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A CONCEPTUAL MODEL OF THE FOOD AND NUTRITION SYSTEM

JEFFERY SOBAL,[1]* LAURA KETTEL KHAN[2] and CAROLE BISOGNI[1]

[1]Division of Nutritional Sciences, Cornell University, Room 303, MVR Hall, Ithaca, NY 14853-4401, U.S.A. and [2]Centers for Disease Control and Prevention, Atlanta, GA 30341, U.S.A.

Abstract—The food system is a widely used concept, but few systematic frameworks model the full scope and structure of the food and nutrition system. Bibliographic searches, a modified Delphi technique, focus groups and interviews with experts on the topic were conducted to identify existing models of agriculture, food, nutrition, health and environmental systems. These models were examined, classified and synthesized into an integrated conceptual model of the food and nutrition system. Few existing models broadly described the system and most focused on one disciplinary perspective or one segment of the system. Four major types of models were identified: food chains, food cycles, food webs and food contexts. The integrated model developed here included three subsystems (producer, consumer, nutrition) and nine stages (production, processing, distribution, acquisition, preparation, consumption, digestion, transport, metabolism). The integrated model considers the processes and transformations that occur within the system and relationships between the system and other systems in the biophysical and social environments. The integrated conceptual model of the food and nutrition system presents food and nutrition activities as part of a larger context and identifies linkages among the many disciplines that deal with the food and nutrition system.

Key words—model, food, nutrition, health, agriculture, diet, systems

INTRODUCTION

The concept of a food system is widely used in agriculture, food science, nutrition and medicine to describe the complex set of activities involved in providing food for sustenance and nutrients for maintaining health. The series of transformations involved in the food system are often characterized by statements like "from field to table" or "land to mouth" (Kneen, 1989). This paper examines the existing literatures on food and nutrition systems and synthesizes them into an integrated framework.

Models of food and nutrition systems are conceptual tools for thinking about relationships between agricultural, industrial, economic, ecological, social, health and other factors involved in food and nutrition. Such frameworks portray the scope of the system, reveal connections between parts of the system and suggest analyses for problems related to the system. Although models of food and nutrition systems have been developed (LaBianca, 1990, 1991; Heywood and Lund-Adams, 1991), currently there is no one source which discusses the system wholistically and integrates past work on the topic. This paper attempts to fill that gap.

The concept of "food and nutrition system" is used here instead of simply "food system" to emphasize and focus on the vital links between food production, food consumption and nutritional health. Food serves many purposes, including providing pleasure, earning a livelihood, maintaining social traditions and supplying nourishment. However, all of these purposes could be achieved in other ways except nourishment, for which food is the sole provider. If it were not for the biological necessity of providing nutrients and energy to maintain health and prevent disease, food would not be produced and consumed on the scale and with the attention that it currently has. Therefore, physiological requirements for eating sufficient nutritients and avoiding dangerous toxicants need to be included as part of the food and nutrition system.

Definitions of the food system exist (Kneen, 1989; LaBianca, 1990, 1991; Tansey and Worsley, 1995), although most discussions of the food and nutrition system do not offer specific definitions. This paper defines the food and nutrition system as *the set of operations and processes involved in transforming raw materials into foods and transforming nutrients into health outcomes, all of which functions as a system within biophysical and sociocultural contexts.*

While the term "food system" is common, the concept of a system is often used loosely and not linked with systems theory, although the latter has been incorporated in agricultural and farming systems (Dalton, 1975; Duckham *et al.*, 1976; Spedding, 1979, 1990, 1996; Jones and Street, 1990)

*Author for correspondence.

and ecological energy analysis (Steinhart and Steinart, 1975; Pimentel and Pimentel, 1996). Systems theory attempts to avoid disciplinary compartmentalization by integrative thinking (Boulding, 1956; Bertalanffy, 1968; Lilienfeld, 1978; Miller, 1978).

Systems theory takes a holistic perspective in examining system boundaries, delineating subsystems and their relationships, emphasizing the process of homeostasis and considering relationships between systems. Systems are viewed as sets of elements that function together as collective units. Boundaries exist between a system and its environment, and may be more or less open or closed because of varying permeabilities. Whole systems have properties greater than the sum of their component parts. Subsystems exist within systems. Systems are dynamic, with homeostatic processes that attempt to maintain stability when a change in one part of the system influences other portions of the system or adjustment to external influences occurs. Materials, energy and information flow between parts of a system and its subsystems and between the system and its environment. Systems offer multiple routes to an outcome, the concept of equifinality describes how an end state can be reached from different initial states through many possible paths.

A systems theory perspective was used to examine existing models and conceptualizations of the food and nutrition system and to synthesize them into an integrated framework. Systems theory provided a broad perspective in which to examine the components of the food and nutrition system, how changes occur and the context in which the system operates.

METHODS FOR REVIEWING EXISTING MODELS AND DEVELOPING AN INTEGRATED MODEL

To gather information about existing models and conceptualizations of food and nutrition systems, this investigation performed a literature review, solicited information through a modified Delphi process and conducted focus groups and personal interviews with experts.

Literature review

Review of the literature on food and nutrition systems searched for key terms of "food system", "food web", "food chain" and others in computerized bibliographic databases, including Agricola, Medline, Psychinfo, Sociofile, Econlit and Biosis. Citations from these searches were screened and relevant references reviewed. Citation lists in these publications were examined for other useful citations. Manual searches of relevant journals, books and reports were conducted and suggestions for key references were solicited from experts. Key publications were traced forward with citation indexes.

Delphi process

The authors used their own experience and information from the literature review to identify individuals knowledgeable about food and nutrition systems, seeking both depth of knowledge and diversity of orientation and background to cover many perspectives and components of the system. A brief survey was sent to 121 individuals, asking them to identify others knowledgeable about the topic, suggest key references on the subject and to provide other information and ideas. Seventy-one (59%) responded. Another 68 individuals were identified through the initial surveys and an additional 25 (37%) survey responses were obtained from them. This "snowball" sampling (Coleman, 1970) provided information about the network of individuals working on the food and nutrition system and identified some considered to be experts by many respondents.

Focus groups

Two groups of experts who responded to questionnaires were convened for focus group discussions about the food and nutrition system. A diverse group of 8 people was included in each discussion. Participants drew a diagram of the food and nutrition system, wrote a definition of the system, and provided feedback about preliminary models we had developed. Discussions were audiotaped and notes were taken, and were later reviewed. Several key people identified in many surveys as experts were interviewed individually and asked to react to ideas and models we developed. A few individuals identified as experts on food and nutrition systems commented on this manuscript.

Analysis

Drawing upon systems theory and the variety of data collected from the literature, Delphi process and focus groups, the investigators reviewed, classified, summarized and integrated existing models of the food and nutrition system. The analysis included qualitative coding (Miles and Huberman, 1994) to identify patterns, themes and examples in existing models of food and nutrition systems. A first step was to identify major types of food and nutrition models or typologies (Novak and Gowin, 1984). The goal was to synthesize existing work into more comprehensive models. Coding criteria included: content of the model (stages and processes), form of conceptualization (linear, circular, network, ecological), scope (number of levels, levels beyond the home discipline), complexity (linkages, feedback) and detail (generality, specificity). Analysis of the models was used to develop an integrated model that included essential elements of existing models. The analysis also offered insights into the advantages and limitations of available models and applications of the integrated model.

EXISTING MODELS

The literature review revealed that the concept of a food and nutrition system was broadly used. Many terms were commonly used to describe the concept, including food system, food chain, food web, food path, food pipeline, food complex and others. While the concept was widely mentioned, relatively few specific discussions of the concept "food system" existed. Many case studies examined the system or parts of the system, but few theoretical analyses were available. An example of theoretical analysis of the system is that of LaBianca (1990, 1991) who suggested a framework for food systems research and analyzed cycles of food system intensification and abatement using archeological data.

Most discussion of the concept of the food system was implicit and limited. The system was usually referred to in words rather than visually. However, we located over 70 diagrams and figures presenting various depictions of the food and nutrition system. Most were ancillary to the main topic of the publication, although a few focused specifically on describing the system or one component.

Most existing models were not comprehensive and focused on placing a specific issue into a larger context. Most were discipline or profession bound. For example, some models were agricultural, others focused on food distribution, while still others examined only nutritional processes. Some models narrowly treated only one segment of the entire system, examining only a specific issue, commodity or nutrient. Citation and discussion of other models rarely occurred.

Types of system models

Analysis of existing models of the food and nutrition system revealed four major types: food chains, food cycles, food webs and food contexts (Fig. 1). Each type focused on a different aspect of the food and nutrition system, while paying less attention to other characteristics.

Food chain

Food chain models focused on the flow of materials or objects through a sequence of steps, emphasizing movement and transformation through a series of stages that are often ordered and linear. The food chain approach is the dominant type of model found in the literature (e.g. Hitchcock, 1980; Austin and Zeitlin, 1981; Marion, 1986; Blanford *et al.*, 1993; King and Burgess, 1993) and is often conceptualized as a stream or series of streams with different channels that interlink (e.g. National Commission on Food Marketing, 1966). Attractive features of food chain models are that common units, such as nutrients or energy, can be used to follow materials through the entire system, and that the ordered steps in the system are delineated. Limitations of food chain models include lack of consideration of influences from outside the chain, bias towards sequential issues in the system and the tendency to focus on limited parts of the chain with the omission of preceding or succeeding factors.

Food cycle

Food cycle models focus on feedback within the food and nutrition system, considering how objects and information link back across different stages or levels (e.g. Kramer, 1973). Food cycle models are used to address concerns about the outputs at each level of the system, especially how waste products accumulate and influence the operation of prior steps (e.g. Kim and Curry, 1993). Such models consider both short feedback loops, such as the build up of waste products in a field and consequent lowering of crop yields, as well as larger feedback loops, such as the water cycle entering and leaving the food and nutrition system. Attractive features of food cycle models are the consideration of mechanisms that link different parts of the system and the effects on other stages of action at each specific point in the system. Food cycle models help conceptualize the entire "life cycle" of foods and nutrients, examining how stages link back to prior stages. Limitations include the rigidity of feedback loops as links between different parts of the system, and

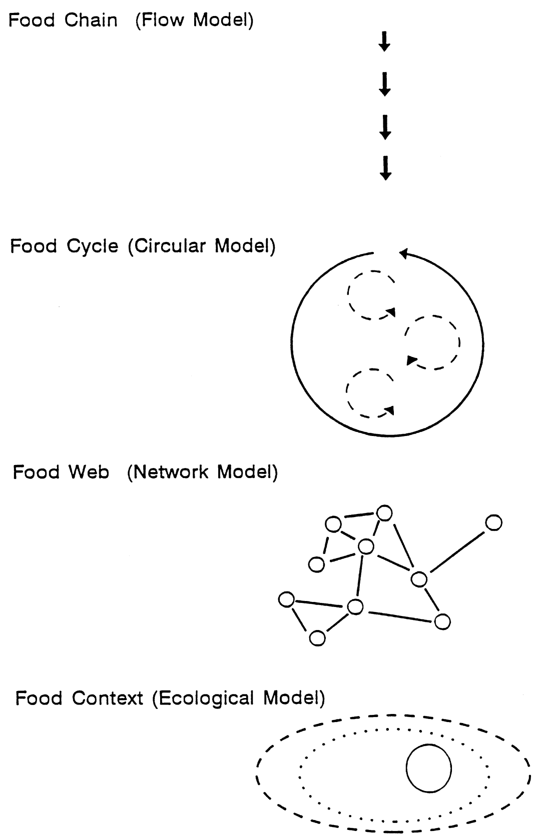

Fig. 1. Types of human food and nutrition system models.

minimal consideration of influences that occur outside flows through the system.

Food web

Food web models are network models that focus on the interrelationships among diverse nodes in the operation and control of the food and nutrition system. Food webs are commonly used to show particular relationships between many and often distant points of food and nutrition systems, and the relationship of those points to other important points inside and outside the system (e.g. Silverstein, 1984; Senauer, 1992). The attractive feature of food web models is the articulation of the many, diverse and changing relationships that shape and control the system. Limitations include the lack of representation of consistent patterns and structures among interrelated points, the tendency to not specify flows of foods and nutrients within the system and the de-emphasis of the environment within which food webs operate.

Food context

Food context models take an ecological perspective focusing on relationships of the food and nutrition system with its environments, which are made up of many other systems (e.g. Burns *et al.*, 1983; Maretzki, 1991; Bowler, 1992). Contexts can be delineated with various degrees of specificity, ranging from listing weather or economics as external influences to providing detailed elaboration of the political or biological outcomes of specific food production decisions. Contexts for the food and nutrition system include both the physical and social environments and the other systems that exist in these environments. Attractive features of food context models include consideration of external influences and constraints and the delineation of the inputs and outputs that the system exchanges with its environments. The major limitation is lack of specificity about the structure of the food and nutrition system itself.

DEVELOPMENT OF AN INTEGRATED CONCEPTUAL MODEL

The four types of models identified in the literature were synthesized to develop an integrated conceptual model of the food and nutrition system. Integrating food chains, cycles, webs and contexts produced a more wholistic and multi-perspective conceptualization of the system. The integrated model recognizes the flow of elements through a series of processes and transformations, feedback cycles, webs of relationships and contexts within which the system operates. The next section describes the integrated conceptual model of the food and nutrition system.

AN INTEGRATED CONCEPTUAL MODEL OF THE FOOD AND NUTRITION SYSTEM

The integrated model of the food and nutrition system uses a systems perspective to present relationships between agriculture, food, eating, and health. The core of the model emphasizes a linear flow, where each subsystem and stage flows into the subsequent one. The linear flow components of the system include three subsystems: producer, consumer and nutrition (Fig. 2). Each subsystem involves three stages that accomplish input, transformation and output. Nine stages represent key processes in the overall system: production, processing, distribution, acquisition, preparation, consumption, digestion, transport and metabolism. Flow through the system transforms raw materials into crops which are processed into foodstuffs that are distributed to consumers who cook and eat foods that contain nutrients which have health outcomes.

The food and nutrition system operates within a context consisting of other systems that can be differentiated into biophysical and social environments (Fig. 3). Feedback loops and webs of relationships operate within the system and between the food and nutrition system and the systems that make up its environments.

Storage exists at every stage of the food and nutrition system in some form. While different things are stored (e.g. raw materials, agricultural commodities, cooking ingredients, nutrients, energy), the purposes of storage are common throughout the system. The general functions of

Food and Nutrition System: Subsystems and Stages

	RESOURCE INPUTS
PRODUCER SUBSYSTEM	Production (input) Processing (transformation) Distribution (output)
CONSUMER SUBSYSTEM	Acquisition (input) Preparation (transformation) Consumption (output)
NUTRITION SUBSYSTEM	Digestion (input) Transport (transformation) Utilization (output)
	HEALTH OUTCOMES

Fig. 2. Food and nutrition system: subsystems and stages.

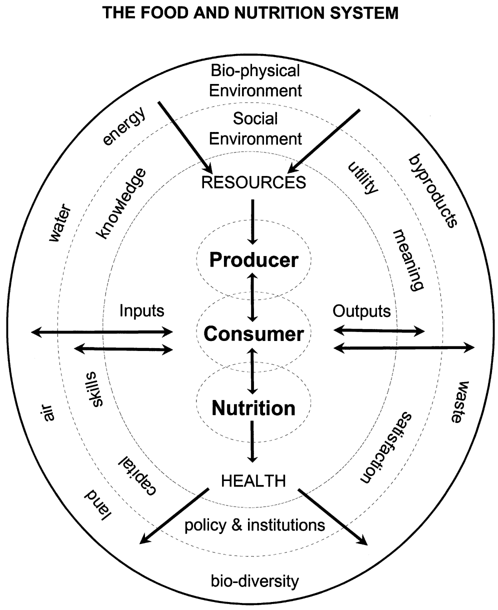

Fig. 3. The food and nutrition system.

storage at all stages are to ensure access to vital elements in the face of varying supplies and to protect supplies from deterioration or diversion.

The following sections address resource inputs, three subsystems, nine stages, and health outputs of the food and nutrition system. Then the network of relationships in the system is discussed, followed by interaction of the system with the biophysical and social environments.

Resource inputs

Resources from the environments of the food and nutrition system provide basic inputs into the system. These include biophysical factors such as materials, bioplasm, energy, air, land and water and social factors such as human capital, economic capital and technological knowledge. Scarcity of inputs can limit the ability of the system to function.

Subsystems and stages

Subsystems operate as components of the larger system, performing specialized roles in conjunction with each other in a division of labor within the system. Each of the three subsystems of the food and nutrition system has a different focus and has traditionally used different indicators to measure its performance. The producer subsystem emphasizes the creation of foodstuffs and uses economic indicators as key measures of commodity production. The consumer subsystem focuses on obtaining foods and uses utilities of various types as measures of food consumption. The physiology subsystem focuses on obtaining nutrients and avoiding contaminants and uses physiological indicators as measures of biological functioning.

PRODUCER SUBSYSTEM

The producer subsystem receives resources from several environments. These are used in the stages of production, processing, and distribution of foods as outputs into the consumer subsystem.

Production

Food production transforms resources into crops and commodities. Production operates by growing crops and animals husbandry by farmers and by collecting foods from the environment by hunting, fishing and gathering. Many types of food production exist (Whittlesey, 1936; Grigg, 1969, 1974, 1995; Turner and Brush, 1987). In subsistence societies most of what is produced is intended for self-consumption, while in developed societies most crops are produced for consumption by others. After production, crops not used by producers are exchanged as commodities in markets ranging from local to global in scale. Exchanges may be simple as in the direct marketing of produce by farmers to consumers or mediated by others in the roles of buyers, brokers or wholesalers (Senauer *et al.*, 1991). Many non-food uses of agricultural products occur, with various farm products moving out of the food and nutrition system (Spelman, 1994).

Processing

Food processing transfers raw agricultural goods and harvested food resources into foodstuffs and foods that may be distributed to households for preparation or eaten directly. In industrial societies food processing is a major manufacturing industry, seeking value added profits for processors. Processing may include a wide variety of crude (cleaning, milling, etc.) and finished (cooking, packaging, etc.) transformations of commodities using mechanical, physical and chemical operations to separate, assemble and preserve foods (Kohls and Uhl, 1990; Hui, 1992). Food preservation permits more extensive distribution across space and longer storage times, extending the ability to disseminate durable foods in the system (Thompson and Cowan, 1995).

Distribution

Distribution is the transfer of output from production and processing through multiple channels to places where food acquisition occurs in the consumer subsystem (Lewin, 1951; Barkema, 1994). Many distribution transfer points exist in complex food systems, with considerable hybridization between different types of food distribution outlets. The wholesale and retail stream distributes foodstuffs through supermarkets, food cooperatives, farmers markets, consumer supported agriculture, etc. (Epps, 1989; Senauer *et al.*, 1991). The foodservice industry stream prepares and distributes foods to consumers (Senauer *et al.*, 1991) channelling them into restaurants, cafeterias, vending machines and caterers. Other food-service channels include government programs providing commodity foods and congregate meal programs for the elderly or schoolchildren, as well as private assistance in food banks, soup kitchens and food pantries (Poppendieck, 1994). Although some consumers may rely on home food production and processing, most use market distribution channels as points of access for foodstuffs and foods in industrialized societies.

CONSUMER SUBSYSTEM

The consumer subsystem focuses on the household as a unit which acquires foodstuffs and foods, transforms them into meals and snacks and eats them. Households range in scale from single individuals to large kinship groups.

Acquisition

The acquisition involves procurement at various outlets of foodstuffs and foods that may be raw, processed or prepared. In industrialized societies foodstuffs are most often purchased through market distribution channels, although some consumers use institutional or interpersonal channels to provide sustenance. Food acquisition may occur for immediate consumption or may be used to provision households for later preparation and consumption (DeVault, 1991). Food choices and selections by consumers are shaped by life course, social influences and personal systems for making choices (Krondl, 1990; Shepherd, 1990; Falk *et al.*, 1996; Furst *et al.*, 1996).

Preparation

The preparation stage involves the transformation of raw foodstuffs into consumable foods. Cooking involves systematic manipulation of foods using a variety of methods that involve physical, chemical and water content changes (Rozin, 1983; Fieldhouse, 1996). Food preparation requires energy, skills and resources to perform preparation activities within the traditions of a particular culture's cuisine. Many household preparation techniques have parallels in the methods used in food processing, with both stages manipulating foods using physical processes to transform raw materials into food products.

Consumption

The consumption stage focuses on eating and involves selection, serving and ingesting food items. Consumption can occur in a variety of settings where foods are consumed as part of food events (Camp, 1989). Patterns of consumption cycle through the year in major food events, through the day as meals and snacks, through meals as courses and through courses as bites of food or sips of beverages (Fieldhouse, 1996). Consumption also involves food distribution in commensal relationships, with differential serving patterns to various types of individuals (Gittelsohn, 1991). Consumption without eating may occur in the medical procedures of enteral and parenteral nutrition that provide nutrients through other channels than usual oral consumption (Rombeau and Rolandelli, 1997). The ingestion of foods is the transforming link between the consumer subsystem and the nutrition subsystem.

NUTRITION SUBSYSTEM

The nutrition subsystem includes the stages of digestion that involves ingestion and breakdown of foods, Transport that distributes food components to various parts of the body and may involve biochemical transformations and metabolism that uses food components in physiological processes. Food components may be positive, negative or neutral in their physiological effects and include nutrients, toxicants, micro-organisms and other substances. Components of interest may occur naturally in the unprocessed food or be added intentionally or unintentionally during earlier stages of the food system.

Digestion

Digestion is the first stage in the nutrition subsystem, where foods enter the gastrointestinal track to be broken down into nutrients. Foods begin conversion as they are physically reduced in size by mastication in the mouth and chemically broken down by gastric acid in the stomach. Processing into smaller units permits absorption of nutrients into the body through the walls of the small intestine. Substances that were not absorbed during transit through the small intestine move into the large intestine to be later excreted as waste products. As a result of digestion and absorption, macronutrients (proteins, fats, carbohydrates, alcohols), micronutrients (vitamins, minerals), water, allergens and toxicants enter the circulatory system and are able to exert physiological influences on the body and its organs.

Transport

After being absorbed, food components are transported to specific sites in the body where they are used or stored. Conversion of substances into different forms is often necessary to facilitate transport through the circulatory system. Other conversions may occur for storage prior to, during and after transport. Physiological mechanisms actively and passively transport nutrients across cell membranes to reach sites for utilization.

Metabolism

The final stage within the food and nutrition system involves the metabolism of particular nutrients for use in the body, where food components are involved in metabolic processes and homeostatic mechanisms. Required nutrients are used for specific biochemical and physiological functions, and insufficiencies and excesses of nutrients in metabolic pathways may disrupt functioning. Excesses may be stored or excreted. Toxicants may be detoxified and eliminated or be activated and disrupt normal biochemical and physiological functioning. The outcome of these metabolic processes occurs as the presence, absence, amount and types of food components influence health and disease.

Health outcomes

Health is the major outcome of the food and nutrition system, although only some of the etiology of health and disease is dietary in origin. Nutrients promote health when present in sufficient amounts to maintain and enhance physiological functions, but excesses or insufficiencies may lead to illness. Nutrients may interact with other factors, sometimes enhancing physiological processes that maintain health and other times exacerbating disease processes by stopping repair, adding to damage or spreading disease. Healthy outcomes include growth and development, maintenance and repair, provision of energy and performance and resistance to physical and biological insults and pathogens that cause disease. Illness outcomes include acute, chronic or mental diseases, lack of performance and breakdown of functional capabilities. Each nutrient plays a different role in health and disease. A variety of food components can lead to disease because of toxicity or deficiency, and acute and chronic illnesses may result from chemical and microbial food contaminants.

Food chain aspects of an integrated model of the food and nutrition system

Description of the food and nutrition system thus far has emphasized a linear, sequential approach, where resources enter the system and proceed through stages. This parallels the dominant theme in most existing models, which portray a food chain. While the flow may not be linear, it can be conceptualized as a complex pattern of streams flowing through the system. Analysis of the food and nutrition system may consider "upstream" and "downstream" events in the system.

Many channels exist in the food and nutrition system, with primary and alternative paths. Substitution occurs between channels, with alternatives and redundancies being inherent parts of the system. Changes in the system and its environment influence the rate and pattern of flow through different channels. The equifinality principle of systems theory states that any outcome can occur as a result of many influences (Bertalanffy, 1968). For example, coronary heart disease may be promoted by fat in foods from many sources and fat produced in one agricultural channel may lead to many differing outcomes, including disease, growth and/or activity.

From a systems perspective there is no single origin and no final end point in the food and nutrition system. One conceptual starting point is the use of resources from the biophysical and social environments for production, but in order to utilize these resources humans must be sufficiently nourished to engage in activities such as farming or cooking. Conceptual endpoints may be seen as human waste and human health, both of which also link back into the system at many points. An integrated system model emphasizes interdependency within the system and between the system and its environments.

Feedback and network aspects of the integrated food and nutrition system

In addition to a generally linear flow in the food and nutrition system, there is also feedback upstream between subsystems and stages that occurs in materials, energy and information. Materials may return to earlier stages of the system and then flow down again as in donation of foods purchased by consumers back to food banks. On a larger scale, materials may be outputs into the environment at one level which become inputs for other stages, producing complex and sometimes unpredicted links. For example, byproducts of industrial food processing may enter the water system and be used for irrigation of crops.

Following a food web model, information feedback occurs at most stages of the system. For

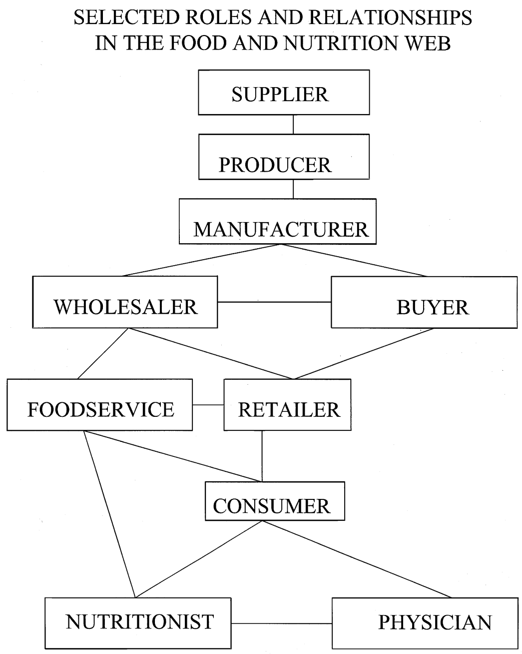

Fig. 4. Selected roles in the human food and nutrition web.

example, if many individuals contract a nutritional illness, information about that disease may be communicated back to households or the food industry. Information in the food and nutrition system passes through a complex web of social roles, such as farmer, manufacturer, buyer, consumer, cook, nutritionist, physician, etc. (Fig. 4). Information about the food and nutrition system may be communicated directly between these roles, as between a distributor and customer, or indirectly through other roles who operate as food and nutrition information brokers, such as government or media information disseminators. Information flow tends to be most extensive within each stage in the system, less between adjacent stages and subsystems and least between systems and their environments. Some of the relationships in the food web are tightly bound together, whereas others are barely connected.

Relationships between the food and nutrition system and its environments

The food and nutrition system is an open system that exists within biophysical and sociocultural environments, both of which are interrelated. Each environment operates on a different level of analysis (Sobal, 1991). The biophysical environment includes physical forces such as climate and energy; physical materials such as soil, water and chemical elements and biological factors such as biodiversity. The sociocultural environment includes economic factors such as capital and markets; cultural values and traditions; individual satisfaction and utility; technology such as knowledge and skills and policies.

The biophysical and sociocultural environments exchange resources and by-products with the food and nutrition system as materials and information inputs and outputs. For example, plant germ plasm, energy, air, water and soil are biophysical inputs that are combined with knowledge, skills, technology and capital by farmers in the production stage of the producer subsystem. Outputs from this stage include food products as well as waste materials, new knowledge, jobs and investment opportunities. Exchange with the environments often creates pressures that require responses by the food and nutrition system. For example, the bio-physical environment has limited renewable resources to provide for food production and a limited capacity to handle by-products such as packaging materials and agricultural chemicals. To remain sustainable, the food and nutrition system must respond with modifications (Board on Agriculture, 1989).

Other systems interact with the food and nutrition system at many points. These systems include the health care, economic, cultural, ecological, governmental, transportation and other systems (Fig. 5). Exchanges with other systems are essential for the operation of the food and nutrition system and are also important forces for change. Other systems have specific orientations and interests in particular components of the food and nutrition system. Interactions of all of these systems occur as they operate together as a system of systems. Relationships between systems are especially significant as the food and nutrition system is increasingly globalized (McMichael, 1994; Sobal, 1998).

Orientation and terminology differences in the food and nutrition system

Subsystems and stages within the food and nutrition system have different and varying orientations. They operate with different goals (profit, pleasure, health), units of analysis (commodities, foodstuffs, foods, nutrients, diseases), units of measurement (dollars, utility, calories) and professional audiences (users, consumers, customers, clients, patients). Interactions and comparisons between parts of the system are often hampered by the inability to translate inputs and outputs into common units of interest and difficulties in converting one unit to another (Dayal, 1981). Use of varying units may provide different perspectives on the system. For example, an economist may see some forms of food processing as adding market value, while a nutritionist may see the same types of food processing as subtracting nutritional value.

Comprehensive analysis of issues in the food and nutrition system requires translation of the frame of reference of each part of the system into that of others. Several system-wide units of analysis have been used across the system, with each providing a broad but limited orientation. For example, economists translate activities at each stage of the system into dollars (Senauer *et al.*, 1991). Ecologists have used energy as a common denominator, showing how it flows and is transformed throughout the system (Pimentel and Pimentel, 1996).

Subsystems in the food and nutrition system are often further partitioned into sectors using classification schemes based on the orientation of a subsystem. The producer subsystem uses categories based on commodities, the consumer system uses foods and the nutrition subsystem uses nutrients.

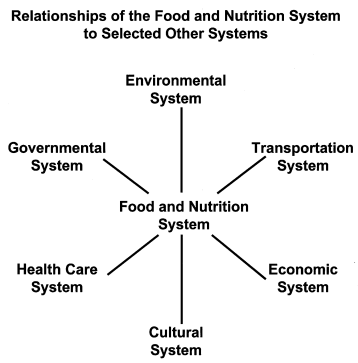

Fig. 5. Relationships of the food and nutrition system to selected other systems.

The producer subsystem is divided by products based on food commodities (e.g. dairy foods, grains, meats, fruits, vegetables), or types of service (e.g. canners, freezers, importers, wholesalers). The conceptualization of sectors is reflected in the work of economists in developing commodity sector models (Bauer and Henrichsmeyer, 1989) or sociologists discussing global food regimes for grains, meats, etc. (Friedmann, 1991).

Consumer subsystem sectors are based on products, foods, dishes and meals. Foods are related to commodities, but are not identical to them. People buy, prepare and eat foods for breakfasts, lunches, dinners, snacks and other special food events. Consumers are often segmented according to lifestyle, preferences or sociodemographic characteristics (Senauer *et al*., 1991).

The nutrition subsystem has been organized around physiologically relevant food components, including macronutrients, micronutrients, fiber, water, environmental contaminants and microorganisms. Each nutrient has specific functions or effects and has dosage levels that can be described in terms of physiological effects, such as no effect, insufficient, optimal, excessive and toxic. Health sectors based on disease and body functioning are also used in the nutrition subsystem, such as differentiating chronic and acute disease or growth/development, activity and maintenance functions.

Because different parts of the food and nutrition system have different foci, goals, units and sectors, communication problems often occur when people from the different subsystems interact. For example, nutritionists who organize the world according to nutrients or health risks may have difficulties relating to producers who approach issues from a commodity perspective or consumers who use a taste perspective. Understanding the organizing themes and sectors within the different subsystems can enhance appreciation of how each subsystem is linked with other subsystems and the system as a whole. An integrated model of the food and nutrition system that extends from agriculture to medicine facilitates multidisciplinary and multiprofessional communication.

CONCLUSION

The concept of the food and nutrition system was examined by reviewing past work, applying systems theory and developing an integrated model. Systems thinking deliberately avoids reductionist approaches that focus on only one portion of the system or view it from a specialized vantage point. The integrated model of the food and nutrition system is a tool that can be used for research, teaching and practice by portraying the scope of the system, making connections between parts of the system and showing links with areas outside the system.

Limitations exist in this effort to develop an integrated conceptual model. This analysis presented a broad conceptualization of the system to encourage viewing the issue from the widest vantage point. Future work may use this model to provide a framework for detailed examination of specific issues and cases. The model described the food and nutrition system of the global network of contemporary industrialized societies. Past societies and more traditional cultures may exhibit variations (Hay, 1978), but would be expected to share many commonalities. The review of existing models and synthesis into an integrated framework described fundamental structures and processes of the existing food and nutrition system. Critique of the current system was beyond the scope of this effort in assaying and building models, but others may find the model useful for appraising limitations in the system and identifying alternatives. A conceptual rather than a quantitative model was developed because a clear conceptual framework is a prerequisite to quantification.

Future work should find utility in an integrated model to analyze the operation of the food and nutrition system at global, national, regional and local levels. A wholistic perspective on the scope and scale of food and nutrition systems strengthens social science work on agriculture, consumers and health. A benefit of taking a systems perspective on food and nutrition is the capability to appreciate the multiple perspectives involved in the system and to understand linkages between the network of people and processes that constitute the food and nutrition system.

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