THOUGHTS ON FIBER UTILIZATION IN SWINE

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ABSTRACT

There is continued incentive for the development of alternative feed resources for use in swine production. The availability of distillery by-products may be expected to increase as the use of corn and cereal grains for ethanol production expands. The acceptability of distillery by-products, milling by-products, forages and other fibrous feeds as energy sources for swine depends on such factors as cell wall content of the plant, degree of microbial fermentation in the large intestine, and extent of absorption and utilization of the volatile fatty acids produced. Physiological effects of dietary fiber, including effects on gastric emptying, rate of transit of digesta, gut motility, digestive secretions, and absorption and utilization of breakdown products need quantification. Limited evidence suggests that there are genetic differences in the response of pigs to dietary fiber and in their ability to utilize it as an energy source. Recombinant DNA technology offers the possibility of cloning cellulase genes from microorganisms for application in swine feeding programs. The extent to which biotechnology will be applied in swine feeding will depend ultimately on the economic incentive for developmental effort and on unknown biological limitations of the pig and its gastrointestinal microbial ecosystem.

(Key Words: Fiber, Cellulose, Intestinal Microorganisms, Volatile Fatty Acids, Biotechnology, Pigs.)

Introduction

Fifty years ago Carroll (1936) asserted that forages could be utilized more widely in swine production. However, agronomic practices and advances in plant breeding since then have yielded dramatic increases in corn and cereal grain production and in oil-seed protein supplements that now provide large supplies of high concentrate feeds for livestock. Our cultivated land is producing at a level near its biological limit (Bertrand, 1980; Press, 1980). The future of the swine industry will depend on the ability of animals to compete with humans for the available food supply. As conventional high energy cereals progressively increase in demand for direct human use, alternative feed resources will be used increasingly for livestock production.

Thoughts on Present and Future Status

Alternative Feed Resources. Alternate feed resources include milling and distillery by-products feeds and forages. The availability of distillery by-products may be expected to increase if economic incentive for the use of corn and cereal grains for ethanol production expands to replace fossil fuels. Wheat by-products (Frape et al., 1969; Hanrahan and O'Grady, 1970; Patience et al., 1977) and corn by-products (Wahlstrom et al., 1970; Harmon et al., 1975a,b) are acceptable energy sources for swine, but their inferior amino acid balance will limit their utility as protein sources unless adequate levels of high-quality protein supplements are given, or until crystalline amino acids are more economically competitive; such may become the case as recombinant DNA technology advances their production (OTA, 1986). The acceptability of forages as energy sources for swine depends on such factors as the cell wall content of the plant, the degree of microbial fermentation in the large intestine and the extent of absorption of the volatile fatty acids (VFA) produced. Alfalfa protein appears to be well utilized as an amino acid source (Pond and Yen, 1984); information on the utilization of amino acids from other forages is very limited and the subject needs further study.

Plant Fiber as an Energy Source. The energy from fibrous feedstuffs fed to swine is available as glucose from complex carbohydrates hydrolyzed by digestive enzymes elaborated by the host animal, or as volatile fatty acids pro-
duced in the large intestine by anaerobic microbrial fermentation of carbohydrates not attacked by host-elaborated enzymes. Recent advances (Englyst et al., 1982; Asp et al., 1983; Englyst and Cummings, 1984) in measurements of fibrous material following enzymic removal of starch can be used along with the acid and neutral detergent methods of Van Soest (1963) and Van Soest and Wine (1967) to characterize energy sources. Limitations in the use of crude fiber (CF) values to estimate utilization of plant fibers by animals are well known and these newer methods should enhance progress in this sphere. King and Taverner (1975) showed that digestible energy (DE; kcal/kg dry matter) is more accurately predicted in swine diets from the percent neutral detergent fiber (NDF) value than from percent CF and suggested the following regression equation to predict DE from NDF: DE = 1.177 gross energy - 1,085 - 40.22 NDF. For a given class of feeds, DE may be estimated with reasonable confidence from CF. Henry (1977) showed a linear relationship between rate of decrease in apparent DE and level of CF such that, for a given percentage unit increase in CF, there is a decrease in apparent DE, the extent of which varies with the feedstuff. For example, a 1.0 percentage unit increase in CF of wheat bran is associated with a decrease in apparent DE of 3.0 percentage units, while the corresponding decrease for beet pulp is only 1.1 percentage units. These differing slopes are related to the composition of the cell wall constituents; i.e., the ratio of cellulose to hemicellulose (acid detergent fiber to neutral detergent fiber ratio, ADF:NDF). Progress in accurate measurement of available energy in plant fibers for swine has been hampered in the past by disagreements on appropriate analytical methods; future progress should be enhanced by more uniform analytical procedures among laboratories and across feed sources. Physiological effects of dietary fiber, including effects on gastric emptying, rate of transit of digesta, gut motility, digestive secretions, and absorption of specific nutrients and on gut hypertrophy (Bohman et al., 1955; Kass et al., 1980; Pond et al., 1980) have been identified but not quantified. Full exploitation of the potential for fibrous feed use in swine production will require such quantification as well as identification and measurement of interactions among the physiological effects and of associative effects on nutrient digestibility created by feedstuff combinations varying widely in fiber content. Further work is needed to understand lignin chemistry and ligno-cellulose bonds and their breakdown processes so as to increase carbohydrate utilization by the host and the intestinal microflora.

Absorption of VFA from the Gastrointestinal Tract. Although VFA are rapidly absorbed by swine (Barcroft et al., 1944), the amounts absorbed are less certain. Estimates based on disappearance from the lumen of the large intestine suggest that 5 to 25% of the maintenance energy requirement of the growing pig may be met by absorbed VFA. However, French data obtained from pigs fitted with arterial and portal vein catheters and a blood flow meter (Rerat et al., 1985) to obtain direct estimates of VFA absorption, suggest that about 30% of the digestible energy intake may be provided by VFA in growing pigs. Contributions of this magnitude by fibrous feeds to digestive energy intake awaken new dimensions of thought for the potential of nonconventional feeds in the total swine production system using contemporary genotypes.

Search for Genetic Differences in Ability to Utilize Fiber. Documented evidence for genetic differences among animals within a nonruminant species is sparse. There is evidence for such variations in humans (Prynne and Southgate, 1979; Jeraci et al., 1980). The statement is often heard that indigenous Chinese pigs are able to thrive on high fiber diets, but published data to support this concept are lacking. Varel (1987) reported data suggesting differences between genetically lean and obese swine in their response to high alfalfa-meal diets. Lean pigs showed a trend toward a larger number of cellulolytic bacteria in the large intestine than found in obese pigs. Obese pigs were more severely affected than lean pigs by high dietary fiber, and the resulting gastrointestinal tract hypertrophy was less than observed in lean pigs (Pond et al., 1980). These extremely different populations, in terms of body composition and gastrointestinal tract morphology, may provide a tool for assessing genetic differences in response to dietary fiber. Estimates of the degree of heritability of traits associated with dietary fiber utilization by contemporary swine populations have not been found in the literature. Such information would provide the basis for approaches to feeding strategies aimed toward maximizing efficiency of fibrous feed utilization in swine production.

Recombinant DNA Technology in Fibrous Feed Utilization. Gene splicing techniques may be applied soon in nutrition by cloning cellulase genes from microorganisms (Montencourt,
1983). Changing the microbial activities in the gastrointestinal tract of swine may be applied in this way to enhance the capacity to break the hemicellulose-lignin bond and to increase the production of cellulase. Cloning procedures could also provide the basis for production in monocultures of superior cellulolytic microbes that degrade cellulosic feedstuffs to a form that would provide more readily available energy for swine. Such developments would change drastically the constraints on swine production imposed by a limited capacity of the digestive tract to process large amounts of lignocellulose. The extent to which such biotechnology will be applied in swine feeding will depend ultimately on economic incentive for developmental effort, as well as on constraints imposed by biological limitations of the host animal and its gastrointestinal microbial ecosystem, yet to be determined.

**Literature Cited**


