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Invited Review: Use of byproduct feeds in southeastern US beef production systems*

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ABSTRACT

Purpose: Byproduct feeds are important in beef cattle feeding systems in the southeastern United States. This article discusses the evolution of a feed from a waste material to a coproduct, presents a current understanding of several important byproducts, and details sweetpotatoes and associated byproducts as an example of a potential feed source that needs continued development.

Sources: Applied research and outreach results are presented to support the use of byproducts currently in widespread use in the region. Practical advice is offered to readers based on 32 yr of experience working with farmers on byproduct-based diets for stocker cattle and brood cows.

Synthesis: There are several well-established byproduct feeds, including soybean hulls, corn gluten feed, distillers grains, and wheat middlings, that have been the subject of a great deal of research and development. Many other potential feed sources remain as waste materials or waste products awaiting more research and development to help them evolve into well-accepted feeds.

Conclusions and Applications: Nutritionists need to understand the characteristics and limitations of byproducts available in their area. Working with producers to set up effective feeding programs that allow them to make quick decisions on ingredient purchasing and adapting to disruption in supply will be critical. Although many feeds appear valuable "on paper" using the Petersen method, factors that influence their usefulness, including the presence of contaminants or antinutritional factors, high moisture content, and imbalance of key minerals, must be considered in the development of an effective feeding program.

Key words: beef cattle, byproduct, sweetpotato, sweet potato

INTRODUCTION

Byproduct feeds have become a major part of nutritional programs for beef cattle across the southeastern United States (Rankins, 2002). Use of major agricultural processing byproducts including those from cotton, soybeans, corn, and wheat have come to make up much of the concentrate fed in many beef systems. Ingredients evolve through a development process that moves them from a waste material to a coproduct, with increasing value along the way. It is important for nutritionists to be aware of the current understanding of how to best use specific byproducts, and to continue to work on those that are difficult to adopt into a beef cattle feeding program. Walker (2000) discusses the evolution of a feed from a waste material, to a waste product, to a byproduct, and finally to a coproduct.

Waste materials have no apparent feed value and are disposed of in the least expensive manner, either through land application or in landfills. A waste product has some alternative use (as a feed in this case) but still has one or more things that greatly limit its value, including high moisture content, very low protein or energy content, a need for extensive processing, presence of contaminants, or lack of a legal definition (AAFCO, 2022).

Once limitations are discovered and addressed, the feed may become a byproduct, which generally has low moisture content; is a good source of energy, protein, or both; is easy to handle in conventional handling systems; and has a legal definition. Although byproducts are highly useful in the commercial feed trade, they generally will have one or more characteristics that still limit their value relative to the standards of corn and soybean meal. Corn gluten feed, for example, works very well in diets for cattle and other ruminants, but its high fiber content and poor protein quality limits its use in diets for nonruminants (Poore et al., 2002). Finally, some exceptionally useful materials will reach coproduct status; coproducts have all the characteristics of the byproducts but have just as much importance as the major product of the processing system.

The classic example of feed evolution offered by Walker (2000) is soybean meal, which at first was a waste material that resulted from pressing oil from whole soybeans. When

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the material was first fed to livestock, it was noticed that it was valuable for ruminants but had a poor feeding value for nonruminants. Through research, it was discovered that heating the soybean meal would inactivate antinutritional compounds, making it of better value to monogastrics, at which time it was adopted widely in the livestock feed industry. Today, soybean meal is the standard protein source against which all others are valued, and it has as much importance to the soybean industry as soybean oil.

DETERMINING FEED VALUE OF ALTERNATIVE FEEDS

One major challenge for nutritionists and farmers is making day-to-day decisions about the purchase of alternative feeds. A simple method for rapidly comparing a wide range of feeds is necessary to make good economic decisions. The Petersen method uses the price of corn and soybean meal, and our well-developed understanding of their protein and energy value, to determine the value of an alternative feed (Petersen, 1932). This method has been incorporated into simple spreadsheet programs that allow the user to enter the estimated moisture, energy, and protein content of the alternative ingredient, and the price of corn and soybean meal (Erickson, 2022). A dollar value of each ingredient is obtained, and these can be compared with the market price to determine the best value at the time. This method has the limitations that it does not value minerals, which can vary considerably in the feeds, and it is dependent on the energy and protein values of the alternative ingredient, which may be relatively unknown. Other systems have been developed (St-Pierre and Glamocic, 2000), but the Petersen method is still widely in use because of its simplicity and utility in making quick decisions for relatively untrained individuals.

Petersen (1932) first recognized the importance of not overvaluing protein in byproduct feeds when making simple substitutions in rations with few ingredients. For example, when dried distillers grains is used to supplement cattle grazing most southern forages (which is common), most of the protein is not needed and the material is primarily an energy supplement. If you value the ingredient based on its actual CP level, you may pay more than it is worth in your system. For the price comparison, only the level of protein needed to meet the requirements of the animal should be valued.

Level of feeding can also dramatically affect the value of any given feed in a forage-based diet. This was demonstrated by Garcés-Yépez et al. (1997), who showed that soybean hulls and wheat middlings had similar value to corn and soybean meal when fed to calves with free-choice bermudagrass hay at a low level (25% of projected TDN intake), but the byproducts were considerably greater in value than corn and soybean meal when fed at a higher level (50% of projected TDN intake). A digestibility trial showed that this was explained by depressed use of the hay when corn and soybean meal were fed at the high level. Associative effects such as these are common when feeding mixed rations but are largely unexplored for many byproduct feeds.

It is important to consider characteristics that greatly limit the utility of a potential byproduct ingredient as a feed when considering the Petersen value. Very wet ingredients are expensive to handle and store and they experience shrinkage (loss of DM in storage). In many cases, these materials must be purchased for 50% or less of their Petersen value to prove useful in feeding programs. It is critical for the nutritionist to understand how these characteristics may limit the value of the feeds they are working with (Rankins, 2002).

SOYBEAN HULLS

Soybean hulls are a recent example of how byproduct feeds evolve through research and outreach programs. Soybean hulls are the seed coat removed from the soybean during processing. At one time soybean hulls were ground and blended back into soybean meal as a “filler” to standardize the CP level at 44%. With improved understanding of energy use in nonruminants, 48% soybean meal became the industry standard, making the “filler” soybean hulls available as a feed ingredient (Poore et al., 2002). When availability increased in the 1990s, there was still a general feeling in the feed industry that soybean hulls were just a filler, with little nutritional value such that they could be purchased at a very low price for use in ruminant feeding systems.

Anderson et al. (1988) reported that soybean hulls made a good energy supplement for grazing animals, which they attributed to the high potential digestibility of the fiber in the ingredient. Their conclusion was as follows: “Soyhulls were similar in energy value to corn when used to supplement the grazing beef animal.” This observation led to extensive research at universities across the region on the use of soybean hulls in a variety of feeding systems including hand feeding various levels with a variety of forages and free-choice feeding (Poore et al., 2002). Soyhulls have also been evaluated for use in finishing rations (Ludden et al., 1995) and for brood cows (Martin and Hibbard, 1990).

In North Carolina, applied experiments in the early 1990s showed soyhulls were comparable to corn and soybean meal, and commercial feeds, at half the price. This work along with similar research and outreach work in other southern states fueled the rapid adoption of soybean hulls in stocker operations feeding a mix of byproduct commodities and eventually by the feed industry.

OTHER BYPRODUCTS COMMON IN SOUTHERN BEEF PRODUCTION SYSTEMS

Other common byproducts in the South include corn gluten feed, wheat middlings, distillers grains, brewers grains, cottonseed, and cotton gin byproduct (gin trash). Corn gluten feed results from wet corn milling (in the production of corn syrup), and corn distillers grains results from dry milling (Klopfenstein et al., 2007). The resulting byproducts differ considerably in feeding value because distillers grains typically contains the corn oil and all the protein, whereas corn gluten feed does not include the oil and is composed mostly of the more soluble protein fractions.

Cotton byproducts are very important in beef feeding systems across the South (Rogers et al., 2002). Whole cottonseed is commonly used to supplement brood cows on hay or pasture during winter, whereas cotton gin trash is commonly fed to brood cows as a substitute for hay in close proximity to cotton gins. Recently, more cotton gin trash is being baled and sold in a broader geographic area, giving it potential for use in byproduct-based TMR for growing cattle. Cotton gin byproduct (aka gin trash) is high in fiber and moderate in CP and makes a good substitute for medium-quality hay when offered free choice. Many gins give the byproduct away to local farmers in the loose form, and due to low density, this system is only of utility very close to the gin (Mullins, 2021). Some gins also package their byproduct in either 227-kg bales or large modules (9 to 11 t) for sale, which allows movement over longer distances and more convenient feeding management than loose cotton gin byproduct (Rogers et al., 2002).

Cotton gin byproduct has interesting feeding characteristics compared with other relatively high-fiber materials such as crop residues. Intake of the material when offered free choice is considerably greater than expected based on the very high fiber content. Hill et al. (2000) reported that dry brood cows would consume very large amounts of gin byproduct, supporting the maintenance of dry beef cows as the only feed component. Rogers et al. (2002) also reported success feeding cotton gin byproduct free choice from a module when offered hay at one-third of anticipated intake as compared with hay free choice. This system provided cost savings of over $1 per cow daily. Cotton gin trash may also have an intake stimulating effect when fed in a TMR for growing cattle (Mullins, 2021).

Cottonseed should be limited to no more than 0.5% of BW for mature lactating brood cows, whereas growing cattle should be limited to 0.33% of BW as performance drops off when the feeding rate exceeds 15% of the total diet DM (Rogers et al., 2002). Cottonseed has been fed free choice to brood cows, but research evaluating that approach showed that cows would gradually build up intake to the point they exceeded the accepted feeding limits, after which they developed an aversion to the cottonseed, resulting in a rapid drop in voluntary intake (Hill et al., 2008). It is recommended that farmers hand feed whole cottonseed, not to exceed the daily limit, which will help avoid problems from feeding too much fat and also will limit the potential for gossypol toxicity (Rogers et al., 2002). Feeding on alternate days (or 3 d a week) has proven to be a viable practice that can help reduce the labor associated with hand feeding.

SWEETPOTATOES AS A CASE IN POINT

Sweetpotatoes (*Ipomoea batatas*) are an important crop in the South, providing several different waste streams that may be useful in animal feeding. The spelling presented here, as one word, was established by the industry to avoid confusion with other types of potatoes (*Solanum tuberosum*). Sweetpotato production has grown rapidly in the United States, with most of the production (USA total of 1.35 million tonnes) in North Carolina, California, Mississippi, and Louisiana, with supply increasing 2.5 fold since 2000. (Shahbandeh, 2022). The crop is of great importance, as it is the sixth most important food crop in the world, with a total of 100 million metric tons produced globally (International Potato Center, 2022). Only 1 to 2% of the world crop is produced in the United States.

North Carolina leads the nation in sweetpotato production and also processes a large part of the North Carolina crop (and crops from other states) by canning. This results in several potential feed products including cannery waste slurry, cannery solids, and cull sweetpotatoes from fresh packing. All these potential feed products remain "waste products" in their evolution as alternative feeds, because they are high in moisture and have characteristics that may lead to animal health effects including sudden death (Thibodeau et al., 2002).

Cannery waste slurry results from steam peeling of the sweetpotatoes. The sweetpotatoes are first steamed, and then, brushes remove the skins, which are conveyed from the processing line with water. The resulting slurry has about 10% DM and is moderate in protein (10% CP) and high in energy (>80% TDN; comparable to corn). The slurry rapidly ferments, resulting in a material with very low pH (3.2) that is stable over long periods of storage. Due to the high apparent value of this material, it has been fed free choice to brood cows in close proximity to the canneries. To improve the logistics of feeding systems, the material is stored in waste pits, from which it is run into troughs via gravity or pumped into tanker trucks for transport to feeding troughs. Cows aggressively consume the material at very high levels, saving a large amount on the winter feed bill for farmers using it (Thibodeau et al., 2002).

In the mid-1990s we received a request from a farmer using sweetpotato cannery slurry for an investigation of their farm because they were experiencing low growth and breeding rates in yearling heifers, and poor body condition, especially during the grazing season, in mature cows. After investigating several risk factors, we started to suspect that the sweetpotato cannery slurry was to blame for the physical problems observed including severe erosion of the teeth and sores and lesions in the mouths of the yearlings first examined. Evaluation of the cow herd revealed that a high percentage of the cows had severely worn teeth, with many middle age cows completely without teeth. Some young cows showed severely eroded middle incisors black in color but with completely normal second incisors, which emerged after slurry feeding was discontinued for the summer grazing season (Rogers and Poore, 1997).

Despite our evidence that the sweetpotato slurry was the cause of the problem, the farmer in question and the local extension agent that had helped them to set up their feeding system would not believe that the feeding of this material was to blame. To confirm our findings, we visited another farm using the material in a similar way and found that their cows were suffering from the exact same dental problems.

In vitro work with dental erosion in bovine teeth confirmed that the slurry, which was high in lactic acid and had a pH of 3.2, caused rapid loss of minerals from the tooth surface. The erosive nature of sweetpotato slurry was comparable to a lactic acid solution with pH 3.2. Neutralizing the slurry to above pH 5.0 completely stopped the dental erosion in vitro (Rogers et al., 1997).

A controlled feeding trial conducted with yearling cattle determined the time course of dental erosion, documented the effects on growth performance of the cattle, and tested the use of recycled poultry bedding to neutralize the lactic acid. Cattle consumed a high level of the sweetpotato cannery slurry, but ADG was less than with a control diet of corn–soybean meal and free-choice hay. Neutralizing the slurry improved DMI and gain compared with the native slurry. The mixing of recycled poultry bedding with the slurry only increased the pH from 3.2 to 4.0, but this was sufficient to dramatically reduce the dental erosion, which was measurable by 28 d in cattle fed the native slurry, with near complete erosion of the deciduous teeth after 112 d (Rogers et al., 1999). The cattle were slaughtered following the feeding period, and they were also found to be have severe ruminal parakeratosis due to the long-term acidosis from which the cattle were suffering. Since the time of this work, we have helped many farmers include this material in TMR at up to 20% of diet DM, which results in good performance without any dental erosion problems. Cannery solids, which includes sweetpotatoes culled during various stages of processing, are of greater value than slurry due to their lower moisture content, and they have also been successfully incorporated into TMR when limited to 20% of the diet DM (Thibodeau et al., 2002).

The other major potential feed product from sweetpotato production is cull sweetpotatoes, which are available year-round from fresh packing operations. These sweetpotatoes will have some kind of defect, including cuts or bruises, or in some cases, they are just too small or large to fit the fresh market. Despite the high calculated value of these sweetpotatoes, extreme caution should be employed if feeding to cattle because they can cause sudden death from acute pulmonary emphysema in herds consuming the product. The toxin 4-ipomeanol and related derivatives, produced by the sweetpotato in response to damage from bruising or infection with pathogens, are potent lung toxins to cattle and also cause liver damage in laboratory animals.

In 2000 we received a call from Bill Kunkle from the University of Florida, who was investigating the sudden death of 42 out of 110 cows in a herd pastured adjacent to a produce packing plant. Upon visiting the site, he found that the plant had started packing sweetpotatoes and had dumped several loads in the cow pastures, which had been a standard practice for years with other types of produce. The farmer had a free feed that was delivered to his pasture, and the cows readily ate the waste produce and experienced good performance. Unfortunately, the farmer paid little attention to the cattle because he did not have to put out feed regularly and did not discover the problem until many cows were found dead or dying. We obtained a sample of the sweetpotatoes that were still remaining, and analysis showed the presence of 4-ipomeanol at about 50 mg/kg along with several other related compounds. This was the first time that a clinical investigation confirmed the presence of 4-ipomeanol in sweetpotatoes that were suspected to cause cattle deaths.

Work with mice explored the possibility of fermenting these sweetpotatoes to detoxify them. Sweetpotatoes high in 4-ipomeanol were fermented (or not), and extracts were prepared and injected into mice. Fermentation did not reduce lung toxicity in the mice and actually increased liver toxicity (Thibodeau et al., 2004).

Sweetpotatoes and their processing byproducts remain a challenge to use safely in an efficient feeding program. Use of cannery slurry at low levels in TMR is a viable system, but handling the material is a challenge. Whole cull sweetpotatoes have been chopped and fermented, which preserves them and makes a good feed as part of a TMR, or as part of an extruded complete feed, as long as they are not high in 4-ipomeanol to start with (M. H. Poore, unpublished data). Despite a lot of research over the years, sweetpotatoes and their byproducts retain their status as a waste product, and because the size of the US crop is growing rapidly, and because of the global importance of the crop, they provide an opportunity for future research and development.

RECOMMENDATIONS FOR APPLIED NUTRITIONISTS

Because the nutritional value of many byproducts is relatively unknown, working with producers to help them develop and manage a byproduct-based feeding program is as much an art as it is a science. A few practical tips are offered to applied nutritionists working with these kinds of programs. Seeking out information on your locally available byproducts, including total amounts available, seasonality of supply, variation in typical analysis, potential associative effects when mixed with other ingredients, and storage challenges, should be well understood.

When developing programs based on TMR, use a variety of ingredients, rather than just 2 or 3. This will allow easy substitution of an alternative ingredient should the supply run low of any of the diet components. Consider which ingredients will readily substitute for others because of similarity of nutritional characteristics. For example, soybean hulls can be readily substituted for corn gluten feed (with adjustment of CP levels) because both are primarily digestible fiber. Ingredients that are high in highly digestible carbohydrates such as bakery byproduct, ground corn, or hominy feed should be included at relatively low levels and should not be substituted for high-fiber ingredients without considerable adaptation time. Even a switch from soybean hulls to wheat middlings requires some level of adaptation as wheat middlings contain a significant level of highly digestible starch (Poore et al., 2002). Using a TMR with a variety of ingredients will also provide some associative effects because of the complimentary effect of blending a variety of carbohydrate and protein sources. Using at least one wet ingredient in a TMR should also be considered to help control dust as long as the use level is low enough to provide efficient handling of the TMR.

For cow-calf farms or for small-scale stocker farms, infrastructure may not be available to store a variety of ingredients and equipment for making a TMR may be cost prohibitive. In these cases, using single dry byproduct ingredients such as soybean hulls, corn gluten feed, or whole cottonseed may be effective as long as maximal feeding levels are understood and forage is sufficient in CP to meet requirements when supplemented with the byproduct in question. A mix of 2 ingredients may prove useful in situations where protein is likely to be deficient such as a 50:50 mix of soybean hulls and corn gluten feed. In these situations, it will be critical to evaluate the mineral levels in the supplemental ingredients and the forages as some ingredients will be very high in phosphorus or other minerals, requiring a high calcium/low phosphorus mineral supplement provided free choice. This is especially the case when the ingredient is dried distillers grains, brewers grains, or corn gluten feed, all of which are very high in phosphorus. Use of wet ingredients such as wet brewers grains can be very challenging for smaller operations due to high handling costs and potential for spoilage (Hatungimana and Erickson, 2019).

When evaluating commodity blends that have become common in the commercial feed industry, it is critical to know the ingredients that make up these blends. Peanut hulls are commonly used in commercial feeds, and they have an extremely low feeding value, often lower than the forages being supplemented. When a commercial feed has a high crude fiber level, it may be because the feed contains a high level of soybean hulls, or it may contain a high level of peanut hulls, which would result in a dramatic difference in feeding value. Therefore, it is critical for the nutritionist to know what specific ingredients are included when evaluating a commercial commodity blend.

The name of many of these alternative feed ingredients should also be reconsidered because a negative social image may be created for the general public. Names such as broiler litter and cotton gin trash sound as if we are using cattle to dispose of waste materials that may be better disposed of in landfills or through other means. We coined the name "recycled poultry bedding" as a substitute for "poultry litter," which creates a more positive mental image, and it has been widely adopted across the world, where the material remains an important ingredient (Rankins et al., 2002; Capucille et al., 2004). For similar reasons we have recently started calling cotton gin trash "cotton gin byproduct." Baled cotton gin trash is also marketed in North Carolina by one feed supplier as "cotton gin fiber." Improving the public perception of byproduct feeding is an important future consideration as consumers become more conscious of how their food is produced.

Consulting scientific reviews for your locally available ingredients will help you rapidly provide advice to farmers seeking to develop a byproduct feeding program and help them manage supply changes that occur seasonally. In 2002 we published a serial book (Rogers and Poore, 2002) that included a collection of reviews that have proved very useful to many nutritionists. The book was dedicated to Bill Kunkle (namesake for the Bill E. Kunkle Symposium at the Southern Section ASAS meetings), who was writing a review on citrus pulp for this book at the time of his death (Poore, 2002). In addition to the reviews already mentioned in this article, chapters in this collection include reviews of citrus pulp (Arthington et al., 2002), brewers grains (Westendorf and Wohlt, 2002), canola and sunflower meal (Lardy and Anderson, 2002), peanut byproducts (Hill, 2002), and potato waste (Bradshaw et al., 2002). Although these reviews are still very useful to practicing nutritionists, updates are needed for most of these ingredients, as well as the many others that are not included.

Although much is understood about the common byproducts that have become standard commodities (soybean hulls, distillers grains, corn gluten feed, whole cottonseed, wheat middlings, and so on), work is still needed to understand how to best use them in a variety of feeding programs and how their value is affected by associative effects in mixed rations. Many other available materials with potential feeding value are not well understood and warrant more careful evaluation in applied research. There are many potential waste materials and waste products that need through characterization if they are to evolve into useful byproduct and coproduct commodities.

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