NUTRITION RESEARCH
FOOD, NUTRITION AND HEALTH
R. G. Hansen
An overview of some issues concerning diet and health.

PATTERNS OF FAT AND CHOLESTEROL CONSUMPTION OF AMERICAN WOMEN AND CHILDREN
C. T. Windham
Classifying people according to their eating habits will improve nutritional recommendations.

HEALTH PROMOTION AND DISEASE PREVENTION: A NUTRITIONAL SCORECARD
N. B. Schvaneveldt
For almost a decade, federal agencies have sought to help Americans prevent disease by improving nutrition. Some of the objectives have been met.

ADEQUATE NUTRITION: AN EDGE FOR THE COLLEGIATE GYMNAST
K. A. Gabel
An educational program helps USU gymnasts eat and perform well.

DIETARY GUIDELINES FOR AMERICANS
G. C. Lauritzen
Dietary Guidelines offered some sound nutritional advice to Americans. Many of us are following these recommendations.

RESEARCH IN BRIEF
An overview of some of the research supported by the Experiment Station.

PANTOTHENIC ACID STATUS AND TRIGLYCERIDE METABOLISM
S. Beck, C. T. Wittwer and B. Wyse
Relationships between pantothenic acid status and levels of circulating lipids may help diagnose and treat metabolic conditions due to abnormal energy metabolism.

CARROTS WITH MORE VITAMIN A
C. Schweitzer
New carrot hybrids may help children around the world avoid eye inflammations leading to blindness.

THE INDEX OF NUTRITIONAL QUALITY: HELPING CONSUMERS EAT WISELY
R. G. Hansen, B. Wyse and C. Windham
Confused about the nutritional value of food? A labeling system developed at USU simplifies matters.

IRON AVAILABILITY
A. W. Mahoney
Our bodies require much less iron than our diets provide, but iron deficiency is still a concern for many. This article explains why we utilize only a portion of the iron that we ingest.
Issues concerning the quality and abundance of food continue to command a great deal of attention in the United States. It is not only what we eat but how it is produced, processed and distributed that are of concern. Ironically, food is abundant in America, although some still go hungry; the safety of food has never been higher, although it is often called into question; and we have access to more nutritional information than ever, although misinformation often prevails. This issue of Utah Science examines several areas of nutritional research supported by the Experiment Station. Clearly, the relationship between nutrition and health is complex. There is still much to learn. And there are other issues that, directly or indirectly, affect the utility of what we learn.

A Pecuhant for Publicity

Of particular concern to me is the manner in which research results concerning the relationship between diet and health are disseminated. The open and unbiased exchange of research findings has long been an invigorating strength of American science. I am concerned that impartiality has occasionally been given short shrift. As a result, many Ameri-
cans are confused about which diets are most healthful. Some have been misled. Certainly tighter budgets and the need to raise money through proprietary research have tended to restrict the flow of scientific information. Of greater concern to me, however, is a pattern of releasing research results so as to engender the most publicity, a process that tends to dampen opposing viewpoints and exacerbates confusion. Consider, for example, the publicity surrounding the report of the Lipid Research Clinics Coronary Primary Prevention Trial (1984), a study that most Americans probably associate with "proof" of the adverse effects of dietary cholesterol on coronary heart disease. This study cost $150 million. Its release was accompanied by massive amounts of publicity. Many researchers questioned the conclusions of that report, but their criticisms garnered little attention. Since that study was released in 1984, other researchers have drawn more cautious conclusions. For example, a report of the U.S. Surgeon General (Public Health Service 1988) stated that "definitive scientific proof that specific dietary factors are responsible for specific chronic disease conditions is difficult—and may not be possible—to obtain, given available technology." The report also noted that "Development of the major chronic disease conditions—coronary heart disease, stroke, diabetes, or cancer is affected by multiple genetic, environmental, and behavioral factors among which diet is only one—albeit an important—component."

Which report should Americans believe?

Eating for Headlines—Or Health?

The publicity accorded the results of several studies have prompted many Americans to avoid or severely limit their intake of animal products, thinking that they are making healthful changes in diet. The willingness to change diets to improve health is commendable; the results may be disappointing. Simply stated, animal products are not the culprit many Americans perceive them to be. Consider the results of a study of the height of American children (Health Services and Mental Health Administration, 1976). It was not too surprising that children from economically disadvantaged environments were shorter than those reared in better conditions, a phenomenon that researchers related to the quality and quantity of food. Other research shows that each generation of college freshmen is taller and young women mature 30 months earlier than they did at the turn of the century. Obviously, favorable environmental factors, including better nutrition, influenced these changes.

Compare these results with the situation in China and the Soviet Union where officials are trying to increase the consumption of animal products in order to improve the nutritional quality and palatability of diets.

It is more than a little disconcerting to realize that the aspects of diet that we are abandoning are those that the Russians and Chinese seek to emulate in order to improve nutrition.

Nutritional Anomalies

There are other anomalies in the nutritional advice we receive. For example, in 1986 the American Heart Association (AHA) recommended that Americans limit their cholesterol intake to 100 milligrams per 1,000 calories, a very difficult level to achieve in a normal, balanced diet. Yet these recommendations also allowed a person to obtain 15 percent of calories from alcoholic beverages, and failed to consider that average consumption...
Many consumers assiduously avoid all types of animal products, even though certain types of fats from animal products are more beneficial than those from plant sources.

of soft drinks in 1984 was 44 gallons—80 percent of which were sugared. This meant that Americans obtained 10 percent of their calories from sugared soft drinks.

Dietitians found that it would be almost impossible for a diet following the AHA guidelines to contain adequate minerals and vitamins with such high consumption of soft drinks (Cleveland et al. 1987). More recently, the AHA is recommending limiting cholesterol intake to 300 milligrams, which would allow a more balanced selection of foods, including those from animal sources. However, it has not officially rescinded earlier recommendations.

The Perils of Obesity

The relationship between obesity and health should command more of our attention. Consider the results of one long-term study (1959–1972) that involved more than 750,000 men and women; weight was examined in relation to height, thus avoiding the issue of an "ideal" weight (Lew and Garfinkel 1979).

Researchers found that the death rate was 1.29 times higher than average among women whose weights were 20 percent higher than average for height. Death rates were more than twice normal for those more than 40 percent overweight. Diabetes compounded the negative consequences of obesity. Women with diabetes who were 20 percent overweight was more than three times normal and death rates were almost eight times normal for those weighing 40 percent more than average.

Obesity was also associated with increased mortality due to digestive diseases, cerebral vascular ailments, and even cancer.

It appears that obesity is the principal nutrition-related disease in America. Yet Americans are inundated with warnings about the ill effects of animal fats while the consumption of empty calories in alcohol and soft drinks is seemingly condoned.

Fallacies About Fat

The role of fat in the diet has also spawned considerable confusion. In popular reports, there has been a tendency to characterize fats as either "good" or "bad." For those whose caloric intake exceeds physiological demand, most fats, which are a concentrated source of calories, are probably bad. For others, however, fats provide essential nutrients and good flavor.

But it’s not as simple as that. Many Americans mistakenly believe that fats derived from plants are somehow more desirable than fats derived from animal products, supposedly because animal products contain more saturated fatty acids. Many consumers do not realize that plant fats also contain saturated fatty acids, consisting of 14 and 16 carbon atoms. The predominant fatty acids, either saturated or monounsaturated, in many animal fats contain 18 carbon atoms. Recent research indicates that fatty acids containing 18 carbon atoms are metabolized differently than those containing 14 and 16 atoms of carbon. Fatty acids typical of animal products may not raise blood cholesterol levels; in fact, under some circumstances, fatty acids from animal products may even lower blood cholesterol levels (Bonanome 1988).

In other words, certain types of fats from animal products may be more beneficial than some fats derived from plant sources, such as coconut and palm kernel oil. Yet many consumers believe that they must assiduously avoid all types of animal products and fail to discriminate among products from plant sources. Given the adverse effects of obesity and certain types of saturated fatty acids, they may be doing themselves more harm than good.

Confusion at the Supermarket

Livestock producers have a direct stake in how consumers perceive the relationship between animal fat.
health and taste. Current grading systems are based in part on the intramuscular fat content (marbling) of meat. The greater the amount of intramuscular fat, the higher the potential quality grade. However, many consumers associate quality with leanness and mistakenly believe that the leaner the meat, the higher the quality grade.

The resulting system serves neither producers nor consumers. Much of the fat that producers add to beef carcasses is removed before it reaches display counters. And consumers who buy meat solely based on leanness often find that the taste and texture are unsatisfactory.

Consumer preferences for milk indicate the relationship between fat content and flavor. Most consumers understand the differences between whole, 2 percent, 1 percent and skim milk. Sales of 2 percent milk—milk containing intermediate amounts of fat—have increased dramatically in recent years as consumers seek ways to limit fat intake without sacrificing flavor.

Consumers would probably also select meat containing intermediate amounts of fat—if they understood the quality grading system. A quality grading system that clarifies the relationship between fat and flavor would better meet the nutritional needs of consumers and help them reduce their caloric intake.

**A Few Simple Suggestions**

Americans' nutritional confusion is often intensified by a penchant for fad diets, and willingness to believe claims that certain foods possess medicinal qualities or can even cure terminal illnesses.

*What is to be done?*

First, we should make sure that certain basic nutritional principles never fall into desuetude: to wit, foods are neither "good" nor "bad" if eaten in moderation as part of a balanced diet.

Second, we should recognize that many Americans need to reduce their caloric intake. The producers and processors of livestock products recognize this and are developing products that contain fewer calories.

Third, we should sometimes be chary of findings whose release is choreographed to coincide with massive amounts of publicity. Our bodies, not headlines, are the final arbiters of the healthfulness of diets.

The fourth suggestion is to balance nutritional intake by selecting foods from a variety of sources, including animal products.

**LITERATURE CITED**


Food consumption data can provide valuable insights into our eating habits and the nutritional adequacy of our diets. In cooperation with the Human Nutrition Information Service of the U.S. Department of Agriculture, we are analyzing and interpreting the most recent data from the Continuing Survey of Intakes of Individuals in 1985 (CSFII-85), the first annual nationwide survey of dietary intake. This survey complements the larger national food consumption surveys conducted by the USDA about every 10 years. The information is used to plan food-assistance and educational programs and in a variety of public programs concerning the supply, safety and distribution of food.

The CSFII involved women 19 to 50 years of age and their children 1 to 5 years of age in the 48 conterminous states, population groups that previous surveys indicated are more likely to consume diets low in some nutrients. (Additional groups might be included in other years.)

**Intake Patterns of Women**

We used numerical classification procedures, generally called cluster analysis, to classify women and children according to similarities in the nutrient content of their diets. Cluster analysis is a generic term for a number of different techniques designed to group objects (in this case, survey participants) into clusters or categories consisting of subsets of the objects (individuals) with similarities on some measured variable (in this case, the nutrient composition of individual diets). We used cluster analysis to identify subpopulations whose members had similar intake patterns of nutrients or groups of nutrients. These subpopulations were then examined for common socioeconomic, demographic or health-related characteristics, and for any relation between these factors and intake patterns.

We classified 1,042 women by average daily intakes of total,
Women who consumed the most cholesterol tended to be less educated and overweight.

Saturated, monounsaturated and polyunsaturated fats as percentages of average daily caloric intake; one analysis included cholesterol intake and another analysis excluded cholesterol intake.

Five groups of women had distinctly different patterns of cholesterol and fat. Forty-one percent of the population were in the group with the lowest average intake of cholesterol (133 mg/1,000 kcal) (Cluster 1, Figure 1); this group contained disproportionately few blacks. These women were also slightly older than average.

Those in the group that consumed the most cholesterol (299 mg/1,000 kcal) (Cluster 5, Figure 1) contained a disproportionately high percentage of black women, women with less education than average and women who

TABLE 1. Proportions and means of clusters (fat and cholesterol).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample proportion</th>
<th>% in cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of sample</td>
<td>100</td>
<td>41 9 28 26 7</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>22</td>
<td>- - - - - 34</td>
</tr>
<tr>
<td>Central</td>
<td>22</td>
<td>- - - - -</td>
</tr>
<tr>
<td>South</td>
<td>34</td>
<td>- - - - -</td>
</tr>
<tr>
<td>West</td>
<td>22</td>
<td>- - - 31 -</td>
</tr>
<tr>
<td>Urbanization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central city</td>
<td>2</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Suburban</td>
<td>52</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Nonmetro</td>
<td>20</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Household size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>- - - - -</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>- - - - -</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>- - - - -</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>- - - - -</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>- - - - -</td>
</tr>
<tr>
<td>≥6</td>
<td>9</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>85</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Black1</td>
<td>10</td>
<td>5 - 14 - 21</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>6</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Nonhispanic</td>
<td>87</td>
<td>- - - - -</td>
</tr>
<tr>
<td>No data</td>
<td>7</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Education, female head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (yrs)</td>
<td>0</td>
<td>- - 1 - -</td>
</tr>
<tr>
<td>1-8</td>
<td>4</td>
<td>- - - - -</td>
</tr>
<tr>
<td>9-12</td>
<td>54</td>
<td>- - - - -</td>
</tr>
<tr>
<td>13-16</td>
<td>35</td>
<td>- - - - -</td>
</tr>
<tr>
<td>≥17</td>
<td>6</td>
<td>- - - - -</td>
</tr>
<tr>
<td>No data</td>
<td>0</td>
<td>- - - 1 -</td>
</tr>
<tr>
<td>Employment, female head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>43</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Part-time</td>
<td>19</td>
<td>- - - - -</td>
</tr>
<tr>
<td>None</td>
<td>36</td>
<td>- - - - -</td>
</tr>
<tr>
<td>No data</td>
<td>2</td>
<td>- - - - -</td>
</tr>
<tr>
<td>Male head present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>79</td>
<td>- - - - -</td>
</tr>
<tr>
<td>No</td>
<td>21</td>
<td>- - - - -</td>
</tr>
</tbody>
</table>
tended to be overweight. Three other groups had intermediate levels of cholesterol intake but differed in their intakes of saturated, monounsaturated and polyunsaturated fatty acids (Clusters 2, 3, 4, Figures 1 and 2).

When data were analyzed according to fat (without cholesterol) intake, no distinct population subgroups were identifiable. These results indicated that consumers may more easily differentiate among cholesterol-containing foods than those containing different types of fat, i.e., women were easily classified when their cholesterol intake was included in the analyses, but were difficult to classify using only fat intake levels. Some women apparently are trying to lower dietary cholesterol; these women are predominantly white, slightly older than average, and can identify foods low and high in cholesterol.

**Fat and Cholesterol Consumption of Children**

We also used the fat and cholesterol content of diets of 302 children included in the survey who clustered into six distinct groups. The largest group, which contained 41 percent of the children, consumed average amounts of fat, relatively low amounts of protein and relatively high amounts of carbohydrates. In combination with the low intake of protein, the low nutrient densities of

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample proportion</th>
<th>% in cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>% of sample</td>
<td>100</td>
<td>41</td>
</tr>
<tr>
<td>Education (yrs), male head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1-8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>9-12</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>13-16</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>≥17</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>No data</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Employment, male head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Part-time</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>No data</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Sample mean**

<table>
<thead>
<tr>
<th>Age</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td>24.5</td>
</tr>
<tr>
<td>Income as % poverty</td>
<td>289</td>
</tr>
<tr>
<td>% food money spent away from home</td>
<td>24</td>
</tr>
<tr>
<td>% of meals eaten away from home</td>
<td>18</td>
</tr>
</tbody>
</table>

**Cluster mean**

<table>
<thead>
<tr>
<th>Age</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td>24.5</td>
</tr>
<tr>
<td>Income as % poverty</td>
<td>289</td>
</tr>
<tr>
<td>% food money spent away from home</td>
<td>24</td>
</tr>
<tr>
<td>% of meals eaten away from home</td>
<td>18</td>
</tr>
</tbody>
</table>

NS = not significant.
— indicates cluster proportion was not significantly different from overall sample proportion at p ≤ 0.05.

1Significant difference between clusters (p ≤ .0001).
2Significant difference between clusters (p ≤ .05).
3Significant difference between clusters (p ≤ .01).
The diets of many children from high-income households were often low in protein. The diets of children from low-income families tended to be relatively high in protein and low in carbohydrates.

niacin, zinc, sodium and potassium indicated that these children consumed relatively few sources of meat protein; the high densities of calcium and magnesium indicated that their milk consumption was slightly higher than average. Children in another cluster tended to weigh less than average and the group contained disproportionately few girls, black children and residents of eastern states. The low protein content of these children's diets was somewhat anomalous given that these children lived in households with the highest income levels. Children in the group that consumed relatively high levels of protein and low levels of carbohydrates tended to be from families with the lowest average incomes.

The diets of children in a third group were most similar to the average intake of all children in the sample. They consumed an average of 1,426 kilocalories, within the range recommended by the Food and Nutrition Board for children 1 to 3 years of age but in the lower range of the level recommended for children 4 to 6 years of age. Total fat and saturated fatty acids provided a somewhat higher than recommended percentage of calories; however, many nutritionists question the wisdom of having young children consume such low levels of fat. Diets of children in this group contained adequate amounts of many nutrients but marginal amounts of vitamin B₆, folacin, calcium, iron, magnesium, zinc and copper. This group contained a disproportionately high proportion of black children; mothers of these children tended to be better educated than average.

Four groups of children were identified when diets were classified according to dietary fat without cholesterol. However, there were few significant differences in intakes of other nutrients or in demographic factors among the groups.

Sorting It Out

Recommendations concerning the level of cholesterol and the kinds and amounts of fat have been controversial. Cholesterol and fat intake have been linked to health problems such as cardiovascular disease and various cancers. Overconsumption of fat can dilute nutrients, thus decreasing the nutritional quality of diets. Many Americans have sedentary lifestyles and require less food energy; they
can ill-afford calorie-dense or foods of poor nutritional quality if they want to maintain a desirable weight and protect their health.

Many government agencies and other organizations concerned about nutrition recommend that Americans moderate their fat consumption. For example, the American Dietetic Association recommends that total fat be limited to less than one-third of total caloric intake and the American Heart Association recommends reducing intake of total fat and saturated fat to less than 30 and 10 percent, respectively, and to limit cholesterol consumption to 300 mg or less per day.

Many of the mothers participating in the CSFII apparently had more trouble distinguishing among dietary fats than among foods containing cholesterol, perhaps because cholesterol is contained only in animal foods while dietary fats are contained in many food groups. The system of food labeling may also contribute to the confusion. A label may list several different fats that the product may contain, depending on the prices of these fats and oils when the product was manufactured. Labels need not include the types of fat (saturated, monounsaturated, or polyunsaturated) of fatty acids, although many food manufacturers now provide this information.

**Leader Nutrients**

Identifying subpopulations with similar patterns of nutrients or groups of nutrients also identifies "leader" or "indicator" nutrients" that indicate the overall nutritional quality of diets.

Leader nutrients are related to the concept of a balanced diet, a central theme of nutrition-education programs for many years. For example, the Basic Four Food Groups, which assume that consuming an appropriate mixture of food items from each group can be the foundation of an adequate diet, was based on leader nutrients (calcium, iron, thiamin, riboflavin, vitamins A and C, and protein) identified in the 1950s.

Today, however, these leader nutrients are not the nutrients of major concern in the United States. Current problem areas involve zinc, magnesium, vitamin B6, and folic acid. It now appears that many people consume substantially less than the Recommended Dietary Allowances of these nutrients and of

---

**FIGURE 2.** Total intake of fat and fatty acids.
Many nutritional recommendations assume that consuming adequate amounts of leader nutrients means you will also consume adequate amounts of other nutrients. These assumptions may not be valid.

calcium, iron and vitamin A. Nutritionists are also interested in the consumption of other trace elements, (e.g., pantothenic acid, vitamin B₁₂) and of dietary fiber, in part because methods have recently been developed to better determine amounts of these nutrients in foods and biological tissues.

Many nutritional programs are based on the assumption that consuming a variety of foods within the four food groups will provide adequate amounts of the leader nutrients. These recommendations also assume that providing adequate amounts of leader nutrients will also meet the requirements for non-leader nutrients, such as vitamins B₉ and B₁₂, pantothenic acid, zinc, and magnesium. However, as more is learned about the nutritional role of non-leader nutrients, improved methods of measuring these nutrients are developed and intake data are examined, the assumptions underlying these recommendations may not be valid.

For example, data from the CSFII and other dietary surveys can be classified according to intake of a group of leader nutrients; the relationship with other nutrients can then be assessed. We are now determining whether women and children can be grouped according to their average intake of leader nutrients (protein, calcium, iron, vitamin A, thiamin, riboflavin, preformed niacin and ascorbic acid) over 4 days and how these groups are related to demographic variables and the intake of other nutrients.

Certain leader nutrients may always be related to specific non-leader nutrients. If so, these leader nutrients could facilitate the formulation of balanced diets and the analysis of nutrient intake.

Conclusions

Classifying people into groups according the similar food and nutrient consumption is important in the analysis of food consumption survey data. We now have access to prodigious amounts of good data; categorizing these data facilitates analyses without diminishing the accuracy of findings. The results of cluster analyses will help plan effective nutrition-education programs and identify important nutritional concerns.

ACKNOWLEDGMENTS

This research was supported by USDA Cooperative Agreement No. 58-3198-6-56 and Utah Agricultural Experiment Station Project 758.

ABOUT THE AUTHOR

Carol Windham is assistant professor in the Department of Nutrition and Food Sciences. Her research interests are in applied human nutrition, particularly the methodology of nutritional and dietary assessment, and nutrition education theory and practice.
In recent years, there has been an increased awareness that changes in diet, exercise, smoking, drinking and other practices can prevent or reduce the most prevalent causes of death and disability in the United States (heart disease, cancer, diabetes, liver and lung diseases, accidents and injuries, infant mortality and infectious diseases and others). Title XVII of the Public Health Service Act of 1976 mandated that the Secretary of the U.S. Department of Health, Education and Welfare (now the Department of Health and Human Services) develop national goals and implement plans to improve the nation’s health (U.S. Congress 1976). The publication of Healthy People in 1979 described these health problems and recommended a strategy to solve them. The secretary of Health, Education and Welfare, Joseph Califano, characterized these recommendations as "a second public health revolution in the United States" and estimated that 67 percent of all disease and premature death were preventable through health and lifestyle changes (Califano 1987). The report defined the following five broad goals to improve health by 1990:

1. Reduce infant mortality by at least 35 percent to fewer than nine deaths per 1,000 live births.
2. Reduce deaths among children 1 to 14 years of age by at least 20 percent to fewer than 34 per 100,000.
3. Reduce deaths among people ages 15 to 24 by at least 20 percent to fewer than 93 per 100,000.

HEALTH PROMOTION AND DISEASE PREVENTION: A NUTRITIONAL SCORECARD

N. B. SCHVANEVELDT

NUTRITION OBJECTIVES
IMPROVED HEALTH STATUS
REDUCED RISK FACTORS
INCREASED AWARENESS
IMPROVED SERVICES PROTECTION
IMPROVED SURVEILLANCE/VALUATION SYSTEM
Growth retardation of infants and children due to inadequate diets is still a major concern.

<table>
<thead>
<tr>
<th>TABLE 1. Promoting health/preventing disease: fifteen priority areas.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High blood pressure control</td>
</tr>
<tr>
<td>Family planning</td>
</tr>
<tr>
<td>Pregnancy and infant health</td>
</tr>
<tr>
<td>Immunization</td>
</tr>
<tr>
<td>Sexually transmitted disease control</td>
</tr>
<tr>
<td>Toxic agent and radiation control</td>
</tr>
<tr>
<td>Occupational safety and health</td>
</tr>
<tr>
<td>Accident prevention and injury control</td>
</tr>
<tr>
<td>Fluoridation and dental health</td>
</tr>
<tr>
<td>Surveillance and control of infectious diseases</td>
</tr>
<tr>
<td>Smoking and health</td>
</tr>
<tr>
<td>Prevention of misuse of alcohol and drugs</td>
</tr>
<tr>
<td>Improved nutrition</td>
</tr>
<tr>
<td>Physical fitness and exercise</td>
</tr>
<tr>
<td>Control of stress and violent behavior</td>
</tr>
</tbody>
</table>

4. Reduce mortality among people ages 25 to 64 by at least 25 percent to fewer than 400 per 100,000.

5. Reduce the average annual number of days of restricted activity due to acute and chronic conditions by 20 percent to fewer than 30 days per year for people ages 65 and older.

Promoting Health/Preventing Disease: Objectives for the Nation subsequently outlined a national strategy to improve the health of Americans (U.S. Department of Health and Social Services 1980). Fifteen priority areas (Table 1) involved 226 objectives concerning ways to improve health status, reduce risk factors, increase public/professional awareness, improve services/protection, and improve the surveillance/evaluation system.

Improved nutrition was one of the priorities, and nutrition also influences several of the other priority areas, particularly the control of high blood pressure, pregnancy and infant health, fluoridation and dental health, alcohol and drug abuse, and physical fitness and exercise.

Although designated federal agencies were to provide leadership for this endeavor, attaining these goals is a collaborative effort between private and public sectors. Success depends on the willingness of citizens to avoid health risks and adopt better health practices.

Nutrition Objectives

What progress has been made in meeting the objectives outlined in the 1980 report? It appears that we are likely to meet some objectives by 1990, make substantial progress toward others and fail to attain others. The following is a brief synopsis of progress toward meeting the nutrition-related goals outlined in the 1980 report. The status of these goals are useful in assessing national policies, and in evaluating personal habits and goals.

Improved Health Status

The goal is to reduce the proportion of pregnant women with iron deficiency anemia (as estimated by hemoglobin concentrations early in pregnancy) to 3.5 percent. (In 1978, the proportion was 7.7 percent.)

The two major factors contributing to iron deficiency anemia in women of childbearing age are pregnancy and menorrhagia (excessive loss of blood during menstruation). It is estimated that 20 percent of women are menorrhagic, many of whom are...
unaware that their blood loss is greater than normal and who may be iron deficient at the start of pregnancy (U.S. Department of Health and Human Services 1988). Pregnant women require more iron as their blood volume expands to meet the requirements of the rapidly growing fetus and placenta. Clinicians generally recommend about 30-60 mg of supplemental elemental iron per day during the last half of pregnancy.

It has been difficult to evaluate success in meeting this objective because most states collect data on hematocrit (packed red blood cells) rather than hemoglobin (the oxygen-carrying component of red blood cells). Iron deficiency anemia is more common among those living below the poverty level. WIC (Special Supplemental Food Program for Women Infants and Children), a Federal food program for socio-economically disadvantaged groups, has helped to improve the iron status.

Another nutrition-related goal is the elimination of growth retardation of infants and children caused by inadequate diets. In 1972–73, it was estimated that 10–15 percent of infants and children among migratory workers and certain poor rural populations suffered growth retardation due to inadequate diets (Nestle 1988). It is unlikely that this objective will be met.

**Reduced Risk Factors**

The report also recommended a decrease in the prevalence of significant overweight (defined as 120 percent of "desired" weight) among the U.S. adult population to 10 percent of men and 17 percent of women, without nutritional impairment. (In 1971–74, 14 percent of adult men and 24 percent of women were overweight.) Obesity is associated with an increased incidence of morbidity and mortality from heart disease, cancer, diabetes, digestive diseases and cardiovascular disease (U.S. Department of Health and Human Services 1988). The incidence of obesity in the 1976–80 surveys did not differ significantly from that in the 1971–74 survey, and it is unlikely that this objective will be achieved (Nestle 1988).

Another goal was to have 50 percent of the overweight population adopt weight loss regimens that combine an appropriate balance of diet and physical activity. People who lose weight tend to regain it, and a combination of exercise and diet seems to be the most sensible approach to weight control. Maintaining weight loss also involves lifelong changes in behavior.

Fad weight loss diets and gimmicks have been estimated to cost consumers $5 billion annually (U.S. Department of Health and Human Services 1988). These diets attract attention but are frequently dangerous, especially when they provide inadequate amounts of essential nutrients.

In 1985, nearly 50 percent of those who were overweight reported that they were trying to lose weight, but only 27 percent of overweight women and 21 percent of the men did so through both diet and exercise; this indicates that this objective is unlikely to be achieved (Nestle 1988).

Another goal is to reduce the mean serum cholesterol level in the adult population aged 18 to 74 to 200 mg/dl or less. (In 1971–74, the level was 214 mg/dl for men and 217 mg/dl for women aged 18–74 years; in 1976–80, it was 215 and 211 mg/dl, respectively.) (U.S. Department of Health and Human Services 1980). An extensive education campaign by the National Heart, Lung and Blood Institute in 1988 may improve the ability to meet this objective.

The objective is to reduce the
Little progress seems to have been made against obesity, which increases the risk of heart disease, cancer, diabetes, digestive diseases and cardiovascular disease.

Mean serum cholesterol level in children aged 1 to 14 to no more than 150 mg/dl by 1990. In 1971-74, the level was 176 mg/dl for children ages 1-17. Insufficient data are available to determine whether this objective will be achieved. Some authorities also question whether it is appropriate to reduce the serum cholesterol level for children less than 2 years of age (Nestle 1988).

Adults should also decrease their average sodium intake (as measured by excretion) to 3 to 6 grams daily. (In 1979, estimated sodium intake was between 4 and 10 grams daily.) (Nestle 1988).

There has been no reduction in the sodium content of packaged foods regulated by the FDA since 1980, although many new lower sodium products have been introduced. According to a recent survey, sodium intake (excluding salt added at the table) is within the desired range (Nestle 1988).

It was also recommended that 75 percent of women should breastfeed their babies when they are discharged from the hospital and 35 percent should breastfeed infants 6 months of age. (In 1978, 45.1 percent of infants were breastfed at 1 week and 18.9 percent were breastfed at 6 months; by 1985 these percentages had increased to 56.4 and 22.1, respectively) (Nestle 1988). These trends indicate that it should be possible to achieve this objective. It should be noted, however, that disadvantaged women are less likely to breastfeed infants (U.S. Department of Health and Human Services 1988).

It is hoped that 75 percent of the population will be able to identify the principal dietary factors known or strongly suspected to be related to heart disease, high blood pressure, dental caries and cancer. In 1985, at least 80 percent of adults surveyed knew the relationship between dietary fats and heart disease and sugar snacks and tooth decay; almost 60 percent associated high salt intake with hypertension (Nestle 1988).

It is also hoped that 70 percent of adults should be able to identify the major foods that are low in fat, low in sodium, high in calories and good sources of fiber. Although data are not available concerning changes in awareness, it appears that an increased awareness of the relationship between diet and disease will also increase awareness of the nutritional value of foods. It also appears possible that 90 percent of adults should understand that weight loss involves either consuming foods that contain fewer calories or increased physical activity—or both. In a 1985 survey, 75 percent of those at least 18 years old said exercise and diet were the two best ways to lose weight (Nestle 1988).

Increased Awareness

It is hoped that 75 percent of the population will be able to identify the principal dietary factors known or strongly suspected to be related to heart disease, high blood pressure, dental caries and cancer. In 1985, at least 80 percent of adults surveyed knew the relationship between dietary fats and heart disease and sugar snacks and tooth decay; almost 60 percent associated high salt intake with hypertension (Nestle 1988).

It is also hoped that 70 percent of adults should be able to identify the major foods that are low in fat, low in sodium, high in calories and good sources of fiber. Although data are not available concerning changes in awareness, it appears that an increased awareness of the relationship between diet and disease will also increase awareness of the nutritional value of foods. It also appears possible that 90 percent of adults should understand that weight loss involves either consuming foods that contain fewer calories or increased physical activity—or both. In a 1985 survey, 75 percent of those at least 18 years old said exercise and diet were the two best ways to lose weight (Nestle 1988).

The report recommended that the labels of all packaged foods should contain useful information about their caloric and nutrient content so consumers are able to select diets that promote and protect good health. Similar information should be available for nonpackaged foods.

In spite of the fact that packaged foods labeled with nutrition information increased from 42 percent to 55 percent from 1978 to 1985 and sodium labeling increased by 7.5 percent to 59 percent during the same period, the objective is not likely to be achieved by 1990. The lack of data makes it impossible to determine whether sodium levels in processed food will be reduced by 20 percent by 1990. Similarly, it is not known whether more than 50 percent of employee and school cafeteria managers were aware of and actively promoted USDA/DHHS
dietary guidelines by 1985, as was stated in another goal (Nestle 1988).

Nutrition education was also to be included in required comprehensive school health education at elementary and secondary levels in all states. Ten states had mandated such a nutrition education program in 1977 and two more states had done so by 1985, which indicates that this objective will probably not be met.

Another goal was to include some nutrition education and nutrition counseling in virtually all routine contacts with health professionals. However, a 1985 survey reported that only 18 to 30 percent of surveyed adults age 18 and over said that proper food intake was discussed during their visits with health professionals (Nestle 1988).

It was also recommended that a comprehensive national nutrition status monitoring system be established to detect nutritional problems in special groups and to obtain baseline data on which to base national nutrition policies.

President Reagan vetoed the National Nutrition Monitoring Bill in November 1988. The bill has been reintroduced in 1989.

The final report on progress toward reaching these objectives should be prepared in the early 1990s. These recommendations are the first time a coordinated approach and management by objectives were employed in public health. The report was also the first time that nutrition information was systematically used to formulate pragmatic goals (Sorensen et al. 1987). While it has been difficult to implement and monitor the objectives, what has been learned will be useful in updating the objectives.

The goals that will probably be achieved by 1990 include breastfeeding, public knowledge about appropriate weight-loss practices, the dietary factors related to major diseases and reduced blood cholesterol levels (Sorensen et al. 1987). Some improvement has been made toward meeting each of the other goals, but they are not likely to be achieved by 1990.

Establishing objectives has helped focus and direct public health programs and policies. These recommendations will continue to influence policy and processes well into the next century.

LITERATURE CITED


ABOUT THE AUTHOR

Noreen B. Schvaneveldt is clinical instructor for the Medical Dietetics Program in Nutrition and Food Sciences Department.
ADEQUATE NUTRITION: 
AN EDGE FOR THE COLLEGIATE GYMNAST

K. A. GABEL

Athletes participating in the first Olympic games probably were aware of the relationship between diet and athletic performance. Today, athletes and coaches are aware that a low level of body fat can enhance performance. A lean body can be achieved with proper nutrition and training, but too often athletes try to decrease their body fat by consuming less food rather than training harder or exercising longer.

Gymnasts place a premium on leaniness. Some may suffer from inadequate nutrition and chronic calorie restriction (Moffatt 1984). Amenorrhea (cessation of menstrual flow), decreased bone density, eating disorders and iron deficiency anemia have also been reported in female athletes who failed to consume enough food (Borgen and Corbin 1987, Cann et al. 1984).

In 1985, we initiated a study to examine the dietary, anthropometric (estimated percent body fat, weight
USU gymnasts consumed about 600 kcalories less than recommended for an 18-year-old female performing light work.

and height) and hematological status of female gymnasts at USU. Food intakes were recorded by gymnasts for three days every other week from October to April to assess nutritional adequacy. Intake of 18 nutrients plus energy and fiber were assessed with computer programs in the Department of Nutrition and Food Sciences. Percent body fat was estimated four times during competitive season by hydrostatic weighing at the USU Human Performance Laboratory. Another method to assess body fat recently introduced into our program is the near infrared (NIR) system developed by the U.S. Department of Agriculture, which employs light waves to provide a direct digital readout of percent body fat. The NIR results will be compared with the results of hydrostatic weighing obtained during the last year. Monthly blood samples were also taken and a total of 33 parameters were assessed, with particular attention to iron and lipid levels.

**Dietary Intakes**

Average intake was about 1500 kcalories for team members (Table 1), which is similar to the estimated intake of 1400 kcalories for University of Utah gymnasts (K. Engelbert-Fenton 1987). According to the Recommended Dietary Allowance (RDA), USU gymnasts consumed an average of 600 kcalories less than recommended for an 18-year-old female performing light work. Because female gymnasts expend approximately 300 more kcalories daily than the average female, their caloric deficit was even more significant. Nutritional counseling was offered in group presentations or on an individual basis, monthly or as needed. Without this counseling, energy and nutrient deficiencies would probably have been more severe.

Carbohydrates in the form of bread, pasta, beans, fruits and vegetables are recommended for all physically active persons because they are a good source of energy. Over four years, the female gymnasts obtained 52 to 57 percent of their kcalories from carbohydrates (Table 1). A percentage of 55 to 65 is acceptable for athletes. Long-distance runners, triathletes or persons engaged in endurance-type events can benefit from deriving 65 to 70 percent of their kcalories from carbohydrates. Most carbohydrates are stored in the body in the form of muscle glycogen. As muscle glycogen is used during exercise, blood glucose may enter the muscle to help maintain muscle glycogen stores. In turn, the liver will release some of its stored glucose to help maintain blood glucose levels. Increases or decreases in glucose stored in the muscle and the liver have considerable effects on physical performance. One full day of fasting or 2 hours of intense physical activity can considerably reduce glycogen levels. Wrestlers and gymnasts are well known for fasting prior to a competitive meet and too often athletes will fast a day or two to cut unwanted pounds. When muscle

<table>
<thead>
<tr>
<th>n</th>
<th>Year</th>
<th>Energy (calories)</th>
<th>% calories from fat</th>
<th>% calories from CHO</th>
<th>% RDA iron</th>
<th>% RDA vitamin C</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1985-86</td>
<td>1360</td>
<td>32</td>
<td>53</td>
<td>59</td>
<td>188</td>
</tr>
<tr>
<td>13</td>
<td>1986-87</td>
<td>1500</td>
<td>28</td>
<td>57</td>
<td>68</td>
<td>202</td>
</tr>
<tr>
<td>13</td>
<td>1987-88</td>
<td>1570</td>
<td>34</td>
<td>52</td>
<td>61</td>
<td>152</td>
</tr>
<tr>
<td>14</td>
<td>1988-89</td>
<td>1630</td>
<td>31</td>
<td>54</td>
<td>65</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>(5 mo.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
glycogen is exhausted, the athlete can no longer perform. It was once thought that protein did not contribute to the energy expended during exercise. However, results of several studies in the late 1970s and early 1980s indicated that increased protein is used for energy during exercise. As muscle and liver protein synthesis is depressed, amino acids are available for breakdown. It is now well documented that non-hepatic tissues, predominantly skeletal muscle, can burn amino acids, especially the branched chained amino acids (leucine, isoleucine and valine). Protein may contribute about 5 to 15 percent of the energy expended during exercise; the largest proportion of energy is provided by carbohydrate and fat (Lemon 1987). The current RDA for protein is 0.8 grams per kilogram (kg) of body weight. The general recommendation is to consume 12 to 15 percent of calories as protein. The USU gymnasts consistently met the RDA for protein and protein as a percent of calories, even though their caloric intake was low.

**Fat and Cholesterol**

Decreasing fat content in the diet probably has the most impact in helping to decrease body fat. In a study involving 155 men, researchers at the Stanford School of Medicine found that the degree of excess weight was linked to fat consumption, not caloric intake (Dreon et al. 1988). In experiments at the University of Massachusetts Medical School, Flatt et al. (1984) found evidence that the body may be able to convert dietary fat into body fat more efficiently than carbohydrates. Results of these studies suggest that 97 of 100 excess kcalories from fat will be stored as fat, while only 77 of 100 excess kcalories from carbohydrate will be stored as fat. In other words, more energy is expended to convert carbohydrate into body fat than is used to convert dietary fat into body fat.

Nutrition education has helped USU gymnasts keep their average intake of fat kcalories close to the 30 percent level recommended by the American Heart Association (Table 1). Weights (range: 53 to 56 kg) and percent of body fat (range: 14 to 17) over the four years have been consistent with average weight and body fat percentages for female athletes. Further investigation will determine if there is any relationship between the percentage of fat consumed and the percentage of body fat.

Daily dietary cholesterol intake was also consistently less than the 300 mg generally recommended. Serum cholesterol is often related to fat calories and dietary cholesterol. The upper level of serum cholesterol currently recommended by the American Heart Association is 200 mg/deciliter (mg/dl). Gymnasts’ average levels of serum cholesterol were below 200 mg/dl, and levels decreased during periods of weight loss (Table 2). Over the four years, one gymnast had hyperlipoproteinemia, a lipid disorder character-

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>191</td>
<td>180</td>
<td>183</td>
<td>181</td>
<td>185</td>
<td>192</td>
</tr>
<tr>
<td>1986-87</td>
<td>183</td>
<td>167</td>
<td>174</td>
<td>188</td>
<td>177</td>
<td>182</td>
</tr>
<tr>
<td>1987-88</td>
<td>178</td>
<td>173</td>
<td>161</td>
<td>179</td>
<td>168</td>
<td>197</td>
</tr>
<tr>
<td>1988-89</td>
<td>212</td>
<td>192</td>
<td>178</td>
<td>168</td>
<td>173</td>
<td></td>
</tr>
</tbody>
</table>
The gymnasts' high consumption of vitamin C apparently enhanced iron absorption enough to prevent iron deficiency.

Iron Status

Another important issue for female athletes is iron status and the risk of iron deficiency anemia. Many female athletes probably do not consume enough iron (Clement and Sawchuk 1984). Several USU gymnasts did not consume meat (a high-iron food) to limit fat intake. Gymnasts' iron intakes averaged 59 to 68 percent of the recommended level for an 18-year-old female (Table 1).

Iron status was assessed by hematocrit (percent packed red blood cells) and by measuring hemoglobin (combination of iron and protein) and ferritin (storage form of iron) levels. Hemoglobin level and hematocrit are the traditional parameters of hematological status, but they identify iron deficiency only during the late stages. Ferritin level is a more sensitive parameter of anemia. A ferritin level between 10 and 40 ng/ml may be indicative of a subclinical deficiency of iron. Levels below 20 ng/ml are related to a decrease in levels of iron-dependent enzymes and clinical signs of anemia, which include paleness, irritability, fatigue, headache, spots before eyes, drowsiness or gastrointestinal complaints (Berkow 1982).

Only one of the gymnasts studied during the four years exhibited symptoms of iron deficiency anemia. However, during some years, ferritin levels in the majority of the gymnasts tended to decrease during training (Table 3). Even when normal hemoglobin levels are maintained, inadequate iron stores (as reflected by decreased ferritin levels) may compromise work capacity (Haymes 1987). Because iron deficiency anemia may impair endurance (Gardner et al. 1977), physically active people must consume enough bioavailable iron from sources such as meat. Nutrition education can help all consumers, whether athletes or nonathletes, select high-iron, low-fat foods, as was demonstrated by the program used for the gymnasts.

Calcium is another nutrient of concern for athletes, particularly for females. Regular exercise and adequate dietary calcium are recommended to prevent loss of bone mass. Calcium consumption (as a percentage of RDA) of the gymnasts was quite high, considering their relatively low caloric intake, probably due to a higher than usual intake of frozen yogurt, the "team's favorite food." Whereas exercise is associated with an increase in bone density, excessive exercise leading to amenorrhea can decrease bone density. Amenorrheic athletes seem to experience a significant loss in the mineral content of the vertebral (Cann et al. 1987). Coaches, trainers and other health professionals working with gymnasts should be aware.

TABLE 3. Average serum ferritin levels in USU gymnasts (1985–89).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1985–86</td>
<td>28</td>
<td>25</td>
<td>31</td>
<td>28</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td>1986–87</td>
<td>31</td>
<td>28</td>
<td>32</td>
<td>20</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>1987–88</td>
<td>27</td>
<td>29</td>
<td>29</td>
<td>25</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>1988–89</td>
<td>33</td>
<td>28</td>
<td>30</td>
<td>25</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>
of the possible incidence of amenorrhea and how it affects the bone density in gymnasts.

A Blueprint for Other Programs

Even though the calorie intake of gymnasts was lower than expected for athletes, a sound nutrition education program reduced the incidence of nutrient deficiencies below that reported in previous studies involving gymnasts. Results of this long-term study, the first to be completed for a collegiate gymnastic team, will provide a blueprint for other collegiate programs. The United States Gymnastics Federation has offered to help disseminate the results of our program. Clearly, good nutrition is compatible with peak athletic performance, even in a sport such as gymnastics in which athletes place a premium on leanness.

LITERATURE CITED


ABOUT THE AUTHOR

Kathe Gabel is assistant professor in the Nutrition and Food Sciences Department, director of the Coordinated Undergraduate Dietetics Program at USU, and nutrition consultant for the USU Women's Gymnastic Team.
The U.S. Department of Agriculture first offered dietary counseling at the start of the twentieth century. Nearly 90 years later, consumers are still asking what they should eat to stay healthy. The publication of *Nutrition and Your Health, Dietary Guidelines for Americans* in 1980 by the U.S. Department of Agriculture and the U.S. Department of Health and Human Services (a second edition was released in 1985) was the first comprehensive guide developed, and was an important landmark in nutrition education. The seven guidelines, which told how to choose and prepare foods, were intended only for populations whose food habits were similar to those of Americans. These guidelines did not address the special needs of individuals with diseases or special nutritional requirements, who should rely on advice from registered dietitians and physicians.

The guidelines were carefully developed in order to accurately accommodate the needs of our diverse population. One earlier attempt to establish guidelines was unsuccessful. In February 1977, the U.S. Senate Select Committee on Nutrition and Human Needs published its guidelines in *Dietary Goals for the United States*, which recommended that Americans obtain 30 percent of calories from fat, 58 percent from carbohydrate and 12 percent from protein, and established guidelines for the intake of sugar, cholesterol and salt. The Dietary Goals were controversial and nutritionists and others had difficulty applying them to food selection. Diets consistent with these goals would result in substantial changes in average food consumption, and were not adopted by the U.S. Department of Agriculture.

These goals, however, focused on the need to develop federal guidelines concerning diet and health. Nutrition is a relatively young science that must continually incorporate additional findings. For this reason, the Dietary Guidelines were revised five years after their initial release. The original committee never viewed the Dietary Guidelines as final but as changing to accommodate new research findings.

While the guidelines are a much needed and welcome source of information, they have not answered all nutritional questions, nor, as noted above, was that their intent. And no matter how good the information, it is still subject to misinterpretation, as...
Even though there are about 10,000 different food items in the average supermarket, many Americans still don't select a variety of foods.

has been noted by several nutritionists. According to Paul A. Lachance (1986), "... food practices are the result of the sum of a person's culture and traditions, desires and emotions, character and experiences." No food guidance system can insure an adequate diet for everyone, and many factors cannot be controlled. Lachance suggested that nutritionists should seek a mechanism "to promote and assure good nutrition without constraining or dictating food choices and the other cultural and social functions of food."

Helen A. Guthrie (1987) pointed out that a change in one dietary component usually involves changes in other dietary components, thus modifying the benefits of the proposed change. For example, reducing total fat by cutting the intake of red meat also reduces intake of iron and zinc. Guthrie also noted that some people would misinterpret a recommendation to reduce consumption of a certain dietary component as a recommendation to eliminate the component, or a recommendation to increase intake of a component (e.g., fiber) to justify excessive consumption (e.g., consuming whole grains, fresh fruits and vegetables and a high-fiber supplement could cause gastrointestinal irritation and decrease the absorption of trace minerals).

The Dietary Guidelines have a major effect on the food industry. Kirk et al. (1987) stated that the industry can help meet the nutritional needs of consumers only if it is financially solvent and markets products with desirable attributes, including taste and appearance. Food products are not forced on consumers according to their nutritional requirements, but are marketed on the basis of consumer tastes and preferences. Industry can effectively influence consumers' choices, but their primary function is not to provide sound educational materials. In other words, nutritional information per se influences but does not dictate either consumer preferences or marketing.

The Dietary Guidelines have also affected agricultural production, particularly in encouraging the production of low-fat meat products. As noted in Designing Foods—Animal Product Options in the Marketplace: "A variety of initiatives within the private sector are well underway to reduce the fat content of animal products, increase their nutritional value, and present the consumer with better, clearer information about the nutrient content of these products."

Eat A Variety of Foods

These guidelines often have to be interpreted before consumers can use them to modify their eating habits. For example, what is meant by eating a "variety of foods"? There are about 10,000 different food items in the average supermarket and adults consume an average of 17 food items a day, not all of them different foods (Wolf and Peterkin 1984). It appears that consumers do not take advantage of the variety that already exists. Most emphasis on variety in diet concerns eating foods from different food groups, e.g., the four food groups. Eating foods from each of the groups does increase the variety of nutrients, but consumers tend to select the same or very similar, familiar foods from the groups instead of trying novel foods.

Maintain Desirable Weight

This seemingly straightforward guideline actually involves several questions. What is desirable weight? Is the same weight desirable for all people? How can a person best achieve desirable weight? There is no single answer for all people in such a diverse population. A successful diet is an adaptation to an individual's habits, culture and preferences. This guideline is also related to the guidelines concerning fat and sugar intake (some nutritionists believe that controlling fat and sugar intake will also let people maintain a desirable weight).
Avoid Too Much Fat, Saturated Fat and Cholesterol

The guidelines are criticized because no specific amounts are recommended for fat, cholesterol, sugar or sodium intake, as other agencies and organizations. The USDA committee avoided recommending amounts of specific nutrients since the guidelines were not intended to treat chronic disease but to prevent it. Supplemental materials provide more specific instructions. Total fat should not exceed 30-35 percent of calories (10 percent as saturated fat, 10 percent as polyunsaturated fat and 10 percent as monounsaturated fat). Most consumers do not take the time to learn the number of grams of fat in foods, even though the labels of packaged foods provide that information. Consumers can calculate the percentage of calories from fat as well as the total calories consumed by using the following formula:

\[
\text{percent calories from fat} = \frac{\text{grams of fat} \times 9 \text{ calories}}{\text{total calorie intake}}
\]

Information on food sources of saturated, polyunsaturated and monounsaturated fats is necessary to select the appropriate percentages of these different fats in the diet. Most fats are mixtures of the three types but some plant oils contain a higher percentage of polyunsaturated fatty acids. A diet should include a variety of types. Although it is difficult to determine how the guidelines have affected food habits, we do know that fat intake in the United States has changed over the last 10-15 years from 40-42 percent in 1977-78 to 36-37 percent in 1985-86.

Eat Foods with Adequate Starch and Fiber—Avoid Too Much Sugar

Since 1910, starch intake has tended to decrease and sugar intake has increased.
The Dietary Guidelines have not resolved all nutritional concerns, but they have helped many Americans apply research findings to improve their health.

tended to increase. Consuming more beans, peas, nuts, seeds, high starch vegetables, fruits and grains can reverse this trend. Although sugar and starch contribute equal amounts of energy on a weight basis, high starch foods also contribute other nutrients and fiber, which help maintain a healthy intestinal tract, and may reduce the risk of certain types of cancer, lower cholesterol levels and control blood sugar levels in diabetics. Not all the different types of fiber in foods have been analyzed. Old methods of analysis determined only crude fiber (material remaining after a series of laboratory tests involving harsh chemicals), while the new methods determine dietary fiber (the plant material that humans cannot digest) and the proportions of soluble (pectins and gums) and insoluble fibers (cellulose and hemicellulose), information which will make it easier to meet this guideline.

Avoid Too Much Sodium

It is very difficult to estimate the sodium intake and estimated intake ranges from 1,900 to 7,000 mg per day. Nevertheless, there is little doubt that Americans consume more sodium than they need. Food manufacturers have attempted to reduce sodium levels, consumers are demanding more low-sodium products and the sodium content has been added to the nutritional labels.

If You Drink Alcoholic Beverages, Do So in Moderation

Each gram of alcoholic beverage provides 7 calories and few nutrients. Excessive alcohol consumption can lead to nutritional deficiencies and other health problems due to loss of appetite, poor food intake and impaired nutrient absorption.

Conclusions

Even though the Dietary Guidelines did not resolve all nutritional con-

LITERATURE CITED


ABOUT THE AUTHOR

Georgia C. Lauritzen is associate professor and Extension nutrition specialist in the Nutrition and Food Sciences Department.
Plant Invaders Use Acid to Get Phosphates From Soil

A little acid seems to give tumbleweeds and halogoton the competitive edge in severe habitats, say soil scientists Lynn Dudley, J. J. Jurinak and Ted Howe.

Both plants are good at colonizing areas inhospitable to other plants, and both produce significant amounts of oxalic acid, which helps liberate phosphorus from the soil and makes it available for plant uptake.

Plant growth is limited by the element in shortest supply. In arid soils, phosphorus is often present in insoluble forms that are unavailable to the plant. The oxalic acid may increase phosphorus solubility from 10 to 100 times. The soil scientists are now developing more sensitive techniques to measure the effects of oxalic acid in arid soils.

Up, Up and Away:

SKY-HIGH WHEAT YIELDS

If they grow wheat in space, the farms may be tiny but the yields should be truly astronomical.

Experiment Station researchers studying how to maximize wheat yields for possible use in space farms developed a hydroponic system with 5,000 plants per square meter (10 to 20 times higher than field seeding rates), carbon dioxide concentrations four times that on earth, and 24 hours of light per day.

The result—as many as 7,000 heads of wheat per square meter and a photosynthetic efficiency of up to 10 percent. Comparable figures for record yields farm fields are 1,000 heads and an efficiency of 2.5 percent.

Forty-four percent of the biomass was grain, about the same percentage as in fields.

The researchers say most of the advantage of optimal environments appeared to be primarily due to increased efficiency of photosynthesis, which may be largely due to enrichment with carbon dioxide, although the hydroponic system and balanced nutrient uptake also probably helped.

REFERENCE

USU Researcher Studies Whey-Based Edible Film

Cereals that don't get soggy and crackers that won't wilt in high humidity are just two potential applications of a whey-based edible film being developed by an Experiment Station food scientist.

Paul Savello is using whey proteins to create a rigid molecular mesh, which could serve as the "backbone" for a moisture-resistant layer of lipids. The resulting bilayered edible film could have a variety of applications in the food and pharmaceutical industries.

He has created small amounts of the "backbone" from whey proteins and enzymes in test tubes, and is now trying to make larger quantities of the compound and examining its molecular structure.

Such a product could have several advantages. Starches now used to coat some products are not rigid and disintegrate when exposed to moisture. Whey-based films could enhance the nutritional value of foods and create high-value products from whey, a byproduct of cheese manufacturing.

More Utah Farmers Have a Date with LISA

Utah's agriculture—and its soil—plan to stick around forever, thanks in large part to 120,000 acres of low-input sustainable agriculture (LISA) conducted on the farms of cooperating farmers by the Utah Agricultural Experiment Station. In addition to saving soil, conservation tillage techniques promise to help agriculture even more.

Now LISA—low-input sustainable agriculture—promises to help agriculture even more. "LISA is an attempt to take agriculture into a form that can be sustained personally and environmentally," said Utah Agricultural Experiment Station scientist Paul Savello.

Substituting nitrogen-fixing plants for nitrogenous fertilizers, almost all of which are of cutting fertilizer expenses.

"Low input" does not mean "low output," as Experiment Station researchers proved with a conservation tillage system involving plants that fix nitrogen.

Researchers planted rye in the fall and then chopped it in the spring to a maximum of 10 inches of soil, planted Austrian winter peas, a cold-tolerant plant that fixes nitrogen, with rye, the producer added 35 pounds of natural nitrogen per acre. The cropping system, which wouldn't hold down weeds, thus cutting herbicide use.

Another double-cropping system involves the Miranda yellow protein pea, a protein that fixes about 80 pounds of nitrogen per acre, which wheat utilizes. The pea could be a "We're not just looking at no-till techniques, but at profit-maximizing systems. It's possible to maintain high productivity and soil quality," said Savello.

The Utah Agricultural Experiment Station conducts conservation tillage research at locations on the farms of cooperating farmers.

Researcher Says pH is the Culprit in this Raw Deal

If your hamburger looks like it's cooked, then it's probably no bull.

For several years, meat processors and purveyors have worried about hamburger that never quite looks like it's been cooked. It now appears that the uncooked appearance is due to high-pH meat (>5.7), according to food scientist Von Mendenhall.

The problem is more common in meat from bulls. Mendenhall checked the pH of ground beef from three purveyors for 150 consecutive internal temperature of 74°C. Hamburger patties within a normal range of pH (5.3-6.2) were slightly red to pink color when cooked.

Bull meat had a much higher pH (>6) and contained more pigment. Fifty-samples, 33 percent of the domestic bull meat samples, 30 percent of the two of trim had higher than normal pH.

Blending bull meat with a high pH (>6) with meats with a lower pH (<5.7) in particles probably wouldn't denature at the same rate. Mendenhall recommends a higher pH had a red to pink color when cooked.

It's no BULL!!!

Cutout days and also cooked samples to an i–5.7) had the grey color associated with after cooking while hamburger with a seven percent of frozen imported bull meat b-piece chuck and 24 percent of the samples may not solve the problem since the pigments that purveyors consider the pH of materials injecting lactic acid into boneless carcasses.

Changing Planting Patterns to

BOOST FRUIT YIELDS

Apple and peach growers could easily double or triple yields simply by changing how they plant fruit trees.

For more than a decade, researchers with the Utah Agricultural Experiment Station have consistently harvested more than 1,100 bushels of apples per acre by planting trees at the proper distance for a particular rootstock and using appropriate management. Some yields have topped 3,200 bushels per acre.

Average apple yields in Utah are about 300 bushels per acre.

Similar modified practices have increased peach yields, said horticulturist David Walker. When peach trees were planted 10 by 14 feet apart (311 trees per acre) instead of 20 by 20 feet apart (108 trees per acre), the cumulative yields increased by more than 3,000 bushels per acre over an 8-year period.

"These are the same trees planted the same day right next to each other," Walker noted. Everything was similar except the spacing.

The row orientation of trees as well as close spacing makes a big difference in yield. The yields of peach trees oriented in a north-south direction increased twice as much as those oriented in an east-west direction. Walker attributed the yield increases in the ability of light to reach foliage rather than being blocked by the outside row.

Walker said many growers in the state are not aware of this research and encouraged them to attend field days at the Kaysville research farm operated by the Utah Agricultural Experiment Station. With drip irrigation, it may even be possible to orient rows in a north-south direction on many steep slopes, Walker added.

"Many growers place too much emphasis on cultivating in two directions to control weeds," Walker said, a practice which increases the space required between trees. An alternative is to have grass sod and mow between rows and control weeds in the row with herbicides.

"These increased yields are possible with proper row orientation and require no additional fertilizer, water or pruning. All growers have to do is harvest and sell the additional fruit," Walker said.
Iron deficiencies are common in women, young children and low-income groups. Widely consumed dairy products seemed likely candidates for iron fortification, but the addition of iron was associated with off-flavors, says food scientist Art Mahoney.

Mahoney recently added an iron-milk protein complex to milk used to make cheese and yogurt, thus increasing iron content of these products without undesirable changes in color or flavor.

Iron content of cheeses and yogurts can be increased to at least 18 mg per 2,000 calories, the recommended daily amount for women, Mahoney says, and the iron is as bioavailable as that in meat and in iron supplements. More research is needed, but the iron-fortification procedure may be especially useful for dairy products used in school lunches and in free commodities for low-income recipients.

Lower Rates Help Power Utah Agriculture

The latest chapter in a cooperative program involving agricultural organizations and Utah Power and Light Company has cut irrigation pumping costs for Utah farmers by hundreds of thousands of dollars annually.

A recent agreement reduces pumping rates during the off-season from September 16 to May 24. Jay Andersen, an economist with the Utah Agricultural Experiment Station, said the agreement also benefits the power company and ratepayers because it encourages the productive use of electricity in the state. Much of this electricity would otherwise be sold out of state at similar rates.

The agreement approved by the Public Service Commission in February establishes a post-season rate of about 3 cents per kilowatt hour. The previous post-season rate was 7.2 cents per kilowatt hour.

Andersen said the new post-season rates will be of particular benefit to users in southern Utah, who should make sure the soil profile is filled prior to the designated irrigation season, which begins May 25. Irrigation to accomplish this could be done in the fall or the spring. The new rates will also make it more economical for growers in the northern part of the state to irrigate fall grain.

For more than eight years, Andersen has helped implement lower rates for irrigation pumping during times of off-peak demand for electricity. The post-season rates should result in savings of about 5 percent of total annual pumping costs, or about $300,000 annually. Savings over the years due to the reduced rates total several million dollars, and have enabled some growers to stay in business.

Annual irrigation pumping costs in the state have declined from about $10 million in the early 1980s to about $6 million, in large part because many farmers have discontinued irrigation.

The Utah Irrigation Pumpers Assn., the Utah Farm Bureau Federation, and the Committee of Consumer Services have spearheaded efforts to reduce irrigation pumping rates.
People who are fasting or on low-carbohydrate diets exhibit many of the symptoms associated with diabetes. Pantothenic (a Greek word meaning "from everywhere") acid is a B vitamin. The vitamin is found in many foods and recognized deficiencies are uncommon. A Recommended Daily Allowance for the vitamin has not been established. Pantothenic acid and other vitamins, which cannot be made by the body and must be provided in the diet, are incorporated into coenzymes necessary for various metabolic reactions.

Pantothenic acid is converted into coenzyme A, which is essential in the metabolism of carbohydrates and lipids, and in the synthesis and degradation of fatty acids. Acetyl coenzyme A is the precursor of cholesterol, fatty acids and many other compounds. These associations indicate that there may be a relationship between lipid levels and coenzyme A; because coenzyme A is ingested in the form of pantothenic acid, there might also be a correlation between dietary intake of pantothenic acid and lipid levels.

Coenzyme A is vital to the citric acid cycle, which is the final common pathway in the metabolism of free fatty acids, carbohydrates and amino acids. In the cycle, acetyl coenzyme A is metabolized to form carbon dioxide, hydrogen atoms and energy. Fats, which are stored as triglycerides, are broken down into free fatty acids and then to acetyl-coenzyme A, which cells use to produce energy through the citric acid cycle.

The research reported here concerned the possible correlation between pantothenic acid status and circulating lipid levels, information that might be particularly useful in the diagnosis and treatment of metabolic conditions caused by abnormal energy metabolism, such as diabetes and some forms of obesity.

Diabetes is a metabolic disease that affects the efficiency of carbohydrate utilization. Carbohydrates are normally used as energy sources in the citric acid cycle, but diabetes decreases the efficiency of utilization of carbohydrates and increases the mobilization of fat from fat storage cells. This often elevates levels of serum lipids, both of triglycerides and free fatty acids. In addition, uncontrolled diabetes elevates levels of B-hydroxybutyrate (the major ketone body associated with diabetes) as the body relies almost entirely on stored fat for its energy. Tissue levels of coenzyme A in the liver are grossly elevated when diabetes is experimentally induced in laboratory animals, possibly reflecting an increased need for the coenzyme.

People who are fasting or on low-carbohydrate diets exhibit many of the symptoms associated with diabetes. Carbohydrate stores in the body are rapidly depleted and the body switches to stored fat as its primary energy source. This increases mobilization of lipids as in diabetes. Fasting also results in high levels of B-hydroxybutyrate.

Based on the results of preliminary experiments, we hypothesized that diabetes may be associated with an increase in the pantothenic acid requirement.

Preliminary Studies
A diet deficient in pantothenic acid was formulated and pantothenic acid was then added to the diet: 0 mg per kg diet (deficient), 10 mg per kg diet (recommended or normal amount), and 100 mg/kg (supplemented).

Both diabetic and nondiabetic rats were used in the early experiments. Diabetes was chemically induced in the animals and the rats were then divided into groups. Nondiabetic rats received diets that contained either deficient, normal or high (supplemented) levels of pantothenic acid. Diabetic rats received deficient and normal diets. Serum was periodically drawn to determine levels of free fatty acids and triglycerides. Rats were fasted before serum was drawn.
Deficient FFA = free fatty acid levels
Enriched TG = triglycerides levels
BOH = B-hydroxybutyrate levels

FIGURE 1. Three- and twenty-four-hour tests.
Pantothenic acid decreased unnaturally high lipid levels, whether due to fasting or diabetes.

Within 2 weeks, rats on the diet deficient in pantothenic acid had significantly higher levels of serum triglycerides and free fatty acids. After 6 to 7 weeks on the diets, rats on the diet deficient in pantothenic acid lost significantly more weight than rats on the normal diets. There were no significant differences in the weights of rats on the normal and supplemented diets.

Diabetic rats on the deficient diet lost significant amounts of weight after 2–4 weeks while nondiabetic rats on the same diet lost weight after 6–7 weeks. Serum lipid levels were higher in deficient rats than in rats on a normal diet. When they received a normal diet, lipid levels of diabetic rats were higher than their nondiabetic counterparts.

Another experiment involved feeding nondiabetic rats different sources of dietary lipids that represented the major types of fat in food (corn and safflower oil, which are predominantly linoleic acid), medium-chain triglyceride oil (octanoic and decanoic acids), maxEPA fish oil (large polyunsaturated fats), and lard (oleic acid). This experiment sought to maximize any dietary effects. However, there were no significant differences in the serum lipid levels between dietary sources.

The results of these experiments were consistent with our hypothesis that diabetes increases the requirement for pantothenic acid. Pantothenic acid decreased unnaturally high lipid levels, whether due to fasting or diabetes.

Recent Experiments

We conducted several experiments with nondiabetic rats (thus eliminating one cause of abnormal lipid metabolism) in an attempt to better understand the mechanism associated with the elevation in lipid levels. We wanted to determine in greater detail the conditions under which the pantothenate deprivation affected lipid levels.

Effect of Fat Levels

Another experiment involved feeding rats diets containing either 20, 30 or...
FIGURE 2. Free fatty acids (FFA) levels with varying fat.

FIGURE 3. Triglycerides (TG) levels with varying levels of fat.
Pantothenic acid supplementation can decrease levels of free fatty acids, triglycerides and B-hydroxybutyrate.

40 percent fat; as a test of the accuracy of pair feeding, another group of rats received a diet containing 30 percent fat and was allowed to eat ad libitum. The pair-fed rats on the diets deficient in pantothenic acid containing 30 and 40 percent fat lost a significant amount of weight after 2 weeks, as did the rats that were allowed ad libitum access to food. Lipid levels were determined after rats had been on the diets for 2 weeks and had fasted for 24 hours (Figs. 2 and 3). Serum-free fatty acid levels were nearly twice as high in rats receiving a diet deficient in pantothenic acid as in rats fed normal levels of the vitamin. Serum levels of rats on the deficient diet containing 30 percent fat were 26 percent higher (p = .002) than in rats fed an enriched diet. When rats were fed diets containing 40 percent fat, there was no significant difference in the lipid levels of rats on deficient and normal diets.

Lipid levels increased more in rats fed a low-fat diet. Free fatty acid levels were nearly constant in rats on a diet containing adequate amounts of pantothenic acid but varied considerably in rats fed a diet deficient in that vitamin. The results were similar for serum triglyceride levels (Fig. 3). On diets deficient in pantothenic acid, triglyceride levels were 86 percent higher (p = .013) when rats received a diet containing 20 percent fat and were 22 percent higher (p = .022) when rats received a diet containing 40 percent fat. Again, the lipid levels were relatively constant in rats receiving adequate levels of pantothenic acid, regardless of the manner of feeding or the amount of dietary fat. Serum pantothenic acid levels were 6–8 times higher in animals fed enriched diets. Serum B-hydroxybutyrate levels were elevated in all of the animals fed diets deficient in the vitamin. The total amount of coenzyme A in the liver was also measured. When rats were fed enriched diets containing 20 percent fat, levels of coenzyme A were 84 percent higher than in rats on a diet deficient in pantothenic acid. When diets contained 30 percent or 40 percent fat, levels of coenzyme A in rats fed enriched diets were 52 percent and 71 percent higher, respectively, than in rats fed a diet deficient in the vitamin. These results show that coenzyme levels were positively correlated with the amount of pantothenic acid in the diet. The elevation in serum lipid levels due to pantothenic acid deficiency also depended on the amount of fat consumed. These findings may help adjust diets to either minimize the adverse effects of metabolic imbalances or to maximize the beneficial effects of treatment with pantothenic acid.

Conclusions
An early symptom of pantothenic acid deprivation is a noticeable elevation in levels of serum-free fatty acid, triglycerides and B-hydroxybutyrate. Over an extended period of time, significant weight loss also occurs. Similar symptoms are associated with diabetes.

These experiments examined the relationships between the types of lipids and pantothenic acid metabolism. The elevation in levels of fatty acids, triglycerides and B-hydroxybutyrate seems to be independent of the source of dietary lipids, but does vary with the relative amount of dietary fat. Pantothenic acid supplementation can decrease the levels of free fatty acids, triglycerides and B-hydroxybutyrate. These findings may be useful in understanding diabetes, obesity/anorexia and other disorders involving energy metabolism.

ABOUT THE AUTHORS
Sullivan Beck is a graduate student in chemistry at USU.
Carl T. Wittwer is an adjunct assistant professor at USU and an assistant professor at the University of Utah.
Bonita Wyse is the dean of Family Life and a professor in the Nutrition and Food Sciences Department.
CARROTS
WITH MORE VITAMIN A
C. SCHWEITZER
Vitamin A deficiency is the primary cause of blindness in children worldwide, particularly in developing countries where thousands of preschoolers annually develop xerophthalmia, an inflammation of the eye caused by lack of vitamin A. If untreated, about half of the children will become blind and many will die (McLaren 1986). Several methods used to alleviate vitamin A deficiency, such as food fortification and interval dosing with vitamin A capsules, have had variable results. It is difficult to treat all afflicted children, particularly since some of the treatments are relatively expensive and not completely effective (Pitt 1985).

The most suitable long-term approach to correct vitamin A deficiencies is to promote the cultivation and consumption of inexpensive vegetables rich in beta-carotene or other provitamin carotenoids. Vegetables are the most economical source of vitamin A (U.S. Department of Health and Human Services and U.S. Department of Agriculture 1986). Horticulturists Phil Simon and the late Clinton Peterson, both with the Agricultural Research Service at the University of Wisconsin at Madison, have produced several carrot hybrids that contain two to three times the normal amount of vitamin A (as alpha and beta-carotene). The vitamin A potency of one of these hybrids, Beta-III, is being evaluated in the USU Department of Nutrition and Food Sciences. This hybrid apparently has the best growth potential in tropical climates and resistance to blight, and might be particularly valuable in correcting vitamin A deficiency.

Importance of Carotenoids

The carotenoids are a group of pigments named for the food in which they predominate, the carrot root, *Daucus carota*, one of the first foods found to possess carotenoids (Klaui and Bauernfeind 1981). Klaui and Bauernfeind report there are more than 500 carotenoids, but only about 55 are precursors to retinol, the active form of vitamin A (Fig. 1). Beta-carotene (Fig. 2), the most prevalent plant food carotenoid, has the highest vitamin A activity. The common ratio of vitamin A potency (on a weight basis) is six beta-carotene to one retinol. Beta-carotene can be centrally cleaved to yield two molecules of retinol; however, excentral or random cleavage also occurs and reduces its activity as vitamin A. Inefficient absorption of carotenes also contributes to their low vitamin A activity. Slight structural differences in other carotenoids, such as alpha-carotene (Fig. 3), reduces their vitamin A activity.

Carotenoids in foods are an important source of vitamin A. Americans derive approximately 50 percent of their vitamin A from the provitamin A carotenoids; the rest is derived
Americans derive approximately 50 percent of their vitamin A from carotenoids in foods. In developing countries, carotenoids account for as much as 80 percent of the vitamin A consumed.

### TABLE 1. Carotene content.

<table>
<thead>
<tr>
<th>Carrot</th>
<th>Alpha-carotene $\mu g/g$</th>
<th>Beta-carotene $\mu g/g$</th>
<th>Retinol equivalents RE/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nantes Coreless</td>
<td>20-80</td>
<td>50-100</td>
<td>9-22</td>
</tr>
<tr>
<td>Beta-III</td>
<td>50-120</td>
<td>90-200</td>
<td>20-50</td>
</tr>
</tbody>
</table>

Chemical Analyses

A complete nutrient profile of the Beta-III carrot is being compared to that of a commercially available carrot, Nantes Coreless. Beta-III seeds from the University of Wisconsin were grown locally. Nantes Coreless seeds purchased locally were grown in Wisconsin. The protein, fat, moisture, dietary fiber and carotene content of the carrots are being determined in our laboratories. Extensive carbohydrate analyses for starch and sugars are being conducted at the USDA Nutrient Composition Laboratory of Betty Li in Beltsville, Md. The results may explain why the flavors of Beta-III and Nantes Coreless differ. (Beta-III is considered to be sweeter.)

Quantitative analysis of carotenoids involves extraction from carrot tissue with organic solvents. The extraction product was then analyzed with a High Performance Liquid Chromatography (HPLC) system, which separates compounds according to characteristics such as polarity. These compounds are then detected according to their absorption of ultraviolet or visible light; each compound produces a unique chromatograph. The results of HPLC analysis were used to estimate vitamin A potency using the conversion factors described above.

There was considerable variation in the carotene content of samples of both carrot types (Table 1). Some of the variability was due to maturity of the carrot; the older the carrot, the greater the carotene content. This trend was also observed in the seeds; carrots grown from the same seed stock contained more carotene the second year of planting, as is reflected in the retinol equivalents (RE) shown in Table 1. The Beta-III hybrid generally contained at least twice as much vitamin A as Nantes Coreless. Actual biological vitamin A activity was determined in animal assays.

Animal Studies

Several types of assays are available to determine vitamin A activity. Two commonly used methods were employed to compare the vitamin A potencies of Beta-III, Nantes Coreless, purified beta-carotene and retinyl acetate.

Liver Storage Assay

This assay utilizes an animal’s ability to store vitamin A (predominantly in the liver) as an indication of vitamin A activity. Male weanling rats were fed a diet adequate for all nutrients except vitamin A for 3 weeks. (Animals were housed at the USU Laboratory Animal Research Center.) During this time, liver stores of vitamin A diminished, but vitamin A
STRUCTURES OF VITAMIN A AND PROVITAMIN A CAROTENES

FIGURE 1. Vitamin A retinol.

FIGURE 2. Beta-carotene.

FIGURE 3. Alpha-carotene.

FIGURE 4. Retinyl ester, retinyl acetate.
Alpha-carotene in both types of carrots may have contributed more to vitamin A levels than indicated by the conversion factors.

<table>
<thead>
<tr>
<th>Vitamin A source</th>
<th>Average liver wt. gm ± S.D.</th>
<th>Average retinol µg/gm liver ± S.D.</th>
<th>Total retinol µg ± S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total vitamin A fed: 600 RE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retinyl acetate</td>
<td>10.41 ± 0.70</td>
<td>57.90 ± 11.06</td>
<td>594.7 ± 91.2</td>
</tr>
<tr>
<td>Beta carotene beads</td>
<td>10.36 ± 0.81</td>
<td>39.29 ± 9.85</td>
<td>408.9 ± 110.5</td>
</tr>
<tr>
<td>Beta-III carrots</td>
<td>10.46 ± 0.89</td>
<td>38.10 ± 3.82</td>
<td>396.8 ± 36.3</td>
</tr>
<tr>
<td>Nantes Coreless</td>
<td>10.63 ± 0.97</td>
<td>38.94 ± 6.10</td>
<td>416.1 ± 87.9</td>
</tr>
<tr>
<td>Total vitamin A fed: 300 RE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retinyl acetate</td>
<td>10.91 ± 0.55</td>
<td>36.96 ± 3.94</td>
<td>403.5 ± 48.4</td>
</tr>
<tr>
<td>Beta carotene beads</td>
<td>10.34 ± 0.79</td>
<td>31.73 ± 6.41</td>
<td>328.1 ± 73.0</td>
</tr>
<tr>
<td>Beta-III carrots</td>
<td>10.80 ± 0.74</td>
<td>36.15 ± 4.37</td>
<td>389.1 ± 45.2</td>
</tr>
<tr>
<td>Nantes Coreless</td>
<td>10.29 ± 0.60</td>
<td>36.95 ± 3.07</td>
<td>380.0 ± 36.5</td>
</tr>
</tbody>
</table>

deficiency was not produced. Four sources and two levels of vitamin A were administered to the animals that were randomly placed in one of eight groups. The vitamin A sources were 1) freshly washed, peeled, grated and analyzed Beta-III carrots, 2) similarly prepared Nantes Coreless carrots, 3) beta-carotene beadlets and 4) retinyl acetate beadlets appropriately added to the deficient feed. The beta-carotene and retinyl acetate beadlets served as standards. One-third of the total dose was given on 3 consecutive days following the depletion period. Forty-eight hours later the animals were sacrificed, livers excised, frozen and stored under nitrogen gas at -70°C until analyzed for retinol content.

Analysis of variance indicated significant differences \((p < .001)\) in the response to different sources and levels of vitamin A (Table 2). In all except one case, the differences were due to retinyl acetate. The lack of significant differences in liver weights meant that average retinol levels \((\mu g/g\) liver\) were very similar to total retinol levels.

Figure 5 is a graph of the interaction between source and level of total vitamin A. At a dose of 600 RE, the conversion of carotenes to vitamin A was at a maximum, thus preventing the liver retinol concentration from increasing, which occurred when retinyl acetate was fed because there is no mechanism to stop the conversion. At a dose of 300 RE, there were no significant differences in average liver retinol concentration among the sources of vitamin A; however, livers of rats receiving beta-carotene contained significantly less total retinol than rats fed the other sources. This may mean that alpha-carotene in both types of carrots contributed more to vitamin A levels than indicated by the conversion factors. Results suggest that the carotenes in Beta-III and Nantes Coreless carrots have equivalent bioavailabilities.

Curative Growth Assay

This study utilized the physiological requirement of vitamin A for growth to compare the relative potency of vitamin A in the carrots to vitamin A standards.

Male weanling rats were fed a diet deficient in vitamin A until their stores were depleted, as indicated by a plateau in weight gain. Weight was initially recorded twice a week, then daily as the plateau was reached. Rats received one of four vitamin A sources at one of three levels for 4 weeks. Growth was monitored by daily weight records, and vitamin A potency was calculated according to weight gain.

Preliminary results indicate that
the bioavailability of the concentrated carotenes in Beta-III carrots is similar to that of the carotenes in regular (Nantes Coreless) carrots (data not shown). Statistical analyses are underway to confirm these observations and to elucidate any differences attributable to vitamin A sources.

ACKNOWLEDGMENTS

The HPLC techniques used in this study were taught by Gary Beecher and Fred Khachik, USDA Nutrient Composition Laboratory, Beltsville, Md.

ABOUT THE AUTHOR

Cynthia M. Schweitzer is a PhD candidate in the Nutrition and Food Sciences Department. Her major professor is Carol Windham.

LITERATURE CITED


FIGURE 5. Total retinol in livers by source and level.
Solutions to many of today's nutritional problems require that consumers understand and utilize nutritional information. A labeling system developed at USU called the Index of Nutritional Quality (INQ) can help consumers in both areas.

The basic assumption underlying the INQ is that a diet should provide just enough energy (calories) and all of the other nutrients required for health. The Index of Nutritional Quality makes it relatively easy to relate the amount of nutrients in a food to energy; the system also provides a wealth of other useful information.

The most widely accepted standard of nutrient intake is currently the National Research Council's Recommended Dietary Allowances (RDA); however, this system was designed for use by nutritionists and researchers and is difficult for most consumers to utilize. A "consumer-friendly" system based on nutrient density relates the RDA to calories, a term that most people readily understand. Such a system maintains nutritional accuracy without sacrificing convenience.

The British use a similar system to express protein allowance (25 grams per 1,000 calories, the median RDA for various ages and both sexes). Expressing nutrient allowances in this manner has several advantages, among them flexibility to accommodate new findings and compatibility.
with computer analyses. The Index of Nutritional Quality defines the relationship between the nutrient content of food and human allowances for those nutrients according to the following equation:

\[
\text{INQ} = \frac{\text{Percent of nutrient allowance}}{\text{Percent of energy requirement}}
\]

The resulting INQ is simply a ratio, an indication of nutritional quality in relation to calories. It is important to remember that this system expresses the quality of a food without the confusing units associated with the metric and the British systems of weights and measures.

This information is easy to illustrate and comprehend, as is evident in the INQ of milk containing 2 percent fat (Fig. 1). The vertical line represents the percentage of recommended daily caloric intake while the horizontal bars show the various nutrients in a cup as a percentage of recommended daily intake, e.g., a cup of 2 percent milk contains 6 percent of the recommended calories and about 33 percent of the recommended calcium. The INQ for calcium is 5.4 (33.1 percent divided by 6.1 percent). A food with a substantial number of the important nutrients in excess of calories (INQs greater than 1) is of good quality. A food containing calories in excess of nutrients will have INQs of less than 1, which means that a person would have to
The INQ system reduces the risk of either deficiencies or toxicities, which is particularly important as people reduce their caloric intakes.

---

**Lowfat milk - 2% fat (245 g)**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>INQs</th>
<th>%</th>
<th>STD</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>1.0</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>5.4</td>
<td>33.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>0.9</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riboflavin</td>
<td>5.3</td>
<td>32.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>0.8</td>
<td>4.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>2.6</td>
<td>16.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1.0</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.9</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>0.9</td>
<td>5.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 1.** Nutrient profile of lowfat milk using the Index of Nutritional Quality (INQ).

consume excessive calories from these foods to obtain the recommended quantities of nutrients. As is apparent from the INQs, 2 percent milk is also a good source of potassium, vitamin A, riboflavin and protein.

To offset the "short-bar" nutrients in a food profile, a consumer would simply have to select complementary foods with "long-bars" for those nutrients. Using a standard format for all food graphs would make it even easier to select foods to obtain adequate amounts of the needed nutrients.

In other words, the goal in selecting foods would be to have the INQs of the nutrients and energy all be 1 or greater.

Surprisingly, the relative simplicity of the INQ tends to confuse some nutritionists, who tend to focus on how the numbers were derived rather on what the INQ illustrates. On the other hand, youngsters seem to intuitively understand the meaning of the information.

**Determining Nutrient Allowances**

Much remains to be learned about the optimum human requirements for nutrients. The observation and correction of nutritional deficiencies and interpretation of the results of studies involving animals have been instrumental in determining requirements. In animal studies, a deficiency of a particular nutrient often impairs growth, although many other adverse physiological consequences are possible, including reproductive failure, blindness (vitamin A deficiency), poor bone development (vitamin D), goiter (iodine), etc. As shown in Figure 2, performance increases as more of the deficient nutrient is supplied; once optimum performance is achieved, however, supplying more of the nutrient does not enhance the response and may even result in toxicity. The same principles apply in human nutrition.

Results of animal studies provide information about a nutrient's role in human nutrition, as do levels of the nutrient and related metabolites or enzymes in human tissue. The recommended intake for a particular nutrient may often involve a range of values. Thus, the simplified RDAs used in calculating INQs are certainly accurate enough to guide the selection of foods.
Selenium is an example of the some of the problems associated with efforts to assess nutritional adequacy. In some areas of the state, feeds contain so much selenium that they may be toxic to young ruminants; in other areas of the state, feeds are deficient in selenium. The “window of adequacy” (amounts that prevent deficiency or toxicity) for selenium is fairly narrow; toxicities or deficiencies can best be avoided by selecting feeds grown on different types of soil.

The situation is similar for some nutrients important in human nutrition. Some nutrients have similar narrow limits between adequacy and toxicity, e.g., some essential trace minerals such as copper and molybdenum, and fat-soluble vitamins. The consumption of nutrient supplements often makes it difficult to balance nutrient intake; the best advice is to consume a variety of foods. The INQ system simplifies this task for consumers, and reduces the risk of either deficiencies or toxicities. This is particularly important as people reduce their caloric intakes.

**Solving Nutritional Problems**

Obesity is the leading nutritional problem in America. The INQ system can help those who are reducing their intake of calories achieve a balanced intake of nutrients. It also makes it easier to compare diets on a daily or weekly basis—the composition of individual foods can simply be added and displayed.

The Index of Nutritional Quality can also help solve another important nutrition-related problem, the consumption of foods that contain “empty” calories—fats, sweets and alcohol. These foods “dilute” the nutrients in the diet since they provide mainly calories and few nutrients. The index clearly identifies foods in this category.

The value of the index in selecting foods for nutritional quality is evident by examining how nutrients dilute the nutrients in a food; for example, compare the INQs of a baked potato (Fig. 3), french fries (Fig. 4) and potato chips (Fig 5).

The information provided by the INQ system is consistent with the following advice offered in *Food*, a recent USDA publication:

In general, the amount of these foods to use depends on the number of calories required. It is a good idea to concentrate first on the calorie-plus-nutrients foods provided in the other groups as the basis of your daily diet. Fats and oils have more than twice the calories, ounce for
No individual foods have a perfect nutritional balance, but the 20 or so foods that we select daily can supply a proper balance of nutrients.

Baked potato (150 kcal)

<table>
<thead>
<tr>
<th>INQs</th>
<th>% 0 10 20 30 40 50 STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>1.0</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>7.2</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>2.7</td>
</tr>
<tr>
<td>Folacin</td>
<td>1.0</td>
</tr>
<tr>
<td>Pantothenic Acid</td>
<td>1.6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.2</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.7</td>
</tr>
<tr>
<td>Fat</td>
<td>0</td>
</tr>
<tr>
<td>Sodium</td>
<td>0</td>
</tr>
</tbody>
</table>

FIGURE 3. Nutrient profile of a baked potato.

French fries (150 kcal)

<table>
<thead>
<tr>
<th>INQs</th>
<th>% 0 10 20 30 40 50 STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>1.0</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>2.6</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>0.7</td>
</tr>
<tr>
<td>Folacin</td>
<td>0.4</td>
</tr>
<tr>
<td>Pantothenic Acid</td>
<td>1.0</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.6</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.6</td>
</tr>
<tr>
<td>Fat</td>
<td>1.2</td>
</tr>
<tr>
<td>Sodium</td>
<td>0</td>
</tr>
</tbody>
</table>


Food Labeling

The goal in food selection is to make food choices that provide complementary nutrients—not to label foods as "good" or "bad."—and to balance nutrient intake on a daily or weekly basis. No individual foods have a perfect nutritional balance, but the 20 or so foods that a person selects each day can supply a proper balance of nutrients.
Potato chips (150 kcal)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>INQs</th>
<th>STD 0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>1.0</td>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.9</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;6&lt;/sub&gt;</td>
<td>0.3</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folacin</td>
<td>0.2</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pantothenic Acid</td>
<td>0.6</td>
<td>4.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.2</td>
<td>8.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>1.1</td>
<td>7.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1.8</td>
<td>13.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>1.6</td>
<td>11.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 5. Nutrient profile of potato chips.

![Figure 5: Nutrient profile of potato chips](image)

Several surveys have shown that consumers neither use nor understand the current system of food labeling, in part because the various units used to indicate nutrient content are difficult to interpret. The system based on the Index of Nutritional Quality is easily understood, even by children in elementary school. Furthermore, most consumers now expect information to be presented in an attractive format, which is possible with the INQ system.

Food labels currently display about a dozen of the 45 or so required nutrients, based on the assumption that those who consume these nutrients from a variety of foods will also consume appropriate amounts of the other nutrients. This was a reasonable assumption when people tended to consume a variety of foods.

![Figure 6: Per capita consumption of beverages in gallons, 1965-1985 (USDA)](image)
Many people derive 10 percent of their calories from soft drinks and another 7 or 8 percent from alcoholic beverages, factors which increase the importance of wise food choices.

FIGURE 7. Fiber.

value of fiber, which is largely provided by vegetables, fruits and unrefined cereals. The physical and chemical properties of fiber aid digestive processes. The Index of Nutritional Quality can identify foods high in fiber. (See Figure 7. Each point on the curves includes the percentage of foods with a given INQ plus those with a lower INQ, e.g., about 25 percent of the grains and grain products had INQs for fiber of 0.3 or less.) The trimodal distribution shows foods containing cereals can be grouped in three categories: 1) unrefined cereals (high fiber, INQ = 1), 2) foods made from 70 percent extraction flour (intermediate fiber), and 3) cakes, cookies and other refined products (low fiber).

Fiber intake appears to have decreased since the turn of the century, a trend that is likely to be reversed with the increased interest in fiber. Because fat and sugar consumption is likely to decrease as people consume more fiber, fiber enrichment of foods is neither necessary nor desirable. Fiber levels are adequate if foods provide 5 to 10 grams of fiber per 1,000 calories.

Conclusion
It is ironic that increased interest in
good nutrition and increased knowledge about the availability and role of nutrients coincide with difficulty in effectively communicating nutritional information to consumers. The popularity of fad diets and misconceptions about food are indicative of this gulf between knowledge and practice.

A labeling system based on the Index of Nutritional Quality could do much to bridge this gulf and would facilitate inexpensive solutions to many nutrition-related problems. As people reduce their caloric intake and consume more "nutrient-empty" foods, it becomes more important to accurately assess the nutrient composition of foods and to better define nutrient requirements. It is equally as important to communicate this information in a form that consumers can utilize.

ABOUT THE AUTHORS

R. Gaurth Hansen is distinguished professor emeritus in the Nutrition and Food Sciences Department.

Carol Windham is assistant professor in the Nutrition and Food Sciences Department.

Bonita Wyse is the dean of Family Life and a professor in the Nutrition and Food Sciences Department.

LITERATURE CITED

Most people recognize the complex relationships between diet and health. As our knowledge has increased, however, so have misconceptions. Many Americans attribute their poor health to food that has "lost" its nutritional value (allegedly due to over-processing), artificial formulations, imitation and substitute foods, specialized fruit and vegetable varieties, production agriculture and industrialization of the food supply. These and similar concerns are used to justify taking vitamin, mineral, protein, and other supplements to compensate for the supposed nutritional inadequacy of diets.

Are these concerns warranted? In spite of widespread claims to the contrary, there is no basis for the indiscriminate use of dietary supplements to guarantee nutritional adequacy. Such a practice is wasteful, and may even be harmful. Moreover, dietary supplements may divert attention from the importance of a balanced diet.

Research has clearly shown that an adequate diet is one based on foods rich in the various nutrients; this is usually accomplished by selecting a large variety of foods from each of the fruit and vegetable, cereal, meat and dairy food groups. The amount of each food must be balanced so the overall diet provides enough of each nutrient. However, the results of several studies indicate that most people do not obtain the Recommended Dietary Allowances (RDA) of critical nutrients such as iron (Black et al. 1986; Farley et al. 1984a, 1985, 1987; Mahoney et al. 1985) and calcium (Farley et al. 1984b) because they do not consume adequate amounts of food rich in these nutrients.

Iron is involved in transporting oxygen to the cells, thus enabling them to utilize the energy in nutrients that fuels our bodies. Iron is also essential in enzymes that detoxify many toxic compounds and that metabolize neurotransmitters essential for our mental and physio-
logical well-being. Iron deficiency can be characterized by anemia, dizziness and impaired physical and mental health. In children, iron deficiency impairs growth.

Our iron requirements can be readily met from the diet, as Farley, et al. (1987) found when they studied diets containing at least 18 milligrams of iron per 2000 kcal, the intake levels of iron and energy recommended for women of childbearing age (NAS/NRC 1980). As the iron density of the diet increased, intakes of energy and fat decreased and intake of crude fiber increased. In iron-dense diets, 31.2 and 33.1 percent of the kcal were supplied by fat; these diets supplied 4.6 and 3.9 grams of crude fiber per 1000 kcal, respectively, for women and men, which are well within the current guidelines for fat intake. In diets low in iron density, about 38 percent of the kcal were supplied by fat; these diets supplied only 2.1 grams of crude fiber per 1000 kcal. People consuming high-iron density diets ate more fruits, vegetables and whole-meal cereal products and less high-fat and high-sugar foods. Diets low in iron included more pastries, beverages, sweets and added fats.

These findings were used to develop the following profile of iron-dense diets: a) 16 to 18 percent of the energy (280-360 kcal) was supplied by meat and eggs, b) at least 11 percent of the energy (220 kcal) was from vegetables and vegetable juices, c) 13 to 18 percent of the dietary energy (260-360 kcal) was from fruits and juices, d) 14 to 16 percent of the dietary energy (280-320 kcal) was from cereal grain products, e) approximately 15 percent of the energy (300 kcal) from dairy products to ensure adequate calcium intake, and f) the remaining 22 to 31 percent of the energy (440-620 kcal) derived from other foods and beverages.

The body actually requires much less iron than our diets provide. The body needs only 1 to 2 milligrams of iron; women consume about 13 milli-

S PRIN G 1989 55
Meat provides about 20 percent of the total dietary iron and about 40 percent of the bioavailable dietary iron.

Two Forms of Iron
Considerable research at USU has concerned iron bioavailability, the proportion of dietary iron that is incorporated into the body. Two forms of iron are absorbed by the intestines, heme iron and nonheme iron. Heme iron is found in red blood cells as hemoglobin and in the red pigments of meat as myoglobin. We obtain most heme iron from meat, fish and poultry.

Depending on the cooking method, between 42 and 68 percent of the iron in meat is heme iron and 47 to 69 percent of the iron is retained in the meat (Fig. 1) (Buchowski et al. 1988, Jansuitivechakul et al. 1985). However, researchers assume that about 40 percent of the iron in meat, fish and poultry is heme iron and that the remaining iron in meat, fish and poultry, as well as the iron in foods from plants or the iron in supplements, is nonheme iron (Monsen et al. 1978). During digestion, the body obtains dietary heme iron from the proteins that contain heme, e.g., hemoglobin and myoglobin; heme iron is absorbed into the intestinal mucosa (the first layer of cells lining the intestinal lumen) as the intact heme complex. This heme complex is broken down by heme oxygenase and the iron is released for metabolism. About 23 percent of the dietary heme iron is considered absorbable (Monsen et al. 1978, NAS/NRC 1980). Many diets with high iron availability contain large amounts of heme iron. We found that meat provides about 20 percent of the total dietary iron consumed by certain populations (Black et al. 1987, Farley et al. 1987); because of its high content of heme iron, meat supplies about 40 percent of the bioavailable dietary iron (Black et al. 1987).
The dietary nonheme iron released from the food during digestion (food iron is always bound to some food component) is solubilized, converted to the ferrous state, and absorbed into the intestinal mucosa by a carrier, a protein in the mucosal cells lining the intestinal lumen. Nonheme iron in the lumen of the intestine contacts the carrier at the surface of the cell membrane. This carrier transports the iron into the cell and releases it. The carrier will attach itself only to ferrous iron. Once nonheme iron is absorbed, it can be metabolized in the same way as heme iron. We have found that diets containing cereals rich in nonheme iron also are high in available iron (Black et al. 1987).

**Factors Affecting Iron Absorption**

Many factors affect the absorption of nonheme iron from the diet (Mahoney and Hendricks 1984). *Ascorbic acid* enhances nonheme iron absorption (Fig. 2), whether it is supplied by food or supplements (Hallberg et al. 1986). It is believed that ascorbic acid enhances the absorption of nonheme iron in two ways: a) its acidity solubilizes nonheme iron and then it forms a complex with it, and b) it reduces ferric nonheme iron in solution to ferrous iron, which forms a complex with the carrier protein in the cell membranes of the intestinal mucosa. *Meat* enhances nonheme iron absorption (Monsen et al. 1978), perhaps when some component in meat or its digestion products forms a complex with nonheme iron, thus maintaining iron in solution until it can be taken up by the carrier protein (Berner and Miller 1985). However, meat has not consistently enhanced nonheme iron absorption (Hurrell et al. 1988).

*Tea* consistently inhibits nonheme iron absorption in humans (Fig. 2) and animals (Zhang et al. 1988). Apparently it forms an iron complex, perhaps with tannin (Rao and Prabhavathi 1982), which does not release iron to the carrier protein of the intestinal mucosa. We found that meat prevents tea from inhibiting iron absorption by rats (Zhang et al. 1988). *Coffee* inhibits nonheme iron absorption and increases the risk of iron deficiency in humans (Munoz et al. 1988) but it does not affect iron absorption in rats (Gregor et al. 1987, Zhang et al. 1988). *Tannin* decreases the solubility of nonheme iron and may form a complex with nonheme iron, thus preventing absorption (Rao and Prabhavathi 1982).

A reduction in *gastric acidity* decreases iron absorption because the acid is needed to solubilize dietary nonheme iron (Mahoney and Hendricks 1984). *Phytic acid*, present in wheat bran and many soybean products, inhibits iron absorption, presumably by forming insoluble iron complexes (Mahoney and Hendricks 1984). None of these

![Iron absorption from different meals](image-url)
Meat enhances the absorption of non-heme iron; coffee and tea inhibit absorption.

Factors seem to affect the absorption of dietary heme iron.
Although heating reduces the amount of heme iron in meat (Figs. 1 and 3), cooking did not affect the percentage of dietary meat iron absorbed by iron-deficient rats (Fig. 3) (Jansuitivechakul et al. 1985, 1986).

**Determining the Contribution of Meat**

These findings raise questions about the effects of cooking on the amount of heme iron in meat, fish and poultry, and the relationship to dietary iron metabolism. If heme iron contributes a major portion of the available (metabolizable) dietary iron, dietitians should be able to refer to accurate tables listing the heme iron content of meat, fish and poultry products. To prepare these tables, Eli Clark in our laboratory will determine the heme iron contents of meat products and will assess the heme, non-heme and total iron bioavailabilities of selected meat products using the method developed by Thannoun et al. (1988) and the findings of Jansuitivechakul et al. (1985, 1986) who found that cooking did not seem to affect the bioavailability of meat iron. This research will help determine the contribution of meat to available dietary iron.

There are no good animal or laboratory models that can be used to estimate the bioavailability of dietary iron for humans. Iron absorption values obtained with rats have been inconsistent with values obtained with human subjects (Thannoun et al. 1987). These discrepancies are probably due to major differences in methodology. Adult subjects are usually used in human studies, while weanling, growing animals are usually used in rat studies. Growing animals are expanding blood volume rapidly and therefore need more iron to synthesize hemoglobin for red blood cells. Human subjects usually are not anemic, while the rats are usually made anemic to ensure maximal utilization of dietary iron. Iron absorption increases as the body’s need for iron increases.
In studies involving rats, diets usually contain less iron than is required for normal growth; this is done to ensure that rats utilize all of the dietary iron. However, human subjects consume a test meal containing 3.0 milligrams of iron and are allowed to select their normal diets the rest of the day. Female human subjects probably consume a total of about 13 milligrams iron daily and males would consume about 16 milligrams of iron during the test period, far greater than their iron requirements of 1-2 milligrams. This means that human subjects would not be expected to absorb more than 15 percent of their dietary iron while the rats could absorb 100 percent of their dietary iron.

Another difference concerns labeling methods. The extrinsic labeling method used in most human studies only measures the bioavailability of nonheme iron. Most rat studies, including those cited in this article, measure total iron bioavailability.

Most people consume adequate amounts of iron, although some women of childbearing age and young children are more likely to have low body iron stores. We are currently developing an animal model that can be used to estimate the bioavailability of dietary iron for humans whose iron status is relatively good. When normal mature rats have been fed diets containing 3 to 5 times their iron requirements and foods are used as the iron sources, the iron absorption values are very close to those reported for human subjects. Development of this
animal model should be useful in evaluating the iron bioavailability of human diets and in planning diets and menus to maximize iron bioavailability. Dietitians could use this information to plan diets for iron-deficient patients and to improve menus in hospitals, schools, nursing homes and other institutions.

ABOUT THE AUTHOR

A. W. Mahoney is professor in the Nutrition and Food Sciences Department. His research has involved the effects of food processing on nutrient bioavailability, the relationship between nutrition and cancer, and using magnesium deficiencies as a model to study seizures.

LITERATURE CITED


