge during the next several

Table 1. Factors influencing future changes in foods and food processing (*1*).

Cost and availability of water, energy, raw materials, and labor
Cost of waste disposal and pollution control
General economic status of the nation
Demographics
Government policies and regulations
Management policies and practices
Consumer attitudes and practices

decades, and they will be, for the most part, evolutionary in nature and of low-consumer visibility.

With respect to food processing and storage, it seems likely that the following trends will occur: *a*) continued attempts to develop food products with extended shelf lives at refrigerated temperatures; *b*) increased use of ionizing radiation as a method of food preservation. If processing of this type involves ^{60}Co or ^{137}Ce, improper waste disposal could have an adverse influence on environmental quality; *c*) increased use of combination processes for food preservation (e.g., irradiation + refrigeration + modified atmospheres); *d*) greater use of automation and optimization of processing to lower product cost and raise product quality; *e*) greater use of all aspects of biotechnology (fermentation, enzyme-catalyzed processes, recombinant DNA procedures); and *f*) reduced amounts of water used and waste produced per pound of food. These would clearly have desirable impacts on environmental quality.

Foods likely to become of increasing importance in the future are: *a*) those characterized as convenience foods; *b*) dietetic foods, i.e., those tailored to meet the needs of persons having special dietary requirements that necessitate foods that are low in salt, fat, cholesterol, lactose, phenylalanine, and tyramine, and foods that have high fiber or are anti-allergenic, etc. These foods will be helpful in curing or alleviating symptoms of coronary heart disease, cancer, diabetes, obesity, and many other maladies and are certain to grow in abundance as the population ages; *c*) foods containing synthesized or chemically modified ingredients. These ingredients will be chemically altered or synthesized to attain specific health or functional properties. Existing examples include aspartame, chemically modified starches, alkali-treated proteins, some flavors, and some emulsifiers. Many additions to this category are likely to occur, especially through the avenue of recombinant DNA research; *d*) fabricated foods. This approach permits unwanted constituents to be excluded and desirable components and properties to be maximized. Growth of products of this kind follows logically from the preceding predictions. The types of foods previously described are unlikely to have profound effects on the environment.

Along with these trends in foods and food processing, changes also will occur in food packaging and food analysis. In the area of packaging, we will likely see the continued development of plastics with improved properties, improvements in encapsulation techniques for food and food ingredients, and the common use of internal barriers to maintain localized differences in food composition (water activity, pH, food additives). The increased use of fabricated foods will encourage adoption of the latter two technologies. During the development of new packaging materials, increasing attention will be given to biodegradability and reuse characteristics.

With little doubt, we will also see the development of many new analytical tests that will enable food safety, bioavailability, and nutrient content to be rapidly and reliably assessed. Government funding should be provided to assist in the development of these tests.

Consequences of Future Trends in Foods and Food Processing

Regardless of what trends occur in foods and food processing, microbiological concerns of two types will continue to exist: those related to the control of known pathogens and those related to the control of pathogens of newly perceived importance. Incidences of the latter type are especially disturbing, since they arise in an unpredictable fashion and require a crisis response. Problems with *Listeria monocytogenes* are a recent example.

Future food-related situations that are potentially hazardous from a microbiological standpoint are as follows:

- Refrigerated foods with extended shelf lives. The current effort to extend the shelf lives of refrigerated foods will continue. This applies to fresh foods (plant and animal tissues and eggs) mildly processed foods (pasteurized milk, bacon, cottage cheese, etc.), fabricated foods, and pre-cooked foods. These types of foods are generally of better sensory quality than foods exposed to more severe methods of preservation (freezing, canning, drying) and are therefore desired by consumers. Newer technologies to extend the shelf lives of these foods often involve atmosphere of modified composition (elevated CO_2 and N_2; lowered O_2). Lowering the oxygen content of the atmosphere can produce a microbiological hazard since this will tend to retard the growth of normal nonpathogenic microorganisms and allow some pathogenic microorganisms such as *Listeria monocytogenes* and *Clostridium botulinum*, type E, to proliferate.
- Foodservice operations. Eating away from home is likely to continue in popularity. Poorly managed foodservice units create microbiological hazards, and segments of the food delivery system will require continued monitoring to assure that safe practices are followed.
- New or altered foods, and new or altered procedures for processing, handling, and storing foods. These types of changes are sure to continue in abundance into the foreseeable future and, in many instances, they will alter food properties such as pH, water activity, and the kind and ratio of solutes present. By imposing these changes, the manufacturer may

unwittingly provide an environment more hospitable for pathogenic microorganisms.

Because air, water, and soil are potential means by which food can become contaminated with pathogenic organisms, continued vigilance is needed to prevent contamination of these kinds from occurring.

Aspects of foods and food processing that represent potential future hazards of a chemical nature must also be considered. Listed below are aspects that should be of concern today and probably will become of increasing concern in the future: *a*) toxicants occurring naturally in foods. These substances have received too little attention; *b*) undesirable chemicals entering food from water, air, and soil, or resulting from farm practices, from food contact surfaces including packaging materials (*2,3*), or from added ingredients; *c*) chemicals developed in food during processing, handling and storage; *d*) chemicals of newly perceived toxicologic importance, especially those having adverse, covert effects, and those having adverse, serious but slow-to-develop effects (*4,5*).

Processes most likely to produce undesirable or potentially undesirable chemical changes in food include: heating, sterilization with ionizing radiation, fermentation, and alkali treatments of proteins. Examples of adverse or potentially adverse chemicals that can arise from major food components during processing, storage, and handling, and which will be of likely concern in the future, if not already, are listed in Tables 2 through 4. The only common entry in all three tables and the only one that has received no significant regulatory attention is that relating to substances with adverse, covert effects. Foods probably contain these substances in abundance, provoking minor to serious annoyances in an unknown, but perhaps substantial, portion of the population. It is not unreasonable to suggest that 20 years from now numerous instances will have been discovered linking various chemical constituents of food—be they naturally occurring, added or developed *in situ*—with adverse, covert maladies such as depression, headaches, fatigue, lack of alertness, and tension. These links are truly an emerging issue. In addition, some chemicals, previously thought to be safe at levels normally encountered in food, will be discovered to have serious adverse effects that are slow to develop (e.g., carcinogens). On the positive side, some constituents of foods now thought to be innocuous will be shown to have protective or health-sustaining benefits (*8*).

Table 3. Some undesirable chemicals arising from carboydrates during processing and storage of foods (*6,7*).

Chemical	Cause
Position and geometric isomers	Heat, oxidation
Cyclic compounds	Heat
Oxidation products	Oxidation
Unidentified chemicals with adverse, covert effects	Heat, oxidation

Table 3. Some undesirable chemicals arising from carboydrates during processing and storage of foods (*6,7*).

Chemical	Cause
Hydroxymethyl furfural	Hexose + water + heat
Furfural	Pentose or ascorbic acid + water + heat
Maillard products	Amine + carbonyl reaction
Unidentified chemicals with adverse, covert effects	Heat

Table 4. Some undesirable chemicals arising from proteins during processing and storage of foods (*6,7*).

Chemical	Cause
D-isomers	Heat + alkali
Crosslinked proteins	Heat + alkali Heat + oxidation
Maillard products	Amino + carbonyl reaction
Oxidation products of susceptible amino acids	Oxidation
Unidentified chemicals with adverse, covert effects	Heat, oxidation

In the past, attention of regulators and health officials regarding food safety has been directed primarily and correctly to contaminants, mainly microorganisms, that were life threatening or caused severe illness. In the future, it is reasonable to believe that these severe threats to life or well-being, at least in developed countries of the world, will occur less frequently as our knowledge about proper procedures for processing and handling food increases and violations of these proper procedures decline through education and better enforcement of regulations. To a degree, this suggested trend has already occurred with pathogenic microorganisms. Early attention was directed to pathogens that were life threatening (e.g., *Clostridium botulinum*), and as these were brought under control greater attention was given to new pathogens that were less virulent (*Listeria monocytogenes*, *Clostridium perfringens*). As this trend continues with both microorganisms and chemicals, it will become possible to focus greater attention on identifying chemicals in food that have adverse, covert effects and thereby accomplish further improvements in the wholesomeness of the food supply.

The relationship between food and quality of the environment is not lost in this proposed sequence of events. The environment, in the form of contaminated water, air, and soil will provide—barring drastic preventive measures—an increasingly rich array of potential food pollutants. The possibilities are many: pesticides and nitrates from farming operations; toxic minerals such as mercury, lead, arsenic, and cadmium, and a variety of other chemicals from mining operations, energy production, waste disposal operations, automobile emissions, and volcanic activity; and radionuclides from accidents with nuclear power plants, weapons testing, and disposal sites for nuclear wastes (*9–12*).

In conclusion, there are some instances where foods (waste disposal) and food processing (emissions and waste disposal) can have adverse effects on the quality of

the environment, but of greater concern is the impact of poor environmental quality on the quality and safety of foods. Adequate safeguards generally exist to prevent foods from becoming contaminated, via environmental mechanisms, with levels of undesirable chemicals sufficient to cause acute adverse responses in humans. However, adequate knowledge and precautionary measures generally do not exist concerning the levels of undesirable chemical contaminants that will provoke adverse, covert responses in humans or serious responses that are slow to develop. Knowledge about these relationships is important since appropriate guidelines for composition of the environment cannot be established in the absence of this information. This knowledge will become an issue of increasing importance during the next several decades.

This work was supported by the college of Agricultural and Life Sciences, University of Wisconsin-Madison.

REFERENCES

1. Fennema, O. The food industry: charting a course to the year 2000. Food Technol. 37: 46,48–52,62 (1983).
2. Crompton, T. R. Additive Migration from Plastics into Food. Pergamon Press, Oxford, 1979.
3. Vom Bruck, C. G., Bieber, W. D., and K. Figge. Interactions between food and packaging materials and its consequence on migration. In: Food Packaging and Preservation: Theory and Practice (M. Mathlouthi, Ed.), Elsevier Applied Science Publishers, London, 1986, pp. 39–66.
4. Miller, S. A., Ed.. Nutrition and Behavior. The Franklin Institute Press, Philadelphia, 1982.
5. Wurtman, J. Managing Your Mind and Mood through Food. Harper and Row, New York, 1987.
6. Fennema, O. Chemical changes in food during processing—an overview. In: Chemical Changes in Food during Processing (T. Richardson and J. W. Finley, Eds.), AVI Publishing Co., Westport, CT, 1985, pp. 1–16.
7. Finley, J. W., and Schwass, D. E., Eds. Xenobiotics in Foods and Feeds. American Chemical Society Symposium Series 234, American Chemical Society, Washington, DC, 1983.
8. Ha, Y. L., Grimm, N. K., and Pariza, M. W. Anticarcinogens from fried ground beef: heat-altered derivatives of linoleic acid. Carcinogenesis 8: 1881–1887 (1987).
9. Concon, J. M. Food Toxicology, Part B: Contaminants and Additives. Marcel Dekker, New York, 1988.
10. Jelliffe, E. F. P., and Jelliffe, D. B. Adverse Effects of Foods. Plenum Press, New York, 1982.
11. Munro, I. C., and Charbonneau, S. M. Environmental contaminants. In: Food Safety (H. R. Roberts, Ed.), John Wiley and Sons, New York, 1981, pp. 141–180.
12. Reilly, C. Metal Contamination of Food. Applied Science Publishers, London, 1980.