A Fresh Look into Milk & Meat Products
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80 FREEZE PROTECTION FOR UTAH'S ORCHARDS
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Becoming socially competent may be a life-long process for some people. Research is showing, however, that learning certain social skills early in life can be advantageous.

ABOUT THE COVER

The emphasis in this issue is on meats, milk and cheese, the primary sources of quality protein for all but strict vegetarians.

A special thanks to Gossner Foods, Inc. for their donation of Swiss and Longhorn Cheese, Smith Food King for the steak and cottage cheese, The Bon for loan of the marble cheese keeper, lazy Susan, and hurricane lamp set, and Needham's for loan of the meat platter.
The overall objective of dairy cattle research is to improve productive and reproductive performance of dairy cattle, consistent with efficient utilization of feed, labor, and capital. Much of the dairy husbandry research to date has dealt with single components of dairy production such as nutrition, genetics, or physiology. But as dairy herds become larger, the failure to consider interrelationships among these components can have significant effects on herd performance and profitability. Research on dairy herd management, which deals with combining the components that influence herd profitability, is a relatively new discipline, but one rapidly growing in importance.

Dairy scientists from USU and the Agricultural Research Service, USDA, are engaged in cooperative research in the area of dairy herd management. Research on feeding total mixed rations has shown that cows can be fed and managed in groups, with savings in labor and no sacrifice in production. Research on feeding by-product feeds, new feed additives, and new forms and combinations of feeds has shown the benefit of adding other feeds such as whole cottonseed, to a dairy ration.

A new approach to solving problems of dairy producers is just getting under-
Cheese-yield pricing pays more for milk with high fat and protein content than the regular milk pricing system.

way at USU. Identified as Integrated Reproduction Management (IRM), this program involves research, extension, and dairy producers in a team approach to solving major management problems dealing with inefficient reproduction of livestock.

Another area of management receiving a great deal of attention is managing dairy cows to maximize income from milk produced for cheese production. Cheesemakers recognize that yield of cheese depends on the protein as well as the fat in milk. Most current payment systems for milk used for cheese pay too little for milk that has high percentages of fat and protein. A pricing system that overcomes this problem has been suggested by food scientists at Utah State University. Several cheese plants have adopted this payment system, known as cheese-yield pricing.

One of the first things that happens when a cheese plant converts to cheese-yield pricing is a flood of inquiries from dairymen wanting to know what they can do to improve the cheese yield of their milk. This article is a result of research on that question.

Many factors affect cheese yield. The ratio of protein to fat is important. Milk containing 82 percent as much protein as fat is best for cheddar cheese. For example, milk testing 4.0 percent fat should contain 3.28 percent protein to optimize both cheese yield and milk price. Milk testing 5.3 percent fat should test 4.35 percent protein to optimize cheese yield and milk price. Holstein milk has a smaller difference between protein and fat test than does milk from high-test breeds like Jersey and Guernsey. Thus, for optimum cheese yield, milk from Holsteins generally needs a higher fat test and milk from high fat breeds needs a higher protein content.

Feeding is a Key

When it comes to influencing protein and fat levels, feed is the major environmental factor over which the dairyman has control. Feeding practices that lower fat percent also affect protein percent, but often in the opposite direction. For example, feeding more energy and less fiber in the ration will raise protein percent, but lower fat percent. Therefore, the ration must provide a balance of nutrients that will help both fat and protein levels.

Protein level in the ration influences milk yield more than it does milk composition. Feeding too little protein can lower milk yield, but feeding protein beyond a cow’s requirements will not improve the protein percent in her milk. Feeding programs can be changed rapidly. Dairymen are limited, however, in the degree to which they can modify milk composition. The key is to maintain a balanced ration. A dairyman should get professional help with balancing rations by contacting a trained Extension Specialist or other qualified nutritional consultant. The dairyman should also understand why certain things are important in a balanced ration and be aware of what he can do as a manager to improve the use of available feeds.

Demands for higher milk production have made it profitable to feed more grain and less hay and silage to cows. As a result, cows take in more energy and less fiber. This has caused higher protein levels and lower butterfat tests in milk. Cows must be fed a ration adequate in fiber as well as other nutrients.

The nutrient requirements of a cow vary with her size and age, and with level of production and fat test of her milk. For example, nutrients needed by cows weighing 1300 pounds and producing different amounts of milk testing 3.5 percent fat are shown in Table 1.

The ratio of protein to fat is highest in milk from Brown Swiss Aryshire and Holstein cows.

Note that the fiber content is the same at all levels. This makes it difficult to formulate rations. Fiber content is easily met and often exceeds the minimum at low levels of production. At high levels of milk production, however, it is very difficult to formulate a ration with enough fiber. Feeds with high energy from total digestible nutrients (TDN) high protein, and high fiber levels are required.

Table 2 lists the TDN, crude fiber, and protein content of 10 common feeds. It is easy to see that whole cottonseed has the highest concentration of energy (TDN). Cottonseed meal is highest in protein and soybean hulls are highest in crude fiber. However, as pointed out earlier, feeds that are high in two or all three of these feed components become important in balancing the ration for a high producing dairy cow. Some feeds that provide both protein and fiber are alfalfa hay, whole cottonseed and

### TABLE 1. Nutrients required in total ration.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Daily milk yield (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>31-46</td>
</tr>
<tr>
<td></td>
<td>46-64</td>
</tr>
<tr>
<td></td>
<td>64</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>13</td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>17</td>
</tr>
<tr>
<td>TDN (%)</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>75</td>
</tr>
</tbody>
</table>

### TABLE 2. Nutrient content of feeds.

<table>
<thead>
<tr>
<th>Feed*</th>
<th>Crude Protein</th>
<th>Crude Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TDN Fiber</td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>52 28 15</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>74 5 12</td>
<td></td>
</tr>
<tr>
<td>Beet pulp (dried)</td>
<td>72 16 9</td>
<td></td>
</tr>
<tr>
<td>Brewers’ grain (dried)</td>
<td>61 15 24</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>78 2 9</td>
<td></td>
</tr>
<tr>
<td>Corn silage</td>
<td>25 8 3</td>
<td></td>
</tr>
<tr>
<td>Cottonseed (whole)</td>
<td>91 17 23</td>
<td></td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>70 12 41</td>
<td></td>
</tr>
<tr>
<td>Soybean hulls</td>
<td>71 35 11</td>
<td></td>
</tr>
<tr>
<td>Wheat bran</td>
<td>62 10 16</td>
<td></td>
</tr>
</tbody>
</table>

*As fed basis.
A younger herd ensures higher fat and protein tests but a more mature herd gives a greater milk yield.

Brewers' grains. If the ration needs both protein and fiber, these feeds should be used. If the ration needs more energy (TDN) and fiber, whole cottonseed, soybean hulls, beet pulp (molasses dried) or possibly dried brewers' grains should be used. In all cases, feed costs must be considered also.

Nearly as important as what is fed, is how it is fed. It is important that all feeds be eaten. If some are not, the diet may be deficient. For example, if long alfalfa hay is fed and the leaves are the major part of the hay consumed, the fiber in the diet is lowered considerably. One result is likely to be a low butterfat test.

A common practice is feeding grain outside the milking parlor immediately after milking. Cows will eat their fill and lie down. Then they will not get up to eat when hay is fed. As a result, cows may not get enough fiber and protein. Feeding hay immediately after milking is a better practice.

Effects of Disease
Most diseases that cause an increase in body temperature will result in higher fat tests, but less total milk, fat, and protein. Normal milk can be produced only by cows free from udder infections. One of the biggest challenges in dairying is preventing mastitis. It has been shown that there is a drop in percent solids-not-fat (SNF) as the severity of mastitis gets worse. Protein is the component most likely to be lowered. Remember that mastitis prevention is important in maintaining a high price for milk when cheese yield is the basis of pricing.

Stage of Lactation and Gestation
Protein and fat levels in milk are highest just after calving. Initially they fall rapidly, then more gradually, dropping to a low point between 45 and 75 days after calving. They then rise slowly through the remainder of the lactation. Boosts in percent protein observed after the sixth month of lactation are often associated with pregnancy. Milk from open cows does not show a rise in percent protein during latter lactation. This is another good reason for dairymen to breed cows back as soon as 50 to 60 days after calving.

There are other environmental effects on milk composition over which dairymen may have very little control. Both fat and protein levels decline, but milk yields improve as cows get older. After a cow is six years of age, her fat tests decline faster than does the protein percent. If a dairymen maintains a young herd to ensure a high fat and protein test, he has to accept less total milk yield.

Season has a well-known effect on fat percent. It has the same but less severe effect on protein. Percentages of both components are highest during winter months and lowest during summer. This is due partly to temperatures and partly to differences in feeding programs. Dairymen cannot change such seasonal effects except by modifying housing.

Breeding is Involved
Genetic changes are achieved slowly. However, genetic effects are permanent and are just as important to a cheese-yield pricing system as to other pricing systems. It is well known that cows within and among breeds differ in milk composition. Milk from high-fat breeds like Jersey and Guernsey also has the highest protein content. However, breeds differ less in protein content than in fat content. The ratio of protein to fat is highest in milk from Brown Swiss, Ayrshire, and Holstein cows. While percent fat and percent protein tend to vary in the same direction, they are by no means tied completely to each other.

Both are inherited and each can be changed genetically more rapidly than can milk yields. Furthermore, the genetic correlations between milk composition and milk yield are slightly negative. This means that improving percent protein or fat genetically will tend to lower the genetic potential for milk yield.

Opportunities to select for percent protein are limited at present because relatively few cows are tested for protein. Therefore, less information is available for sire summaries. The most rapid genetic improvement in percent protein can be obtained with direct selection for protein percent, just as improvements in fat percent or milk yield are most rapid when selection is for one specific trait. Selection for percent fat also will raise percent protein because they are correlated genetically; however, the change will occur more slowly for each. The ideal selection procedure will consider all of the important traits. The goal of many dairymen in recent years has been to select for high milk yield. Under the new cheese-yield pricing system, however, selection should be for cheese-yield potential. In other words, dairymen should select for total pounds of fat and protein in the proper proportion.

Finally, it may not always pay to change practices to improve fat and protein levels. Dairymen must make sure any changes result in more net income in the long run.

About the Author
Robert C. Lamb is research leader for dairy management for ARS, USDA. He also holds an appointment as research professor in ADVS Department at USU, where he coordinates the dairy research program. His areas of research are on improving dairy herd management practices and on integrated reproduction management for dairy herds.
The Utah State University Lactic Culture System annually saves the cheesemakers of the nation millions of dollars. The instrumentation and media were first provided to the industry by a local corporation established by five USU students in 1976. There are now approximately 60 cheese plants using external pH control systems, and many culture suppliers market instrumentation. The media costs where the USU System is used are less than half those of the next best system available (Figure 11) (Dairy Record, p. 57, January, 1983). Our approach encourages the production of large numbers of the lactic bacteria required for normal cheese production (Figure 1). But numbers do not represent all the sources of savings that can accrue in the production of lactic culture!

Selection of Bacteria
Traditionally, unknown blends of lactic cultures have been supplied the cheese industry in the USA. This requires that cheesemakers experiment with 20,000 liter volumes of milk. Bacteriophage (phage) viruses have a heyday in such conditions, and a cheesemaker is lucky to get 90 percent grade A cheese. Some have had over 40 percent of their production degraded because of poor quality associated with unreliable cultures.

In 1980 we introduced the New Zealand, paired strain culture program into two Utah plants. Howard Heap, of the NZ Dairy Research Institute, spent three months at USU and helped with the strain selection process. Subsequently, three pairs of strains were rotated daily for two years in these plants and acceptable cheese quality exceeded 99 percent! Whenever a phage appeared against one of the strains, a resistant mutant was isolated and entered into the program to replace the parent strain (Figures 2 and 3). In 1982 we noted that two of the strains in the pair had not experienced significant phage problems during the two-year trial. These organisms were paired and introduced without rotation. This reflected new programs in New Zealand and Australia where only one pair had been used for over two years. In 1981 the entire New Zealand industry used only one pair to produce their annual production of over 105,000 tons of cheese. This was an unheard of feat prior to that time. Since May 1982 the single pair has been introduced into over 40 cheese plants throughout the USA including the second largest plant. There, the manager has said, "Don't you ever let me run out of this culture!" Acid production control and cheese quality is better than ever before and increasing industry requests for this miracle pair are barely met. The improved quality means greater profits because top grade cheese receives the highest market value. Similar quality improvements have occurred where a single blend of six strains is used.

Randy Thunell received his MS at USU, and while completing graduate studies at Oregon State University, he helped perfect a comparable culture program involving the use of a multiple-strain culture blend.

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See references.

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Figure 1. Photomicrograph of the lactic bacteria used in cheese production courtesy of Dr. M. Kalab, Food Research Institute, Ottawa, Canada. The clear zone between the bacteria and cheese structure indicates curd shrinkage probably due to acid production or breakdown due to proteolytic activity.

Figure 2. Milk with brom cresol purple dye in Microtiter plates (Cooke Engineering, Inc., Alexandria, VA) turns yellow when phage activity is absent and remains purple if phages inactivate the bacteria. Newly isolated strains were evaluated using this technique.

Figure 3. A Spiral Plater distributes bacteria either in a uniform or nonlinear pattern on agar media in petri plates. This was used to quantitate bacteria and phage.
Figure 4. Fermenters in which each lactic strain is propagated before concentrating and packaging in syringes.

Figure 5. A 10-mL syringe/needle unit minimizes contamination during inoculation. The syringe contains sufficient bacteria to inoculate a bulk culture tank.

Figure 6. The first model of the "Vatimer" can be attached to the side of a cheese vat and used to generate data to detect curd cutting time and other coagulation parameters.

Figure 7. Pressure/vacuum bulk culture tanks can be fitted with a filter system to minimize the chance of contamination.
With a nearly perfect system should we now relax? Definitely not! What happens if the single pair is hit by an as yet unknown virulent phage? Are the organisms in the pair the best obtainable or should they be replaced with even better ones? These questions coupled with some claims that cheese yield differences were associated with culture selection, motivated a look into an unexplored source of cultures.

The Irish Interlude Insight
In 1981 I spent three months in Ireland introducing the USU Lactic Culture System to that nation. The chance to explore the literature and to spend considerable laboratory time at University College, Cork, led to the suggestion that we use cultures we traditionally throw away. Lactic cultures are first isolated on appropriate solid media and are then transferred into milk and incubated over night. If they coagulate the milk, they are kept for cheese-making trials. If they fail to coagulate the milk, they are discarded. The cultures kept can coagulate milk because they are able to break down casein in order to supply their protein needs. They are called protease positive (Prt+) (Figure 1) and have sufficient external proteolytic enzymes that assure rapid growth in milk. Protease negative (Prt−) cultures lack this activity, grow only to the limit set by the soluble nitrogen matter in the milk, and we have refused to use them in cheese production even though they produce less bitter cheese. Extremely high inoculum levels of Prt− cells would be required and these levels could not be produced in conventional milk-based culture systems. However, ten times as many such cells are produced in the USU System.

Tons of normal cheddar cheese have now been manufactured using Prt− cultures. O’Leary and Hicks, working at the University of Kentucky, were sent Prt− cells for yield studies. They found as high as 1 to 2 percent yield increases to be associated with these cultures depending upon the strain selected. This potentially represents one to two 20 Kg blocks of cheese per vat and millions of additional dollars annually. Additionally, the use of these organisms makes it possible to separate cell growth from acid production. In the USU System growth occurs in the culture tank and acid production in the cheese vat. Thus, there are no concerns about phage or antibiotic activities in the cheese vats.

Current research involves evaluation of these organisms to see if they increase yield in cottage cheese, casein manufacture and if they improve the body characteristics of buttermilk and sour cream. A recently invented instrument, the “Vatimer,” (Figure 6) allows objective measurement of cheese cutting time, making it possible to more easily evaluate such improvements. We are investigating making cheese at higher temperatures since the organisms do not need to grow during cheese manufacture. Early results indicate that the make time might be reduced from five to four hours. This could be another economic breakthrough associated with the proper selection of bacteria.

Bulk Culture Tanks
Bulk culture tanks that are open to the atmosphere aspirate in several cubic feet of air upon cooling and prior to inoculation with the desired bacteria. Contaminating bacteria and phage can thus gain early entry into such tanks. The industry has provided protection by enclosing tanks in separate rooms provided with filtered air. Additionally, it has been routinely assumed that phage will get into the tanks or that the inoculum contains phage. Phosphate or citrate salts are, therefore, used in conventional media called phage inhibitory media. These cost millions of dollars annually (Figure 11) and are counter productive since they reverse the positive effects of the calcium chloride that is legally added to cheese milk to improve coagulation properties.

Such problems are readily solved by three simple changes: (a) use only pressure/vacuum dairy process tanks for bulk culture production, (b) provide a small pore (.2 micron) filter on top of the tank so that all air aspirated into the tank will have to pass through the filter (Figure 7), and (c) insure that no contamination occurs during inoculation. We met the latter requirement by fitting a small rubber septum into the top of the tank inoculation port. The inoculum is grown up (Figure 4), concentrated and frozen in disposable 10 mL syringe/hypodermic needle transfer units (Figure 5). These units are thawed by immersion in chlorine solution and the culture is injected into the tank through the rubber septum (Figure 10). This technology eliminates the contamination threat associated with pouring from a pop-top can or sprinkling powder through a two-inch opening in the top of the tank.

Medium
The most economical medium incorporates fresh liquid whey, water (Figure 8) and a phosphate and stimulant blend (Figure 9). The water is needed because there is too much lactose in undiluted whey. The phosphates are used to prevent phage development as explained above. The stimulants are yeast and protein hydrolyzates required by the lactic cultures. Improvements in this phase centralize around selection of the best nutrients and elimination of the phosphates and citrates. The latter reduce the quality of the milk coagulum and are not necessary if pressure/vacuum tanks are used. Furthermore, these salts have been associated with declines in cheese yield.

Example Potential Savings
The potential savings associated with the optimum combination of these aspects of cheddar cheese production are shown in Figure 12. The data are based upon actual studies conducted at a typical cheese plant producing 36,300 Kg of cheese daily and at the University of Kentucky pilot plant. The annual capacity of the commercial plant was increased to over 7.5 million Kg of cheese without additional capital investment.

Similar savings have been associated with culture production for cottage cheese manufacture (Figure 13) (personal communication, Dave Thomas, Western General Dairies, Ogden, Utah, 1983). The selection of the best bacterial strains and their efficient propagation under protected conditions can provide economical incentives to the cheesemaker. Adoption of such technology has meant the difference between staying in or going out of business for some manufacturers. These significant savings all hang on the way we treat spherical bacteria, each only one micron (one millionth of a meter) in diameter!

About the Author
Gary H. Richardson, professor of Food Science and Food Microbiology in the Department of Nutrition and Food Sciences, conducts research in dairy instrumentation and lactic culture production. He teaches courses in food analysis, food fermentation, and food quality assurance. Richardson was awarded the Pfizer Award in 1978 for cheese and cultured dairy products research and the Macy Award in 1983 for development of the USU Lactic Culture System.
USU SYSTEM
INTERNAL pH CONTROL SYSTEM
PHAGE INHIBITORY MEDIUM

Figure 11. Comparative costs of media to produce 50 kg of finished bulk culture for cheese manufacturers.

Figure 8. Whey and water are measured into the bulk tank to prepare the medium for the USU Lactic Culture System.

Figure 9. The stimulants and salts required to assure optimum growth of the lactic bacteria are added next.

Figure 10. The bulk tank is inoculated through a rubber septum located in the tank inoculation port.

REFERENCES

Storing Nutrition

Figure 1. Photograph of dried peaches.
"I've got some flour I stored away twenty years ago and it is as good as the day I put it away."

"These dried prunes are sealed and you can store them forever."

Statements such as these are often heard by homemakers. A study of over 200 randomly selected families in Utah indicate that people in Utah do store large quantities of food (Table 1).

### TABLE 1. Per capita food storage in 200 homes in Utah, 1974.

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Pounds/Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>45</td>
</tr>
<tr>
<td>Wheat and flour</td>
<td>163</td>
</tr>
<tr>
<td>Beans and other legumes</td>
<td>11</td>
</tr>
<tr>
<td>Vegetables</td>
<td>83</td>
</tr>
<tr>
<td>Fruit</td>
<td>116</td>
</tr>
<tr>
<td>Dried milk and milk products</td>
<td>13</td>
</tr>
<tr>
<td>Sugar</td>
<td>42</td>
</tr>
</tbody>
</table>

The above cited study was conducted in the fall and most of the meat was in the frozen form. Thirty-five percent of the vegetables were stored fresh, 12 percent frozen, 22 percent home canned and 29 percent had been canned commercially. Sixty-six percent of the fruit was home processed.

A later study was conducted in the late spring when storage supplies might have been diminished. These results were analyzed by daily nutrient needs per capita in the 391 households surveyed (Table 2).

From the column showing the average days of nutrient supply available, it is evident that the population in this study could go about 1/2 year without having a diet that did not meet the recommended dietary allowance for any nutrient. One can also see from the range column that some families have almost no food in the home and others have extremely large amounts. One home, at least, had adequate food to supply nutrients for their family for five years.

Large quantities of food are certainly being stored in homes in Utah. Will these foods be nutritious and palatable when they are finally used?

Long-term food storage studies have been conducted at the Nutrition and Food Science Laboratories on campus for the past five years to provide some answers.

Figure 1 illustrates typical findings after dehydrated fruits and vegetables were stored for 2 years at different storage temperatures and in different containers. Dehydrated fruits and vegetables, even though very low in moisture content, undergo marked changes in appearance which depend largely on temperature. Samples stored at the higher temperatures deteriorated in color rapidly and were rated unacceptable by a sensory panel after only six months of storage.

Carotene and ascorbic acid, two types of vitamin activity for which fruits and vegetables are consumed, were decreased in the fruits and vegetables stored at higher temperatures.

Nonfat dried milk (NFDM) was also held under different storage conditions. Again, storage temperature was the most critical factor in determining consumer acceptance. Table 3 shows the results obtained when a large consumer acceptance panel evaluated the acceptability of long-term stored NFDM as compared to freshly prepared NFDM. Both were served as a reconstituted drink or as an ingredient in puddings. The particularly strong flavor components diminished the differences in acceptability; however, flavor defects were still recognized.

Calcium, protein and riboflavin are the major nutrients that milk contributes to the diet. Calcium, being a mineral, is not lost during storage. While protein quality is influenced by temperature over long periods of time, it has been impossible to show any detrimental influence on practical diets. That is true because milk provides such a good quality protein (i.e., lysine) the amino acid most influenced by the browning reactions associated with higher temperature storage is not limited. Additionally, the average American diet is so high in protein anyway, that protein quality is not a practical consideration. Riboflavin is stable to temperature but not to ultraviolet light. All samples stored were kept in the dark and did not decrease in riboflavin content over time stored.

To maintain quality in stored foods, it is very important that the temperature at which they are stored be kept as low as practicable. Recommendations from these studies would indicate storage temperatures lower than 70°F, preferably as low as 50°F. It is also recommended that foods be rotated so that they are not stored for over five years even in the best conditions. Food items that have become old in storage can be used as components of composite food products to diminish their lack of acceptability when eaten alone.

### ABOUT THE AUTHORS

Deloy G. Hendricks is a professor in the Department of Nutrition and Food Science with an emphasis in nutrition as it relates to humans. Currently he is studying three areas: food storage in Utah, nutrient bioavailability, and nutrient behavior interactions.

Charlotte Brennand is an assistant professor of Nutrition and Food Sciences specializing in flavor chemistry and sensory evaluation.

### TABLE 2. Days supply of nutrients available in food stored by some Utah families, March 1976.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Average days of RDA* of nutrient per capita</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>234</td>
<td>0 days to 5.2 years</td>
</tr>
<tr>
<td>Protein</td>
<td>415</td>
<td>0 days to 11.3 years</td>
</tr>
<tr>
<td>Calcium</td>
<td>157</td>
<td>0 days to 4.9 years</td>
</tr>
<tr>
<td>Iron</td>
<td>292</td>
<td>0 days to 4.6 years</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>177</td>
<td>0 days to 5.7 years</td>
</tr>
<tr>
<td>Thiamin</td>
<td>425</td>
<td>0 days to 11.0 years</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>213</td>
<td>0 days to 6.0 years</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>189</td>
<td>0 days to 6.3 years</td>
</tr>
</tbody>
</table>

*Recommended Dietary Allowance

### TABLE 3. Consumer recognition of stale milk.

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Milk</th>
<th>Vanilla Pudding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.62</td>
<td>7.14</td>
</tr>
<tr>
<td>Control</td>
<td>5.43</td>
<td>7.12</td>
</tr>
<tr>
<td>Stale</td>
<td>3.84</td>
<td>6.38</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Day 2</th>
<th>Milk</th>
<th>Chocolate Pudding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.99</td>
<td>7.02</td>
</tr>
<tr>
<td>Control</td>
<td>5.48</td>
<td>6.74</td>
</tr>
<tr>
<td>Stale</td>
<td>3.54</td>
<td>6.57</td>
</tr>
</tbody>
</table>

Stale milk: instantized, polyethylene bag, 5 years old, room temperature.
Curing meat with salt and sodium nitrite inhibits spoilage and adds desirable flavor and color.

Introduction

Cured meat products constitute a large part of meat industry production in the United States. According to the American Meat Institute, over 90 million hogs were slaughtered in the U.S. in 1979, and 30 percent of all pork was used to make cured products such as hot dogs, bacon, and ham. Only about 1.5 percent of all beef goes into cured products such as corned beef and hot dogs, but this still constitutes over 279 million pounds of cured beef products. Cured meats, almost by definition, are those products that are processed using sodium nitrite as a preservative and for color and flavor enhancement. It is possible to salt-cure meats without use of sodium nitrite, but this is rarely done. Sodium nitrite has 4 beneficial functions in cured meats. It inhibits rancidity, develops the pink color characteristic of cured meats by reacting with the muscle pigments, it may contribute to cured-flavor development, and, very importantly, it inhibits microbial growth, especially by food poisoning organisms such as Clostridium botulinum. Proper refrigeration during transport and storage will, by itself, inhibit botulinal growth. In addition, the incidence of C. botulinum spores in meat products is quite low (1 spore per 7 lbs. of meat, Lechowich et al., 1978). Nonetheless, botulism would be a significant health...
WITHOUT WORRYING

hazard without adequate processing methods and/or additives to destroy or inhibit spore development.

Sodium nitrite has been a controversial food additive because of the discovery that nitrite may react with certain meat compounds during heating to form carcinogenic nitrosamines (Crosby et al., 1972). This finding stimulated a great deal of research on nitrosamines in meat products, as well as interest in potential substitutes for nitrite in meat curing. Many of the results were good news, from the consumer standpoint. Surveys showed that only severely heated cured meats contained nitrosamines. Thus, only some dry-cured, fried products such as country-style ham and bacon fried to temperatures above 170°C (i.e., crisp) contain detectable nitrosamines (Pensabene et al., 1974; Greenberg, 1977). Hams, hot dogs, bologna and other cured meats do not contain detectable nitrosamine levels (Nitrite Safety Council, 1980). Bacon cooked at lower temperatures or in microwave ovens, does not contain nitrosamines (Pensabene et al., 1974). It was also found that vitamin C (ascorbate) inhibited the formation of nitrosamines during cooking (Sander, 1974). Thus, regulations were enacted to lower the permissible level of sodium nitrite for bacon from 156 ppm* down to 120 ppm, and bacon must also contain 550 ppm ascorbate. Further, a program was set up to monitor both sodium nitrite and nitrosamine levels in bacon from all federally inspected meat producers. Thus, today consumers can be confident that bacon is a safe-to-eat product.

A second concern has been that nitrite itself is carcinogenic, or that it can react with amines in the stomach to produce nitrosamines. A study published in Science (Newberne, 1979) concluded that sodium nitrite in drinking water increased the rate of rat lymphatic cancer by about 5 percent over control animals given pure water. This study stimulated demands that sodium nitrite be banned as food additive. An expert panel appointed by the FDA reviewed the study and refuted the findings, stating a number of irregularities in the study. The committee also concluded that the author incorrectly classified benign tumors as malignant. Thus, this study could not be used in support of a ban on sodium nitrite. Subsequent studies have shown that sodium nitrite in drinking water of mice was not carcinogenic (Pearson et al., 1980).

So far, no evidence has shown that nitrite reacts to form nitrosamines in the stomach. Even if this were the case, cured meats make a very small contribution (2 percent) of the dietary intake of nitrite (White, 1975). Vegetables such as lettuce and celery contribute over 80 percent of the average dietary intake of nitrate, which is easily converted to nitrite in the body (Tannenbaum et al., 1974). Nitrite is naturally present in saliva, and some nitrite will always enter the stomach, regardless of diet (Tannenbaum et al., 1974).

**Objectives**

Although much has been learned about the safety of sodium nitrite in cured meats, interest in nitrite substitutes remains. Nitrite substitutes must have antibotulinal properties, and enhance cured meat color. Tompkin (1978) proposed that sodium nitrite inhibits botulism by complexing with meat iron, limiting the iron available as a nutrient for microbial growth. Thus, the purpose of this study was to determine the antibotulinal potential of iron binding systems, including either nitric oxide (NO) gas or carbon monoxide (CO) gas (for pink cured color) and ethylene-diaminetetraacetate (EDTA), oxalate, or phytate (for binding of free iron).

**PROCEDURES**

**Emulsion Preparation**

Lean pork was ground, then blended with other ingredients to yield an emulsion containing 2.5 percent sodium chloride, 0.5 percent dextrose, 10 percent added deionized water and 250 micrograms/g (i.e., ppm) of either sodium phytate, sodium oxalate, or EDTA. The control treatment contained 156 ppm sodium nitrite. For samples treated with NO or CO gas, the emulsion was reblended for 30 sec to 3 minutes in a gas-filled blender. (The blender lid was modified to connect the blender to the NO or CO gas cylinder.)

**Spore Addition**

The meat emulsions were inoculated with *Clostridium botulinum* spores (100/g meat), and re-blended for adequate mixing.

**Packaging, Cooking, and Storage**

Eighty-gram portions of meat emulsion were vacuum packaged in polyethylene bags, then pasteurized in a water bath at 70°C for 30 minutes, similar to commercial practice. Normally, any product so prepared would be refrigerated until consumption. However, in this study, samples were abused by storage at 27°C, to determine the effectiveness of the various treatments in delaying botulinal growth as measured by bag swelling. Swollen bags were frozen for later chemical analyses, including nitrite levels and sample toxicity to mice.

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*ppm = parts per million. For example, 156 ppm sodium nitrites = 156 micrograms sodium nitrites per gram of meat.*
Results and Discussion

No botulinal inhibition was observed in control samples (Figure 1a), or in CO-treated meats, with or without addition of iron chelating agents (Figure 1b). The samples all swelled rapidly, and were highly toxic. The CO was probably driven from the product during cooking, since the meat turned brown. When the meat emulsion was first exposed to CO, a bright red color was observed due to carboxymyoglobin formation. The brown color of the cooked product was probably due to formation of denatured metmyoglobin, the brown pigment of cooked meat.

Definite botulinal inhibition was observed in samples treated with sodium nitrite (Figure 1c), and in NO-treated samples, both with NO alone or plus iron chelating salts (Figure 1d-f). The number of swollen bags decreased when meat was formulated with either NO or NO plus an iron-binding agent (Figure 1d,g). Samples treated with NO + oxalate or phytate probably received more NO, since these samples contained a higher level of residual nitrite when measured immediately after cooking (143 and 130 ppm compared to 82 and 56 ppm for NO and NO + EDTA treated samples respectively). Thus, it is likely that the lower number of swollen bags observed in the NO + oxalate or NO + phytate treated samples were due to their higher content of nitrite and related compounds, rather than to any specific antibotulinal effects of oxalate and phytate.

The nitrite levels of unswollen bags of uninoculated meat product formulated with 156 ppm sodium nitrite varied considerably (Figure 2a). This variation may partly explain why all bags of a treatment did not swell on the same day. All swollen samples contained very low levels (10 ppm) of residual nitrite. However, some bags that remained unswollen after 110 days storage also contained residual nitrite levels below 10 ppm (Figure 2b). A typical nitrite depletion curve for a sample treated with NO gas is shown in Figure 2b.

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Figure 1. Number of swollen bags with time in meat product formulated: a) without nitrite; or formulated with: b) carbon monoxide, with or without iron chelating agents; c) 156 ppm sodium nitrite; d) nitrite oxide (NO); e) NO + EDTA (tetrasodium ethylenediaminetetraacetate); f) NO + sodium phytate; and g) NO + sodium oxalate. All were then inoculated with 100 C. botulinum spores/g meat, pasteurized at 70°C for 30 min, vacuum packaged in plastic bags, and stored at 27°C (from Vahabzadeh et al., 1983).

Figure 2. Nitrite depletion over time in: a) an uninoculated meat product formulated with 156 ppm sodium nitrite, or b) a meat product exposed to nitric oxide gas, then inoculated with 100 C. botulinum spores/g meat. Both treatments were cooked at 70°C for 30 minutes, vacuum packaged, then stored at 27°C. Note that uninoculated bags (part a) did not swell during the 30-day storage period (Vahabzadeh et al., 1983).
Summary

Results of this study indicated that NO gas would not be a practical substitute for sodium nitrite in meat curing, since nitrite itself is formed when meat is blended in the presence of this gas. Neither could CO be used in meat curing, since the pink color of raw, CO-treated meat disappeared after cooking. More importantly, all samples treated with CO swelled rapidly and contained botulinal toxin.

Results of the present study also suggest that the available iron content of cured meat systems is not the factor limiting botulinal growth. Nitrosopigment and soluble iron contents in swollen samples did not change compared to those in unswollen samples, while total heme content decreased slightly. Residual nitrite was very low in all swollen samples. Apparently, residual nitrite reacts directly with the botulinal cell, thereby inhibiting growth, rather than indirectly slowing growth by complexing iron in the medium.

Conclusions

In conclusion, iron-binding systems were not effective in delaying botulinal growth. NO gas was about as effective as sodium nitrite in delaying swelling, probably because NO was converted to nitrite and related compounds. In addition, NO is a dangerous gas. Thus, there would be no practical advantage to curing with NO. The primary practical result of this and similar studies is the proof that sodium nitrite itself is antibotulinal and may be safely used in meat curing. With proper product formulation and cookery methods, nitrosamines are not formed in cured meats. Thus, the antimicrobial benefits of sodium nitrite as a meat curing additive far outweigh its potential risks.

Figure 3. Clostridium botulinum type A cells, 5000 x magnification.

REFERENCES


ABOUT THE AUTHORS

Farzaneh Vahabzadeh and S. K. Collinge are graduate students in the Department of Nutrition and Food Sciences.

Daren P. Cornforth is assistant professor of Nutrition and Food Sciences with research interests in fresh and processed meat processing.

Arthur W. Mahoney is professor of Nutrition and Food Sciences with research interests in food iron bioavailability.

Frederick J. Post is professor of Biology with research interest in food microbiology.
Figure 2. Distillation apparatus used to isolate lamb flavor compounds.

A. Auxiliary steam source
B. Boiling flask
C. Condenser
D. Cold traps
E. Separatory funnel

Figure 3. Removal of ether from the sample.

Figure 4. Final flavor concentrates of lamb flavor.
A STUDY OF MEAT FLAVOR

C. P. BRENNAND

What is considered meat flavor can be divided into three major categories. The first is a general broth-like flavor that is common in all red meats, regardless of source. This category can be represented by the flavor of boiled lean meat. A second category includes those flavor clues that identify a meat as, for example, lamb, not pork. The third category is dependent on the method of cooking the meat. Dry heat methods produce different flavor compounds than does moist heat cooking.

Research in flavors requires use of both sensory and chemical methods. However, the use of people in sensory panels as research tools introduces a certain amount of variability. There is also a paucity in vocabulary when it comes to describing flavors. Many of our flavor perceptions of meat are based on other qualities such as the color of the meat; its grain, texture, and juiciness; and even the size of the cut. In the absence of visual clues, panelists have a difficult time identifying the type of meat by flavor alone. A group of over 200 judges evaluated lean meat balls made from beef or lamb. The majority of the panelists were unable to recognize lamb.

This confusion also carries over to the "white" meats. Samples of boneless lean meat pieces of rabbit, chicken, turkey and duck were given to a group of people who were then asked to identify the flavor. The results are shown in Table 1. Rabbit and duck were identified the least frequently; however, they are also consumed less frequently, therefore the panelists may not be as familiar with these flavors.

Despite this confusion, people are a necessary part of the flavor identification process. When dealing with complex sensory problems, each panelist needs to undergo a training period and have his/her ability to differentiate flavors tested prior to gathering data.

Comparison of Lamb, Beef and Pork Tissue Types

Since the major possible precursors of meat flavor—protein and fat components—are found in all types of meat, a means of limiting the potential sources of flavor compounds in the analysis is helpful. With this in mind, broth samples were prepared using lean meat alone, adipose tissue only, or both lean and adipose tissues from beef, pork and lamb. These samples were then given to a sensory panel previously trained in recognizing species flavor differences. For each sample, the judges evaluated the intensity of beef-like, pork-like and lamb-like flavor present and also assigned an intensity score for meaty flavor.

The data in Figure 1 show the relative importance of fat and of lean tissue in the recognition of species-specific flavor characteristics. For each species except lamb, broth samples prepared from lean and fat tissues received significantly higher scores than either alone for the appropriate species-related flavor intensity attribute. When all apparent fat was removed from broths, all samples regardless of origin were considered more beef-like than pork-like or lamb-like. The beef, lean-meat broth was rated significantly less beef-like when fat was not included. The broth from beef fat alone was not considered more beef-like than any other species attribute. Therefore, the presence of both lean and fat tissue is beneficial in identifying beef-specific flavor. Broths from lamb fat tissues and from combined fat and lean tissues were rated equally lamb-like, and both were considered more lamb-like than the broth prepared from lean meat only, indicating that fat is the necessary component for lamb-specific flavor.

These results have implications for both the researcher and the cook. Research on lamb's species-specific flavor can be focused on the adipose tissue and thus simplify the study. On a home basis, the consumers that do not like the flavor of lamb can decrease it by removing all fat. Consumers that like the typical flavor of lamb would do better to leave the surface fat on both for flavor and to decrease the likelihood of the meat becoming dried during the cooking.

Turkey Systems

Most beef and lamb steaks have 15-25 percent fat. This fat content improves the texture, the perception of juiciness and also helps to prevent the cut of meat from sticking to the grill. Turkey breast meat has a fat content of about 3-5 percent; as a result, steaks fabricated out of turkey breast meat have a tendency to be dry, tough and to stick to the grill. When fat is added to the turkey steak, the properties of the turkey steak can be improved; however, the type of fat added can introduce flavors from other meat species.
The species-specific flavor can be identified in the fat of lamb but beef-flavor is not contained in beef fat

In a study involving 15 percent turkey, beef, pork or lamb fat added to lean turkey breast meat, the panel members were asked to identify if the meat being sampled was beef, pork, lamb, venison, chicken, turkey, or "other". The responses are shown in Table 2. The samples containing both lean turkey breast and turkey fat were correctly identified as turkey by only 16 of 86 judges. Panel members tended to consider all samples as being pork-flavored. The light color of the steaks could have been attributed to chicken or turkey meat, but the steak- or chop-like character of the meat, combined with its color apparently biased the panel toward the flavor being considered pork-like. Adipose tissues from lamb and pork are recognized as the carriers of species-specific flavor compounds. The pork fat sample was considered to be pork-flavored by over half of the judges but this cannot be considered significantly different from the number of times the turkey fat sample was considered to be pork-flavored. The distinctive flavor of lamb fat caused an increase in the "lamb-flavor" responses to samples made with that fat. Samples that included beef fat were identified as having the appropriate species flavor the fewest times. This reinforces the model system results showing that beef fat does not carry the species-specific flavor for beef and that lamb fat does contain the species-specific flavor for lamb.

Chemical Analysis

Over 300 volatile compounds have been identified in meat. All of these are potentially important to the flavor of meat. One of the problems in identifying species-specific flavor compounds is that the flavor may be due to the presence of specific compound(s), or to the exact concentration of the compound(s), or to an interrelationship between the constituents. No one
compound in meat flavor has been recognized as representing the characteristic flavor in any of the species. Ironically, the compounds found in the larger concentrations are rarely as important to the flavor as compounds found in much lower concentrations. The compounds occurring in trace quantities are not only hard to identify through analytical means, they may smell very different when considered in larger quantities.

A potential problem is that the important flavor compounds may change during the isolation procedure. Once again using sensory panels, the presence of lamb-specific compounds was monitored through a steam distillation and extraction process. The overall distillation/extraction process is illustrated in Figure 2. Samples of fat were taken from the boiling flask (B) after it had reached a 'cooked' state.

The vapor from the boiling adipose tissue was collected as an aqueous distillate in cold traps (D). This was then extracted with ether using a separatory funnel followed by removal of the ether with a Rotoevaporator (Figure 3) and a stream of nitrogen to yield a flavor concentrate (Figure 4) of about 3 mls. Samples taken from points B, D, and E, the final flavor concentrate were evaluated by a trained sensory panel. All samples received similar lamb-like intensity ratings (Figure 5). The flavor concentrate consisted of the flavor compounds that were dispersed in the aqueous phase taken from the cold traps after an ether extraction process. The ether was driven off and a small portion of the concentrate was dispersed in water for the panel's sampling. Since the intensity of lamb-like flavor did not change with the extraction procedure (Figure 4), the final flavor concentrate represents the characteristic flavors of lamb.

A gas chromatograph equipped with a means of splitting the stream of gas between the detector and an exit port lends itself to flavor studies. Each fraction or individual compound can be smelled as it elutes off the column. An extract from lamb adipose tissue yielded aromas varying from skunky to perfume-like. This type of nasal appraisal can provide valuable clues as to which compounds are worth further studying. One area of interest on chromatograms of lamb-flavor concentrates coincides with the retention of certain medium-chain fatty acids. Branched-chain fatty acids of 9-10 carbons have been suggested as important to the "sweaty" flavor of lamb. The compounds 4-methylnoanoic acid and 4-methylnoanoic acid are considered lamb-like by trained sensory panelists, but do not receive intensity scores as high as those received by lamb fat.

### TABLE 1. Recognition of simmered rabbit and poultry meats.

<table>
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<tr>
<th>Actual Meat Type</th>
<th>Species Identification</th>
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<tbody>
<tr>
<td></td>
<td>Rabbit (%)</td>
</tr>
<tr>
<td>Rabbit</td>
<td>8.6*</td>
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<tr>
<td>Chicken</td>
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<td>Turkey</td>
<td>5.7</td>
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<td>Duck</td>
<td>2.9</td>
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*Correct identification: N = 35.

### TABLE 2. Response to flavor identification question on turkey steaks.

<table>
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<th>Type of fat used</th>
<th>Species Identification</th>
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</thead>
<tbody>
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<td>Beef (%)</td>
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<tr>
<td>Turkey</td>
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<tr>
<td>Pork</td>
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<tr>
<td>Lamb</td>
<td>8.14</td>
</tr>
<tr>
<td>Beef</td>
<td>3.49*</td>
</tr>
</tbody>
</table>

*Correct response based on type of added fat: N = 86

Chemical studies of meat determine the effect of animal diet and processing on meat flavor

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**Overview**

The knowledge of meat flavor chemistry is increasing rapidly; however, the flavor of a beef steak or a lamb chop cannot be reproduced in a test tube—or in a vegetable-protein meat substitute. The information being derived about meat flavors increases our understanding of the role of such factors as the effect of an animal's diet upon meat flavor and the changes induced by processing. Knowledge of the basic flavor composition also provides a reference profile for comparison when a meat has off-flavors that cannot be identified.

**ABOUT THE AUTHOR**

Charlotte P. Brennand is an assistant professor of Nutrition and Food Sciences specializing in flavor chemistry and sensory evaluation.
Iron deficiency anemia is a common ailment especially among pregnant women and children under two years of age. It is also frequent in nonpregnant women of childbearing age; but is infrequent in men until they reach retirement age. The present approach to treatment is to increase iron consumption, either through the diet and/or by supplementation. Frequently, 50 to 100 or more milligrams of iron are prescribed to treat a known iron deficiency. Unfortunately, even these very large doses of iron often do not improve the anemia (hemoglobin concentration in the blood) significantly. Clearly, the total amount of iron consumed is not the only factor limiting the concentration of hemoglobin in the blood; however, anemia can frequently be traced to an inadequate intake of dietary iron.

The Committee on Dietary Allowances, Food and Nutrition Board, National Academy of Sciences, has estimated that adult women of childbearing age lose 1.5 milligrams of iron daily and that adult men lose 1.0 milligrams. They recommend that the respective iron intakes be 18 and 10 milligrams daily from diet and that the respective intakes of energy be approximately 2000 and 2700 kcal daily for women and men. The Committee on Dietary Allowances has therefore assumed that approximately 10 percent (8.3 percent) of the dietary iron consumed will be metabolized. This means that the average woman needs to consume 9.0 milligrams of iron per 1000 kcal while the average man needs to consume only 3.7 milligrams per 1000 kcal. The average diet in the United States provides approximately 6.0 milligrams of iron per 1000 kcal. Thus, it is easy to see why iron deficiency anemia is frequent in women and infrequent in men.

Two major considerations in dealing with the prevention of dietary iron deficiency anemia will be presented. One involves ways of improving the iron density (milligrams of iron per 1000 kcal), and the other is concerned with increasing the proportion of iron consumed that will be metabolized by the body.

Increasing Iron Density of the Diet

The well-worn concept of 'empty calories' is useful here. Anything consumed that is rich in energy (kilocalories) but contributes very little else may be considered of low nutrient (in this case, iron) density. This is important because people have a basic hunger for energy, salt, and water, but none for specific nutrients. Therefore, the nutrients have to be provided coincidental with dietary energy. Fortunately, eating appropriate quantities of a variety of foods selected on the basis of their nutrient content will provide both energy and nutrients in adequate quantities.

In a recent study, the iron contents of the typical diets of four male professors of Nutrition and Food Sciences at Utah State University averaged 8.9 milligrams iron per 1000 kilocalories (see Table 1). More importantly, three of the four professors consumed more iron per 1000 kilocalories than the 9 milligrams per 1000 kilocalories needed by women to meet their Recommended Dietary Allowance (RDA) for iron.

All servings of food eaten by the four professors were weighed and recorded for seven consecutive days. These men consumed large amounts of vegetable and cereal products and ate modest amounts of meat. This is reflected in the low percentage of energy consumed as fat in their diets. It is concluded from these data that women could meet their RDA for iron from commonly available foods. The issue then becomes one not only of what specific vegetables are to be consumed to achieve this goal, but also what quantities of these foods should be consumed relative to those of other foods. This should be a fruitful area of study for nutrition education.

Increasing Bioavailability of Dietary Iron

The bioavailability of iron from any source such as an iron supplement, food or meal composite, is considered to be that portion of the total iron which is metabolizable. Whatever remains would not be metabolizable unless chemically changed in some way. Philosophically, this concept is important because the amounts of iron metabolized by avian and mammalian species are directly associated with their iron need. When assaying iron
To evaluate iron utilization from foods, rats are depleted of body iron by bleeding and feeding an iron deficient diet. Food iron incorporated into a balanced rat diet is then fed to rats to determine efficiency of iron repletion as measured by hemoglobin iron gain.
bioavailability, it is therefore necessary to use an organism whose need exceeds the total amount of iron provided. In animal assays of iron bioavailability, iron need is assured by a growth phase and/or by creating an iron deficiency through feeding an iron deficient diet and phlebotomy (blood letting). Because iron-replete healthy subjects are usually used in human assays of iron bioavailability, it is doubtful that their need is great and that they are physiologically "actively seeking" iron; i.e., their need may not even be equal to the biologically available iron being provided. It is therefore inappropriate to compare the iron bioavailability data from animal and human studies unless the subjects of both species are of similar iron status. In fact, it is questionable if assays of iron availability yield good information on the quantities of metabolizable iron available in a source when healthy human subjects are used. In such a situation, the amount of iron that the subject can accept may be less than the amount of metabolizable iron that the source can provide. The subject thus becomes the factor limiting the amount of iron metabolized. When this occurs, one can only conclude, for the sources of iron being tested, that the bioavailability is at least equal to the value obtained and may be higher.

Testing Bioavailability

It is expensive to conduct human studies of bioavailability using balance measurements (quantitatively weighing food intake and all excreta). Therefore, radioactive isotopes of iron are frequently given human subjects along with the food in a single meal to quantitate their percent retention of iron. This poses serious ethical questions about the use of radioactive isotopes in addition to requiring expensive whole-body counters to quantitate the radioactive iron retained. For these reasons, rats are used as models for predicting the bioavailability of food iron for humans. The literature is limited on studies where the bioavailability of iron determined in rats has been directly compared with that obtained in human beings when both were of similar iron status. However, we found various reports of data on three sources of iron (meat, hemoglobin, and ferrous sulfate) that had been given to iron deficient and/or healthy rats or human beings.

An intake of vitamin C along with meat fish or poultry enhances iron retention

The correlation coefficient for the rat responses compared with the human responses was calculated to be 0.93. (A perfect correlation would be 1.00.) Using data from a recent report on female blood donors who had given six units of blood in a 12-month period and who did not consume iron supplements, we estimated that they were utilizing 47 percent of their dietary iron. This value is considerably more than the assumed 8.3 percent absorption used by the Food and Nutrition Board in establishing the RDA for iron for women and is similar to what would be anticipated for iron-deficient rats. We concluded from this that the rat can be used effectively to study and predict the bioavailability of iron for human beings. Much work will have to be done before the exact predictive relationship can be established between the rat and human responses; but, this should certainly be another fruitful area of study.

Associated Factors and Estimates

Several factors in the dietary have been found to either enhance the bioavailability of iron or to decrease it. Vitamin C and the presence of meat, fish, or poultry in the meals being tested have enhanced the retention of iron by healthy human volunteers. Elaine Monson and Joseph Balintfy quantitated these enhancing factors by summing the milligrams of vitamin C plus the grams of cooked meat, fish, or poultry in the meal to create a mathematical function that can be used to estimate the percent of the nonheme* iron in the meal that will be absorbed. They assumed that when no enhancing factors were present in the meal, three percent of the nonheme iron would be absorbed by the average healthy human being. They also assumed that the percent absorption of nonheme iron increased to eight percent when 75 units of enhancing factor were present. Further, it was assumed that 40 percent of the iron in meat, fish, or poultry is heme iron, 23 percent of which presumably will be absorbed by the average healthy human being. This information may be computerized and used to estimate the amount of absorbable iron in meals and to ultimately derive an estimate of the quantity of absorbable iron consumed daily by a healthy human being. Factors such as egg yolk, coffee, tea, fiber, antacids, and phytates (compounds naturally present in many cereal products that bind minerals) that appear to decrease the absorption of dietary iron by healthy subjects are not considered in this method of estimating absorbable iron. Nonetheless, this method will yield a rough estimate of absorbable iron in the human diet.

Another interesting concept for estimating the amount of absorbable iron in meals is being proposed by Leif Hallberg, a Swedish physician. He suggests that iron bioavailability be defined as: The amount of iron (milligrams) absorbed from a meal per unit energy (1000 kcal) by subjects who are borderline iron deficient, i.e., nonanemic subjects with depleted iron stores. Based on the results of his work, Hallberg projected that such subjects will absorb 40 percent of a reference iron dose (3 milligrams of iron as ferrous ascorbate). He then determined the iron stores of his volunteer subjects and "adjusted" their absorption values to what he anticipated for one with depleted iron stores. With this process, the absorption of the iron in test meals may be expressed relative to the value obtained for ferrous ascorbate for the same subject. This approach acknowledges that people have a specific appetite for energy but not for specific nutrients and that the iron status of the individual will affect the amount of iron he/she will absorb.

*Heme, n. Biochem., a deep red pigment consisting of ferrous iron linked to protoporphyrin and obtained from hemoglobin by treatment with acid.
True hemoglobin iron gain is a function of body weight gain and hemoglobin iron gain. All rats are weighed at the beginning and the end of a repletion period.

Hemoglobin concentration is determined in blood from rats after depletion and after feeding specific foods containing iron.

Blood is routinely drawn from a capillary bed behind the eye of the rat. This method of drawing blood is rapid and causes slight discomfort similar to drawing blood from the arm of a human. Blood drawn into a small capillary tube is then pipetted into tubes and analyzed colorimetrically.

Iron concentration of foods are determined by atomic absorption spectroscopy.
The proportion of iron absorbed is only a fraction of what is consumed

Although Hallberg's approach has not been refined to include enhancing and inhibiting factors affecting absorption of dietary iron, it addresses important issues of expressing results accurately and standardizing of the test subjects and reference iron sources.

Form and Timing

It is well known that the ionic form of iron in food products can vary according to the process methods to which they have been exposed.4 Not much research, however, has been done on the effects of processing on the bioavailability of food iron. The bioavailability of iron in an infant formula, for example, can be increased or decreased depending on when, in the processing sequence, the iron supplement is added. We have shown that curing meat can reduce the availability of its iron by approximately 25 percent (Table 2); but, roasting and canning do not change its bioavailability (Table 3). An interesting feature of curing on the bioavailability of meat is the increased iron absorption observed as the amount of sodium nitrite added to the meat is increased (Table 2). This increased absorption was accompanied by decreased formation of this iron into hemoglobin by the anemic rats; and, they did not store this iron in their livers. Subsequently, we have observed that curing hemoglobin or myoglobin (the iron-containing red pigment of meat) decreases the bioavailability of this iron. Thus, we conclude that curing decreases the bioavailability of meat iron. However, one cannot conclude that cured meats are detrimental in an individual's diet until further research is done.

We also have demonstrated that the amounts of total and metabolizable iron in mechanically deboned meat are increased compared with normal meat, although the absorbability of iron in mechanically deboned meat is decreased (Table 4). This is because mechanically deboned meat contains much more iron than does hand deboned meat. This holds true for both mechanically deboned turkey and beef. In another study, we found that amount of fat in a diet did not affect iron bioavailability. Beef fat, however, yielded a higher bioavailability of iron in turkey meat than did corn oil, pork fat, or even turkey fat (Table 5). The effects of various processing procedures such as frying, microwaving, baking, and retorting on the bioavailability of iron in various foods need to be studied.

Equations the Goal

The ultimate goal of most research on iron bioavailability is to accurately predict the amounts of absorbable iron in foods, meals, and total diets. Ideally this would be done mathematically using simple calculators. First, however, we must have precise information on how differences in age, sex, and nutritional status, and consumption of various foods in many different combinations interact. Much progress has been made in identifying chemical and biological factors that increase or decrease iron absorption. Some progress is being made toward the standardization of these factors, which must precede developing the prediction equations.

Considerably more research will have to be completed before one can take iron absorption data obtained for individual food or supplement sources, as tested with laboratory animals or microbes, and compute how much iron John and Jane Doe will absorb from their personalized diets. Certainly this appears to be a reasonable and reachable goal. One that ultimately will be applied by food production and handling industries as they strive to provide the most nutritious food possible. It will also be medically valuable, as physicians evaluate whether iron deficiency anemia in patients is due to dietary inadequacies or to the biochemical characteristics of the individual. Certainly, the consuming public is already receiving benefits from completed research as they consume fortified foods and are treated medically.

REFERENCES


ABOUT THE AUTHORS

Arthur W. Mahoney received his PhD from the University of Maine in 1965 and has worked on appetite regulation at Harvard University. Much of his work at Utah State University has been on effects of food processing on the metabolism of iron, calcium, and protein. He is also collaborating with scientists at the University of Utah Medical School studying the epidemiology of nutrition and cancer.

Deloy Hendricks is a professor in the Department of Nutrition and Food Science with an emphasis in nutrition as it relates to humans. Currently he is studying three areas: food storage in Utah, nutrient bioavailability, and nutrient behavior interactions.


### TABLE 1. Nutrient intake of male professors.

<table>
<thead>
<tr>
<th>Professor</th>
<th>DB</th>
<th>DC</th>
<th>DH</th>
<th>AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kilocalories</td>
<td>3340</td>
<td>2705</td>
<td>1880</td>
<td>2520</td>
</tr>
<tr>
<td>Iron, milligrams</td>
<td>20</td>
<td>27</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>Iron, mg/1000 kcal</td>
<td>5.9</td>
<td>9.8</td>
<td>9.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Vitamin C, milligrams</td>
<td>58</td>
<td>108</td>
<td>50</td>
<td>77</td>
</tr>
<tr>
<td>Fat, percent of kcal</td>
<td>32</td>
<td>31</td>
<td>29</td>
<td>32</td>
</tr>
</tbody>
</table>

1 Each professor weighed every serving of food consumed for seven consecutive days.

### TABLE 2. Effects of nitrite curing and residual nitrite bioavailability of beef iron.

<table>
<thead>
<tr>
<th>Nitrite added (mg/kg)</th>
<th>Residual nitrite (mg/kg)</th>
<th>Regeneration efficiency (percent)</th>
<th>Absorbed iron (mg/kg)</th>
<th>Absorbed iron gained as Hb (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked control</td>
<td>0</td>
<td>0</td>
<td>58a</td>
<td>57a</td>
</tr>
<tr>
<td>Cured beef</td>
<td>10</td>
<td>2.03</td>
<td>50bc</td>
<td>—</td>
</tr>
<tr>
<td>Cured beef</td>
<td>25</td>
<td>2.53</td>
<td>46bc</td>
<td>—</td>
</tr>
<tr>
<td>Cured beef</td>
<td>50</td>
<td>5.63</td>
<td>39c</td>
<td>65a</td>
</tr>
<tr>
<td>Cured beef</td>
<td>100</td>
<td>9.47</td>
<td>41c</td>
<td>78b</td>
</tr>
<tr>
<td>Cured beef</td>
<td>150</td>
<td>14.38</td>
<td>44bc</td>
<td>—</td>
</tr>
<tr>
<td>Cured beef</td>
<td>200</td>
<td>13.65</td>
<td>46bc</td>
<td>80b</td>
</tr>
</tbody>
</table>

1 Values in the same column with the same letter are not significantly different from one another (Mahoney et al.).
2 Computed as the amount of iron gained as hemoglobin relative to the iron consumed.
3 Computed as the amount of iron absorbed relative to that consumed.
4 Computed as the amount of iron gained as hemoglobin relative to the amount of iron absorbed.

### TABLE 3. Heat processing does not alter iron bioavailability of beef.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Raw</th>
<th>Rare</th>
<th>Medium</th>
<th>Done</th>
<th>Baked</th>
<th>Boiled (min)</th>
<th>Retort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regeneration efficiency, %</td>
<td>33</td>
<td>35</td>
<td>36</td>
<td>36</td>
<td>5</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Absorption, %</td>
<td>66</td>
<td>63</td>
<td>71</td>
<td>70</td>
<td>31</td>
<td>34</td>
<td>37</td>
</tr>
</tbody>
</table>

1 There were no treatment effects that statistically meaningful when compared with the Raw Meat control. These data were taken from the dissertation research of Ms. Oranong Jansusilvechaku.
2 Computed as the gain in hemoglobin iron relative to the iron consumed.
3 Computed as the amount of iron absorbed relative to that consumed.

### TABLE 4. Mechanical deboning increases the quantity of metabolizable iron in meats.

<table>
<thead>
<tr>
<th>Meat</th>
<th>Regeneration1 Efficiency</th>
<th>Metabolizable1 Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD beef shank3</td>
<td>63a</td>
<td>11</td>
</tr>
<tr>
<td>MD beef shank3</td>
<td>47b</td>
<td>18</td>
</tr>
<tr>
<td>HD beef plate3</td>
<td>61a</td>
<td>9</td>
</tr>
<tr>
<td>MD beef plate3</td>
<td>52b</td>
<td>12</td>
</tr>
<tr>
<td>HD turkey frames4</td>
<td>40c</td>
<td>4</td>
</tr>
<tr>
<td>MD turkey frames4</td>
<td>39c</td>
<td>7</td>
</tr>
</tbody>
</table>

1 Milligrams of iron per kilogram uncooked product.
2 Computed as the amount of iron gained as hemoglobin relative to the iron consumed.
3 These data were taken from the M.S. thesis of Ms. Bonnie R. Farmer.
4 These data were taken from the M.S. thesis of Lowell Allred, M.D.
The beauty of fall leaves is more than "skin deep." While the artist's palette of color is splashed across the Utah mountainside and valleys, critical developments in leaves are preparing their mother trees for the coming cold of winter (Figure 1). The short days and cool temperatures of Fall turn on mechanisms in senescent leaves that produce a hormone that promotes cold hardening (so the tree can survive winter). This hormone is transported to the buds and wood of the tree through its bark.

Before this hormone-initiated first stage of cold acclimation (hardening) can take place, however, several things must happen. First, the tree must have completed its annual growth. Second, it must have an adequate food reserve. Third, days must be getting shorter. Fourth, temperatures must remain high enough to allow metabolic activity. Fifth, the tree must have leaves.

With those five conditions fulfilled, a tree can proceed through its cold acclimation process and become completely dormant. Dormancy is essential to tree survival during winter conditions. Fruit trees, in fact, must endure low-temperature chilling as a part of their annual rest period if they are to remain healthy and productive. Rest in peach trees can be monitored by soaking detached twigs in various concentrations of a growth promoter called gibberellic acid. Their subsequent growth responses can be translated into a rest-intensity curve (Figure 2). The more intense the rest, the longer the period of dormancy.

In Figure 3, the medium-sized curve (B) represents the natural rest-intensity curve for peach trees during one year in Utah. When a tree's leaves were removed prematurely, rest intensity was very low (small curve A). When the leaves were protected by polyethylene greenhouses, rest intensity developed more slowly over a longer period of time (C). Cold hardiness also developed in the protected trees at temperatures above 15°C. Then, when the shelter was removed, stronger than normal rest intensity developed (large curve with shoulder).

Removal of leaves from peach trees by hand in early September (when bud regrowth could no longer occur), affected more than rest intensity. Defoliated trees developed their cold hardiness significantly later than did the untreated trees. Their cold hardiness developed in response to low temperatures. During the early fall, flower buds on normally leaved trees were more than six degrees harder than those on defoliated trees (Figure 4).

Fooling Mother Nature

If leaves are the source of a translocatable cold-hardiness promoter under short-day conditions, then accelerating or extending leaf activity under such conditions should increase a tree's level of cold hardiness. To test this likelihood, we attempted to maintain leaves on trees later than normal in the fall.

Leaves fall when an abscission layer develops at the base of the leaf petiole following a change in hormone translocation out of the leaf. When a growth regulator, similar to the natural plant hormone auxin, was applied to peach leaves in the fall, the normal hormone changes responsible for leaf fall were no longer in control of leaf fall and leaves remained on the trees (Figure 5). Subsequently, with moderate temperatures and access to water and nutrients from the tree, the leaves produced metabolites that included the translocatable cold hardiness promoter. Having the promoter produced over a longer than usual time increased the final level of hardening of the tree.

Many chemicals that might promote leaf retention in the fall have been applied to peach trees in Utah. The best chemical used thus far is naphthaleneacetic acid, a close relative of the naturally occurring plant growth hormone, indoleacetic acid (auxin). Leaf retention responses to being treated with naphthaleneacetic acid are indicated in Table 1.

CAPTIONS

Figure 1a and b. Although less spectacular, leaf activity of fruit trees in the fall is just as dynamic as the color changes in Canyon Maple.

Figure 5a and b. Leaf retention of 'Johnson Elberta' peach trees resulting from hormone applications.

Figures 2, 3, 4 and 6 are on page 83, due to color paging restraints.
The Value of Recreational Boating

J. E. KEITH AND L. FARNWORTH

Determining the value of recreational activities provided by public facilities has been a significant problem to public resource managers for decades. Most other uses of public lands and waters such as irrigation, grazing, or timber harvesting can be valued by examining the prices which the market sets. In this way, the worth of these marketable goods is determined by the willingness of buyers to purchase, and sellers to provide their goods or services. With many publicly provided goods or services such as parks, picnicking, and boating areas, no well-defined market exists from which to determine their worth. Since the 1950s, methodologies have been developed to examine values of these "non-market" goods. For the most part, these methodologies are centered around recreation activities. Recently, other aesthetic values such as aesthetics (scenic views) have been included in valuation studies.

The first method that was developed links the value with expenditures made by recreators during the trip. This problem with the expenditure method is that it measures the gross value of a recreation visit, rather than the net value. For example, the price of a can of peas indicates willingness to pay for peas once the shopper has reached the store. The expenditure method would include the cost of the trip to the market in the value of the can of peas.

The second method was developed by Marion Clawson and Jack Knetisch (1956) following a suggestion by Harold Hotelling in a letter written to the U.S. Forest Service in the early 1950s. It was based on the assumption that, on the average, people are about equally willing to pay the same price for a given recreational experience.

Therefore, if one observes the number of trips to the same site which are taken by different individuals at varying costs, a relationship between costs incurred (as a result of the trips) and the number of trips taken is apparent. This relationship is assumed to indicate the behavior of a given individual as to how many trips he or she would take when faced with different costs and it is called the "demand curve."

By examining the difference between what an individual had to pay (actual costs) and what he would be willing to pay, one could also determine the extra value or "consumer surplus," which is generated. The visitor paying the highest cost has no surplus. (Figure 1 is a representation of the demand curve and its associated consumer's surplus).

This method of valuation has been modified and improved over the past 30 years and is known as the "travel cost method" of valuing non-market goods. It is the resultant consumer's surplus that is used as a measure of the value of the recreational activity. There have been several studies of recreation in Utah using this method. Boating (Wennergren, Fullerton, Keith, and Meale, 1975), deer hunting (Wennergren, Fullerton, and Wrigley, 1977), snowmobiling and cross-country skiing (Keith, 1980; Keith, et al., 1978), and other activities (e.g., Keith and Workman, 1975).

A third approach to valuing non-market goods was developed by several researchers during the 1960s and 1970s. This approach uses direct questions in a survey to determine recreators' willingness to pay for a visit (Bohm, 1972; Brookshire et al., 1976). This method has become known as the "bidding game," or "contingency valuation method." Questions are asked that seek to determine the maximum amount a recreator is willing to pay in addition to any other expense he or she incurs. While this method is relatively straightforward in its application, several questions have arisen as to its accuracy. For example, people may bias their answers depending upon their interpretation of the reason for the analysis. If a respondent feels the question may eventually lead to increased use fees, he might reduce his "bid," or if he believes he could influence a decision for increased production of services, he might increase his "bid." The relationship between the measures of value that are generated from the travel cost method and from bidding games is of considerable interest to both researchers and recreation managers. Both measure consumer's surplus, and therefore should be very similar.

PHOTOS

Waterskiing and picnicking brings families and friends together at the popular Hyrum Dam resort. Studies are being done to determine value, in terms of the price one is willing to pay for this enjoyable experience.
Study Conducted

In 1982, Utah State University researchers undertook a study of reservoir recreators on Hyrum Dam and Willard Bay in Utah and Twin Lakes and Glendale reservoirs in Franklin County, Idaho. Researchers used both valuation methodologies. The Utah sites are relatively developed, including boat ramps, dock, public campgrounds and facilities. Fees are charged for their use. The Idaho sites are less well developed, although both have concrete boat ramps and some docking facilities. No charge is made for their use. Recreators at each site were interviewed, and data collected concerning the costs associated with the trip, length of stay, party size and activities. A bidding game was also included, in which recreators were asked to determine the maximum fee they would be willing to pay, both for the particular trip and for an annual fee, such as might be associated with an annual use permit for the particular site. This annual bid is theoretically the equivalent of the total surplus generated for an individual over a season of use.

Both individual (based on the average visitor) and aggregate (based on all visitors) demand curves were developed for the four sites. Table 1 indicates the result of calculations of consumer’s surplus per trip and per year based on both the demand curves that were most statistically significant and the bidding games.

Note that for Willard Bay, Glendale and Hyrum, the bid value is relatively close to the surplus value calculated from the travel cost method. For the most part, the individual surplus values from the travel cost method are within statistical error (two standard deviations) of the bid value. The differences are large enough, however, so that valuation of the recreation activity can appear to be quite different, depending upon the surplus measure used.

The large discrepancy among values for Twin Lakes was probably due to the lack of statistical significance for the regressions for that site. Twin Lakes visitation tended to be a few visits per year (average of slightly over three) compared to other sites, which averaged 10 (Willard), 7 (Glendale), and 9 (Hyrum), per year for each visitor. In addition, users of Twin Lakes tended to be clustered in two groups—those who visited once or twice and travelled long distances, and those who visited frequently and resided very near the site.

Results indicate that boating recreators value these recreation sites highly. While no visitation rates are available for the two uncontrolled Idaho sites, Hyrum Reservoir had a total of 146,171 visits and Willard Bay had 224,024 visits during the sampling period (June through August, 1982). Fees collected at the two sites totalled $27,761 at Hyrum and $85,839 at Willard Bay during the same period. Using the individual surplus and bid data, multiplied by the number of visits, an additional value of $222,180 to $565,682 for Hyrum and $949,862 to $1,066,355 for Willard Bay, indicates the value of this recreational activity is very high. Therefore, operators of these and other boating facilities should be sensitive to the value of their recreation sites.

### TABLE 1. Surplus values by site.

<table>
<thead>
<tr>
<th>Recreation Site</th>
<th>Average Surplus/Trip</th>
<th>Average Surplus/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indiv</td>
<td>Aggreg</td>
</tr>
<tr>
<td>Glendale*</td>
<td>$5.46</td>
<td>$3.47</td>
</tr>
<tr>
<td>Hyrum*</td>
<td>1.52</td>
<td>1.29</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>8.72</td>
<td>16.12</td>
</tr>
<tr>
<td>Willard Bay*</td>
<td>4.76</td>
<td>1.44</td>
</tr>
</tbody>
</table>

*Demand curves with statistically significant coefficients at .1.

### LITERATURE CITED


### ABOUT THE AUTHORS

John E. Keith is an associate professor of Economics. He received his BS and MS in Range Science from USU, and an MA and PhD in Economics from USU. His research activities include recreation evaluation studies and water allocation research.

Lon Farnworth is an associate professor of Economics and graduate assistant, Department of Economics. He received a BS in Economics from USU. He worked on recreation value projects in Arizona and Utah.
It is assumed by many home economists, psychologists, and educators that certain social competencies provide the foundation upon which quality peer relations are built. From this perspective a social deficit hypothesis has emerged. That is, weak social competencies are thought to limit an adolescent's ability to establish and maintain friendships. Conversely, strong social competency skills are thought to enhance an adolescent's ability to form friendships.

While social competency is gaining increased attention, there is no universally accepted definition. However, several taxonomies and philosophical treatises (e.g., Adams, Shea and Kacerguis, 1978; Anderson and Messick, 1974; Greenberger and Sorenson, 1974) have proposed individual knowledge about appropriate emotional states for specific social contexts (social knowledge), ability to empathize with other persons (empathy), and belief in the power of self-initiation (locus of control) are three fundamental social dimensions underlying a comprehensive definition of social competence. Further, these same three competencies are thought to be reflected in social skills that assist a person in establishing and maintaining positive peer relations.

Unfortunately, the relationship between these social competency indices and peer popularity has been generally ignored as an important research area in adolescent samples. A social skills hypothesis would predict a positive association between social competency and peer popularity as a measure of positive friendship formation. Indeed, previous research with preschoolers, school-age children, and adults indicate social sensitivity, empathy, social knowledge about others' emotions, and self-initiative are correlated with positive social adjustment and quality interpersonal relationships (e.g., Bell and Hall, 1954; Dymond, 1950; Dymond, Hughes, and Raabe, 1952; Johnson and Johnson, 1978; Nowicki, 1975; Rose, Frankel, and Kerr, 1956; Rothenberg, 1970). Therefore, as part of our research program to study social competency and peer relations, we have recently completed a correlational study. It was hypothesized that (a) older adolescents, in comparison to younger ones, would manifest higher levels of social competence, and (b) social knowledge, empathy and locus of control would be predictive of peer popularity.
METHOD

SAMPLE
Adolescents from two local rural junior high schools and its feeder high school were sampled in the present investigation. A random sample of the names of 30 adolescents (120 youths) who were 14, 15, 17, and 18 years of age was obtained from administrative lists.

MEASUREMENT
Social knowledge. Four short stories devised by Rothenberg (1970) were used to assess the adolescent’s knowledge of appropriate emotions for specific contexts. Each story consists of dramatic interactions between a male and female with two vignettes focusing on a male and two centering on a female actor. Presented in a standardized audiotape format, the focal character was portrayed in a situation where due to the social context, he or she changes in feelings from an initial to a later expressed emotion. Female actors were presented in a dialogue resulting in happiness or anxiety. Male actors were presented in a social situation leading to anger or sadness. After hearing each tape, the adolescent was asked to describe how the focal character felt and why he or she felt that way. Responses were scored for (a) description of feeling, and (b) understanding of motives.

Empathy. This construct was measured by the Mehrabian and Epstein (1972) Empathy Scale. The Likert Scale assesses self-reported susceptibility to emotional contagion, appreciation of the feelings of unfamiliar and distant others, extreme emotional responsiveness, sympathetic tendencies, and willingness to be in contact with others who have problems.

Locus of control. General expectancy for internal and external locus of control was based upon Rotter’s (1966) assessment of perceived reinforcement of control. High scores on his scale reflect high internality or belief in self-initiative and self-effort in the resolution of the problems.

Weak social skills limit an adolescent’s ability to establish and maintain friendships

Peer popularity. Peer ratings were obtained on a five-point rating scale from 1 (unpopular, no friends) to 5 (popular, many friends). Ratings were obtained by five peers who were identified as school mates who were judged by the adolescent as being good friends.

PROCEDURE
All adolescents responded to the empathy and locus of control scales prior to listening to the four taped vignettes which assess social knowledge about emotions. At the close of the interview each adolescent was asked to provide the names of five peers who knew them well. Each of these peers were contacted by phone and asked to respond to the peer rating measure.

RESULTS
SEX AND AGE DIFFERENCES
Females were observed to have higher empathy scores than males, \( F(1, 87) = 63.05, p < .0001 \). While there were significant age differences on the social knowledge \( [F(3, 87) = 7.45, p < .0001] \) and locus of control \( [F(3, 87) = 4.13, p < .01] \) measures, only an age difference trend was observed on the empathy measure. On all three dependent measures the age differences reflected a general trend toward increased scores with advanced age levels (see Table 1).

Overall, adolescents held higher scores on their understanding of motives \( (M = 2.82) \) than actual description of correct feelings \( (M = 2.05) \). In Rothenberg’s (1970) original investigation, contrasting third- and fifth-graders, the older children scored higher on both description of feelings and understanding of motives. In the present study, when a similar comparison was made for age differences, and the analyses were collapsed across description of emotions for sex of actor, neither the sex or age factors approached significance. However, both sex and age emerged as significant factors on the adolescents’ understanding of the motives behind the emotional states. For the woman actor, male subjects held higher social knowledge scores than female subjects on understanding motives, \( F(1, 87) = 9.91, p < .01 \). Conversely, females held higher scores than males when asked to identify appropriate motives for the male actor. Although this latter finding was only a trend \( (p < .10) \), age differences were also observed on the ability to understand motives. With increasing age, adolescents were observed to have a more complex and comprehensive understanding of the motives underlying the appropriate emotion for the social context for both the female \( [F(3, 87) = 9.66, p < .001] \) and male actor conditions \( [F(3, 87) = 5.02; = 5.02, p < .003] \).

SOCIAL COMPETENCY AND PEER POPULARITY
To assess the proposed relationship between social competence and peer relations during adolescence, a series of correlations were computed between the social competency indices and popularity ratings while partialling out the effects of age. As summarized in Table 2, for males, both social sensitivity and locus of control were associated with peer popularity. For females, social knowledge and empathy were correlated with popularity ratings.
TABLE 1. Mean comparison on social competency indices for male and female adolescents.

<table>
<thead>
<tr>
<th>Social Competency Measures</th>
<th>14 yrs. (n = 25)</th>
<th>15 yrs. (n = 22)</th>
<th>17 yrs. (n = 22)</th>
<th>18 yrs. (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Social knowledge</td>
<td>9.12</td>
<td>9.05</td>
<td>10.50</td>
<td>10.20</td>
</tr>
<tr>
<td>Empathy</td>
<td>13.96</td>
<td>14.32</td>
<td>15.96</td>
<td>16.42</td>
</tr>
<tr>
<td>Locus of control</td>
<td>27.36</td>
<td>25.27</td>
<td>29.68</td>
<td>30.92</td>
</tr>
</tbody>
</table>

Discussion

The association between age and social competence supports the notion that adolescence is a period of continuing social competency formation. Further, the lack of sex by age interactions indicates the developmental trends are similar for male and female adolescents. Although females maintained higher empathic abilities than males over all age levels, the potential interest in heterosexual involvement during adolescence is reflected in the sex differences in understanding motives. Males responded with more depth of understanding of motives with female actors, while females were more knowledgeable with male actors. It should be recalled, however, that with advancing age, male and female adolescents reported a more complex and comprehensive understanding of motives behind emotional states for both male and female actors. Thus, one must conclude overall, that like childhood, adolescence continues to be a significant period of the life cycle which contributes to social competency formation.

The hypothesis that social competence in social knowledge, empathy and self-initiated directedness would predict peer ratings of popularity received partial support. For both male and female adolescents, social knowledge about emotional states was predictive of peer popularity. Thus, sensitivity to recognizing emotional states and their underlying motives may enhance an adolescent’s ability to establish and maintain quality peer relations. The findings that empathic tendencies for females and locus of control for males were also predictive of peer popularity once again support the notion that social competencies that are predictive of positive peer relations appear mediated by sex role based competencies. For female adolescents, empathic abilities may enhance their capacity to share interpersonally with others and enhance their peer popularity. For male adolescents, a sense of internality may focus the male’s behavior on self-initiative which provides leadership in interpersonal relations with peers.

Finally, in that several studies have now demonstrated that poor peer relations are predictive of long-range and extensive mental health problems (e.g., Achenbach and Edelbroch, 1981; Nicholson and Antill, 1981; Janes, Hesselbrock, Myers and Penniman, 1979), it appears that systematic intervention is warranted with adolescents who are lacking in social competencies that underlie friendship skill formation. This study suggests that any such intervention program effort should include assessment and training in social knowledge skills for both boys and girls. Further, such efforts should also include empathy training for girls and goal directedness training for boys.

Support for this project was provided by the Science/Education Administration of the USDA and the Utah State University Agricultural Experiment Station through the W144 Regional Research Project on Development of Social Competency. An extended variation of this report is accepted for publication in the Journal of Youth and Adolescence.

REFERENCES


ABOUT THE AUTHOR

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Published by the Utah Agricultural Experiment Station, Utah State University, UMC 48, Logan, Utah 84322.

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