Fuzzy Logic for More Rational RDAs

It controls Japanese subways, air-conditioning systems, and camcorders. And it may one day assist health professionals in setting objective Recommended Dietary Allowances (RDAs) if ARS nutritionist Eric O. Uthus has his way.

It's fuzzy logic—a mathematical approach to problems that can't be defined precisely, such as how much of a particular vitamin or mineral an individual needs to consume each day.

That amount varies, depending on many factors including the person's age, gender, heredity, and intake of other nutrients, says Uthus, a biochemist at the Grand Forks (North Dakota) Human Nutrition Research Center.

What's more, use of scientific data to set an RDA requires judgment calls. For instance, the process poses questions like: Do we want to saturate body tissues with enough of the vitamin to provide a 30-day reserve or a 60-day reserve? There is no specific number that will satisfy everyone involved in determining the RDA.

"Fuzzy logic enables us to deal with situations that are not clear-cut," says Uthus. "It should make the RDA process more objective."

Uthus teamed up with German physicist Bernd Wirsam to develop a prototype for establishing an RDA for zinc. Co-owner of a company that uses fuzzy logic to optimize industrial processes, Wirsam was the first to apply the method to nutrition. He developed a computer program to describe the range of intakes of specific nutrients—from deficiency to excess.

The program then calculates, based on the nutrient composition of the foods an individual eats over the course of a week, how closely that total diet meets all the requirements, as defined by the German Society of Nutrition. And it suggests small changes in the diet that allow the individual to meet recommendations.

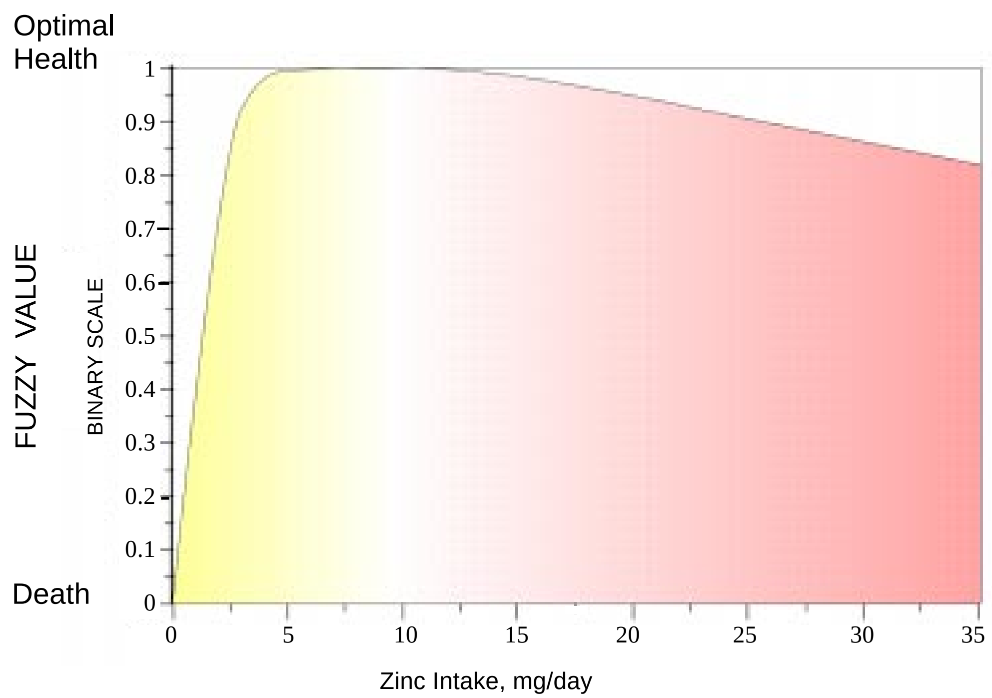
The mathematics of fuzzy logic were developed in the 1960s by the chairman of the electrical engineering department at the University of California, Berkeley. The Japanese adopted it in the 1980s to control hundreds of household appliances and electronics products that must cater to vague human concepts, such as "the air is cool." Fuzzy logic defines "cool" in computer terms.

Unlike classical logic in which something belongs exclusively to one set or the other, in fuzzy logic there is no distinct border separating sets. Something can belong to two or more sets—on a binary scale of 0 to 1. But its membership in all of the sets must add up to 1.

Uthus explains: "If we asked 100 people what room temperature is comfortable, we would get a range of answers. These values would fall into a bell-shaped curve with, perhaps, most of the people saying that 70°F was ideal. So the closer the temperature is to 70°F, the greater its membership in the 'comfortable' set. But while 70°F may be comfortable to the majority, it may be too cool to some and too warm to others, giving it partial membership in the "cool" and "warm" sets.

Likewise, when volunteers are given a particular vitamin or mineral in graded amounts, there is no definite border where one intake is deficient and a slightly higher intake is adequate. It's a range of values. Wirsam uses fuzzy logic to convert these ranges into a single number, says Uthus, who provides nutritional data and expertise.

A Grand Forks colleague helped to select two fairly sensitive biochemical indicators to use in developing the prototype curve for zinc. The amount of zinc in red blood cells is a good indicator of zinc deficiency, he says, because it falls off rather quickly as intake decreases. For the other end of the curve, zinc excess, they used the activity of



FUZZY LOGIC CURVE FOR ZINC CONSUMPTION
[Shows relative health status of individuals with varying intakes of zinc]

superoxide dismutase in red blood cells. This enzyme requires a balance of copper and zinc to function properly, so its activity drops when zinc intake is excessive.

Wirsam uses these findings to describe fuzzy sets based on five intakes: *zero* intake, *minimum* intake—the least amount needed to prevent deficiency, *optimum* intake—the amount that confers the most health, *safe upper limit*—the most that can be consumed without causing any toxicity, and *toxic* intake.

Using this method, the researchers came up with a zinc RDA of 9 milligrams per day. That's well below the 15 mg recommended for adult males by U.S. and German committees but close to a 1993 recommendation by Europe's Scientific Committee for Food, says Uthus.

"Intuitively," he notes, "9 mg looks good when considering the fuzzy logic curve [see diagram] because this intake is at the peak, or optimal level, of the curve, while the recommended value of 15 mg is not."

Uthus emphasizes, however, that the recommendation is based on scanty data and is meant to demonstrate the principle of using fuzzy logic to set RDAs.

"The model I envision," he says, "is one in which variables could be easily added as new information comes to light. A highly developed model could be used to study how other nutrients interact with a given vitamin or mineral to alter its requirement."—By **Judy McBride,** ARS.

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A Breakdown of Cultural Barriers

Scientists in the ARS Corn and Soybean Research Unit at Wooster, Ohio, have developed a novel way to cut out the insect middleman in their research with corn viruses. They've pioneered a method for transmitting viruses to plants directly, without using insects as vectors.

"There are many technical and economic advantages to being able to transmit viruses without using insects," says plant pathologist Raymond Louie, Jr. Development of the method was a necessary step for research progress, he says.

Previously, plant viruses such as maize streak and maize rough dwarf—which inflict millions of dollars worth of damage on corn crops in developing countries—could only be studied by using vectors such as leafhoppers and planthoppers. These insects transmit and spread the viruses naturally when they feed on corn plants.

Until recently, scientists have had to obtain, breed, and maintain specific insects known to serve as vectors of the viruses they've wanted to study. This complicated the research effort.

Some insects could not be brought into the United States, thus prohibiting research on some viruses. Other insect vectors had to be cultured in the laboratory, which is an expensive and labor-intensive process.

Scientists at Wooster experimented with a variety of transfer methods that not only delivered the plant viruses to the plant host, but allowed the researchers to isolate a specific virus and reduce the risk of contamination by other viruses.

"We often have a problem in studying viruses because insects may carry and transmit more than one type," says Louie. "With manual transmission, we can be sure we are infecting the corn plant with a known virus. This capability offers us the opportunity to study the effects of infection by either a single virus or a mix of viruses"

Using insect pins mounted on an ordinary engraving tool, ARS researchers have been able to successfully transfer all major corn viruses into mature corn seeds that were first presoaked for about 2 hours in water. The tool vibrates the pin, which is pushed through a drop of virus and into the seed's vascular system. When done properly, this allows the virus to enter the corn embryo within.

Scientists say bypassing insect vectors will allow them to more easily isolate viruses for characterization, help them to determine the virulence of a particular virus without contamination from other viruses, and lead to more accurate identification of resistant germplasm.—By **Dawn Lyons Johnson,** ARS.

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