Rumen Function Enhancements: Ionophores, Buffers, Probiotics, etc.

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For years, ruminant nutritionists have utilized the rumen vat for one of its unique attributes – its ability to convert non-useable products into products of the nutritional value that enhances the growth of beef cattle, sheep and dairy cattle. Examples of this have been the utilization of fiber that is non-useable by humans or other non-ruminants. In addition, we have learned how the rumen converts urea to a useable form of dietary protein.

In recent years the focus of ruminant research has shifted to the microbial population, and how altering microbial populations may fine-tune the nutritional diets utilized. Let's address three of these that currently are used: Ionophores, buffers and probiotics.

Ionophores

Polyether antibiotics hae been used for a number of years in the poultry industry as a coccidiostat. However, in the early 1970's biological screening of these compounds showed potential efficacy in cattle diets. Monensin sodium was the first ionophore cleared by the Food and Drug Administration for use in feedlot cattle. This occurred in 1976, and its clearance for stocker cattle occurred in 1978. In 1982, Lasalocid sodium was cleared for use in feedlot diets.

Biological and Economic Efficiency

Considerable research has evaluated the effect of ionophores and how they apply to the feedlot industry and cattle industry in general. The predominant benefits of ionophore inclusion in stocker and feedlot diets include:

1. Improved feed efficiency.
2. Improved rate of gain in stockers and a slight improvement in average daily gain in feedlot cattle.
3. Decreased feed intake which may enhance the carrying capacity of cattle on a given quantity of forage.
4. A potential protein sparing effect, thus, possibly lower protein requirements, or at least making more efficient use of the dietary protein content.
5. Increased digestibility of low quality forages.
6. Some reduction in the incidence of coccidiosis in cattle.
7. A decrease in the incidence of lactic acidosis.
8. Some reduction in the incidence of feedlot bloat.
9. Partial intake regulation in self feeding supplement systems.
10. Some reduction in the incidence of pulmonary emphysema.

Mode of Action

There are many parts of the mode of action of ionophores that are not fully understood. However, an ionophore is a compound which makes cations (ions which carry a plus charge) lipid soluble. In the preliminary clearance of Monensin sodium, the predominant mode of action discussed and assumed to be the factor influencing the biological efficiency was the alteration of all the volatile fatty acid ratios. Specifically, the proportion of propionate was increased and the portion of acetate and butyrate decreased. In the typical ingestion of feed stuffs, the cellulose portion of roughages is broken down in the rumen by cellulose enzymes with the end product being glucose. As the starch from grain is digested by rumen amylase enzymes, the starch molecules are converted into glucose sub units. In the rumen, the glucose is further quickly converted to pyruvate and volatile fatty acids (VFA's) which become the major dietary energy source in ruminants. The relative porportion of these volatile fatty acids will vary based on type of diets. In a predominant roughage diet a common VFA molar percentages breakdown is 65% acetic, 20% propionic and 12% butyric. In contrast, in feedlot diets where 70% or more grain is fed, the molar percentages VFA are 40% acetate, 37% propionate with the remainder being butyrate and other volatile fatty acids that occur in a lesser percentage.

Effect on Rumen Metabolism

One of the main effects of ionophores is to alter the rumen microfora to favor propionate production. A further effect on the rumen is that methane production is reduced when ionophores are included in the diet. Two factors result in the netabolizable energy value of feed stuffs being increased:

1) there is an increase in the dry matter digestibility of the diet and,
2) an increase in hydrogen retention in proprionic acid production.

Effect on Nitrogen Metabolism

Shortly after the elucidation of the VFA influence, scientists indicated that ionophores may have a protein sparing effect. Ruminal studies have indicated that the presence of an ionophore causes a reduction in ammonia production, resulting in an increased protein flow from the rumen to the lower gut.

Effect on Mineral Metabolism

Recent research evidence has indicated that the feeding of ionophores will:

1. Increase the apparent absorption of sodium, magnesium and phosphorus.
2. Increase the retention of magnesium and phosphorus.
3. Alter the soluble concentration of certain minerals in ruminal fluids of steers fed high energy diets.

Other Beneficial Effects

Ionophores affect lactate levels as cattle are transferred from either high forage diets to high grain diets, or from irregular intake of daily rations, results in a buildup of lactic acid which can cause lactic acidosis. Research at KSU has demonstrated that inclusion of ionophores in the diet results in higher rumen pH values and lower lactate concentrations. In this study, the control cattle exhibited classic signs of acidosis such as lower blood pH and increased blood lactate, while the ionophore treated cattle exhibited non of the acidosis signs.

Probiotics

The word probiotic means for-life or pro-life which tends to, in itself, encourage use and application. As we move to a society very conscious of drug residues many feel this concept has the potential to partially replace the conventional use of antibiotics.

Dr. Jim Males, Animal Science Department at South Dakota State University, recently presented two excellent papers summarizing the potential mode of action of probiotics and how they might impact the cattle industry. The following are some of the excerpts from the material that has been published by Dr. Males, and other scientists on the potential role of probiotics.

One of the difficulties that veterinarians and nutritionists have had with probiotics is the lack of consistency. When one analyzes the type of product they are, analyzes the typical lack of knowledge of what is present, or lacking in the rumen, it shouldn't be suprising that the response to probiotic type compounds, whether used as a direct application to the animal or to enhance feed stuff fermentation patterns such as silage, has been extremely variable. The primary microorganisms that have been used are either Lactobacillus or Streptococcus bacteria (lactate producing bacteria), fungi and yeast. These microbial cultures have been basically used in about four different ways. First, considerable research has evaluated their potential benefit as a silage additive, or preservative. In addition, some excellent research exists on the use of microbial products with stressed cattle and, even in some instances, routine use in stocker and feedlot diets. More recently, use of these products in the dairy industry to enhance milk production has been evaluated.

The applications of these products as a silage preservative has been extremely variable. Some results show very favorable and encouraging results; others show virtually no effect. KSU scientist Dr. Keith Bolsen, may have elucidated some of the key reasons why this may occur. Dr. Bolsen indicated that one of the possible reasons for the variability in response to silage inoculants could relate to:

1. Levels of lactic acid bacteria currently present in silage.
2. The general fermentable characteristics of the silage and how a product may impact the fermentation process.
3. General silage making techniques including storage structure.
4. Climatic conditions while the silage is being made.

Another KSU scientist, Dr. Dale Blasi, recently summarized eight different types of hay additives currently available. His summary of what these products are and their potential is as follows:

a) *Drying agents* or *desiccants* containing potassium carbonate, sodium carbonate or sodium silicate, applied during cutting to dissolve the outer layer of alfalfa and other legumes.

b) *Unbuffered organic acids* such as propionic or propionic acetic acid blends, applied uniformly in correct rates, offer consistent and reliable results for legumes and grasses containing 24 to 28 percent moisture. While they offer greater protection against spoilage than aerobic bacterial inoculants, they are more expensive and their caustic and corrosive properties can be hard on machinery and manpower.

c) *Buffered organic acids* have a higher pH than unbuffered organic acids but are more expensive. Some companies may recommend lower application rates to keep prices in line with unbuffered organic acids, but that may result in inconsistent protection.

d) *Acid salts* such as sodium diacetate, which work similarly to organic acids without the volatility. Because they also may be less effective, uniform application is vital.

e) *Anhydrous ammonia,* an excellent preservative, but users need to consider additional costs for labor and plastic covering as well as safety hazards.

f) *Urea,* as an alternative to anhydrous ammonia. Because of sporadic results, not recommended in this area as a preservative.

g) *Anaerobic bacterial inoculants* are designed specifically for higher moisture silage and haylage situations, but not particularly recommended for haying.

h) *Aerobic bacterial inoculants,* designed for alfalfa hay with 20 percent or less grass in the stand.

The use of microbial products with stress cattle has unfortunately been equally variable. Dr. Steve Rust at Michigan State University summarized 21 trials.

21 Trial Average

Average Daily Gain	0 to 14 days	0 to 28 days	0 to 84 days
Control	1.21	1.83	2.06
Treated	1.52	1.99	2.13
Feed Conversion			6.90
Control			6.82
Treated, % morbidity			
Control			29.3
Treated			23.6
% Mortality			
Control			3.65
Treated			1.4

The overall summary looks relatively encouraging. The discouraging part is that in 14 of the 21 trials, no effect on performance or health was noted, characterizing the amount of variability that exists.

The work with stocker and feedlot cattle has been similar to the other studies in which in a few trials show small incremental increases in performance, but other trials have shown no response.

More recent work being done with dairy to evaluate the impact of these products including fungi and yeast on milk production has been equally interesting. In Dr. Males' recent summary of 11 experiments, six showed an increase in milk production but, unfortunately, five showed no difference. Some studies have shown an impact of these products on increased dry matter and cellulose digestibility which is encouraging but, unfortunately, not consistent in all studies.

In Dr. Males' summary he raised three key points in evaluating when and how to use these products.

1. Only consider reputable products.
2. Know what you want to achieve in utilizing a product.
3. Know your costs and returns and closely evaluate the cost/return benefits.

Buffers

In the last 15 years numerous research trials have evaluated the potential role of buffering compounds in both beef and dairy diets. The most extensive work and oftentimes the work showing the greatest beneficial response to buffers has been dairy cattle

Unfortunately, the term "buffer" is somewhat misleading in that many compounds are often referred to as buffers and yet do not biologically contain the acitivity that really should be present for the compound to be classified as a buffer. In the truest sense of a buffering compound, they should actually alter the physiological environment. While many compounds are actually referred to as buffers, they simply act as acid-consuming or acid-neutralizing agents. An example of this is magnesium oxide.

Dairy Cattle

An excellent review was recently published by Dr. Erdman, University of Maryland, in which he summarized data from 82 experiments on the use of buffering compounds in dairy cattle. Predominant compounds evaluated were sodium bicarbonate, sodium bentonite, magnesium oxide and potassium carbonate. A summary of the excellent review would include the following points:

1. Buffering agents in low forage dairy diets were effective in increasing rumen pH, rumen acetate:proprionate molar ratio and milk fat percent.
2. In diets containing at least 30% dry matter from forages, effects of dietary buffer on rumen pH and milk fat percent were less pronounced.
3. Seventeen studies where corn silage was the sole forage showed the addition of sodium bicarbonate to the ration increase feed intake by 1 lb/day and the conversion of feed to milk.
4. when alfalfa haylage, alfalfa silage or alfalfa hay was included in the diet the response to buffers were considerably less. In fact, there was generally no justification for the use of dietary buffers in alfalfa hay based diets (based on th summary of eight trials).

Beef Cattle

Extensive research has looked at the beneficial effect of sodium bentonite and sodium bicarbonate in beef diets. Because of the nature of rumen diets, in general, the inclusion of buffering compounds has been less beneficial.

Based on the summary of the research work in the beef area, it appears there are three instances where dietary inclusion of buffers may be advantageous in beef diets.

1. *High silage diets.* The research work in high silage diets has been variable, but in a number of instances the inclusion of buffers in feeding fermented diets such as silage, has shown a beneficial response.

2. *Stressed cattle.* In managing stressed cattle or formulating receiving rations, one of the problems is the tremendous variability that exists in daily feed consumption when new cattle start on feed. In this instance, the use of buffers has shown some potential in offsetting some of the acidosis problems that occur due to underconsumption or overconsumption.

3. **In the instances when the concentrate level in a feedlot ration exceeds 92 to 94%, some beneficial effect has been noted by the inclusion of buffering compounds.** As in most situations, this research has not been particularly consistent.

In summarizing when and where to use buffering compounds, the greatest advantage to date has been in dairy diets. In beef cattle diets, an individual needs to evaluate the type of diet that is being fed and whether proven research studies support the inclusion of a buffer in that particular situation.

Summary

The rumen fermentation "vat" has long been an area intriguing to veterinarians and ruminant nutritionists. It has been a source of enticement for potential manipulation. When trying to do this, we should not lose sight of the important attributes that the ruminant has in its ability to convert fiber or other products into more utilizable compounds resulting in the conversion of products, not utilized by humans or non-ruminant species, to animal protein. However, it is also important to note that as new research information becomes available and a greater understanding of rumen function is known, there is little doubt that products that allow us to manipulate this rumen function will enhance the production efficiency of animal agriculture. Equally, this is an area where biotechnology may render new compounds that enhance fiber utilization, protein efficiency, etc., resulting in an economical benefit to the cattle industry.

For Your Library

AGRICULTURAL BIOETHICS:
Implications of Agricultural Biotechnology
Steven M. Glendel, A. David Kline,
D. Michael Warren, Faye Yates

Agricultural Bioethics presents a multidisciplinary discussion of the implications of agricultural biotechnology from ethical, social, and economic perspectives. Just published by the Iowa State University Press, the book is based on a selection of papers presented at the Agricultural Bioethics Symposium held in November 1987, at Iowa State University. The social and ethical dimensions of biotechnology have been and are the object of intense debate both within the molecular biology community and beyond. This debate is ever more important because the impact of developments in agricultural technology is so far-reaching. It is advantageous that the dialogue on ethical concerns has paralleled the development of the technology.

The major topics addressed in the 23 chapters include safety and regulatory issues, the impact of biotechnology on scientific and industrial communities, public perceptions of biotechnology, and the economic prospects, social considerations, and ethical dilemmas surrounding biotechnology. The papers present new technical procedures and data that can help analyze the short-term and long-term implications of developments in biotechnology. Among the social considerations are the impact of biotechnology on rural America and the role of university research in biotechnology. The last section of the book, Ethical Dilemmas, discusses the moral responsibility of biotechnology, the moral impact of genetic engineering, and bioethics.

Agricultural Bioethics is intended for use in academic courses on biotechnology and bioethics, as well as a resource text for the numerous scientists involved in biotechnology.

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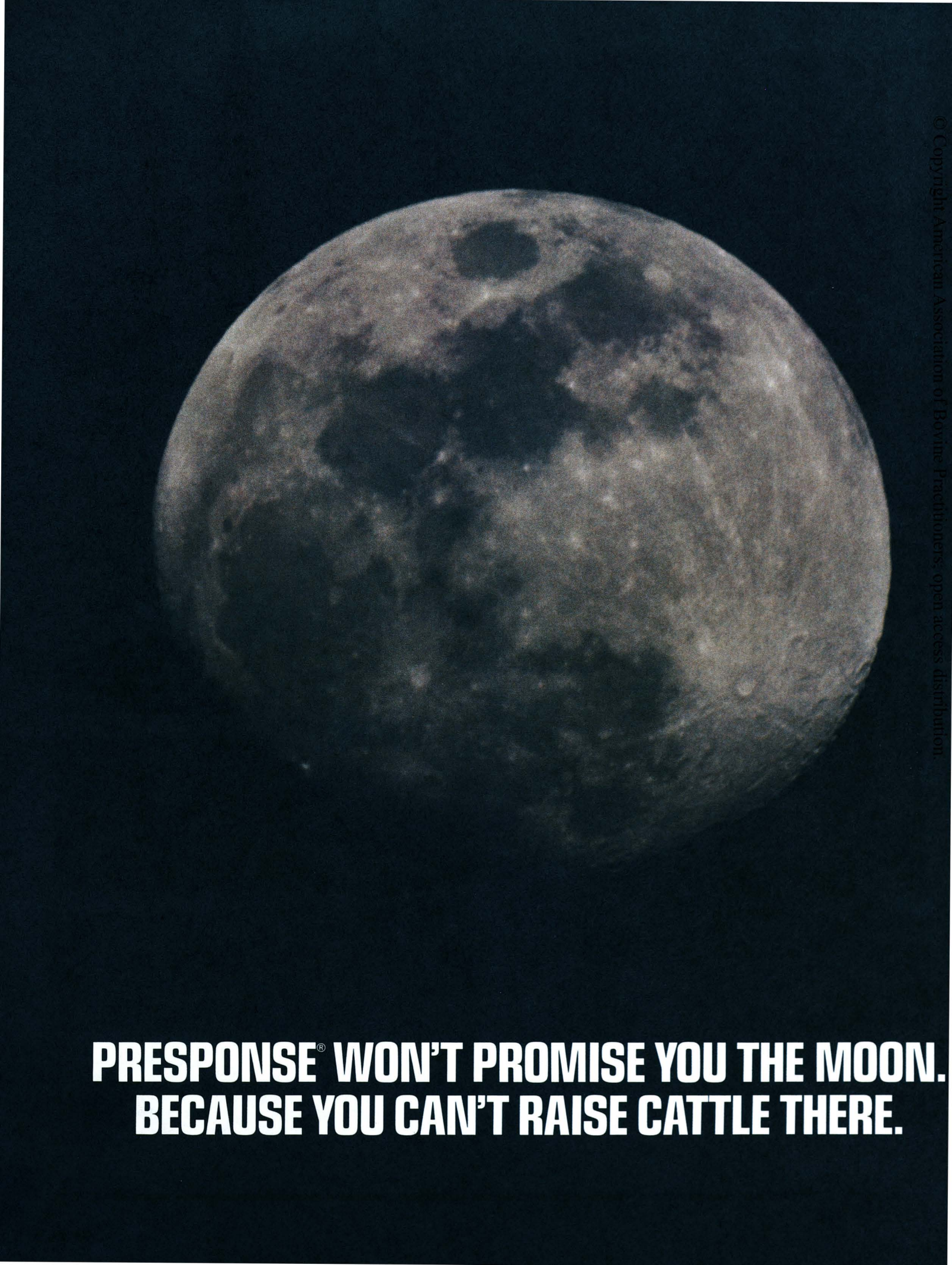

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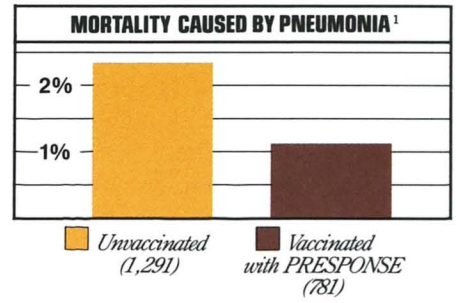

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