By-Product Feed Utilization for Forage Diets

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Introduction

Beef cattle production in Florida is based upon the utilization of grazed forage. This forage base is a dynamic source of nutrients during the year. Due to the variation of forage nutrient availability, grazed forage often does not meet the nutrient requirements or desired level of performance of the beef cattle grazing the forage (Moore et al., 1999). Therefore, supplementation programs are an integral process in many cattle enterprises that are dependent on forage-based management systems.

Supplemental feed costs are often the largest cost of the beef cow enterprise. However, effective feeding and/or supplementation programs are needed if optimal cattle performance is to be achieved on forage-based production systems. A vast array of supplement feedstuffs exist for beef cattle producers to utilize. Understanding the various characteristics, feeding properties, and interaction with forage-based diets is an important consideration for selecting supplements. Price is not always the best selection criteria for supplement feed decisions. The ability of the feedstuff to match cattle nutritional needs in an economical manner should have the greatest emphasis.

Forage Quality and Yield

As previously mentioned, the forage base is one of the key factors affecting the need for supplementation of grazing beef cattle. Forage chemical composition and forage intake potential are interrelated and important variables affecting cow nutrient supply. Forage chemical composition varies throughout the year. In Florida, one of our predominate forages utilized for grazing is bahiagrass. Warm season grasses such as bahiagrass are generally low in energy (Garces-Yepez et al. 1997) and supply a moderate amount of protein. Brown and Kalmbacher (1998) summarized total daily nutrition (TDN) and crude protein (CP) content of central and south Florida bahiagrass. Likewise, US Sugar Corp. has amassed an extensive database of bahiagrass chemical composition. Combined these data offer an opportunity to review the extent of nutrient content variation on a monthly basis in bahiagrass. Energy and protein content of bahiagrass (Table 1) has a range of about 7% TDN or 0.15 Mcal/lb of net energy of maintenance and a range of 6% CP. Other chemical characteristics that are important for the estimation of intake potential (ADF, NDF, etc.) vary to a greater extent throughout the year.

Additionally, the growth pattern of the forages in Florida is variable and dependant on many factors. Environmental conditions (temperature and precipitation) that affect forage growth change throughout the year and will dictate forage growth and availability for grazing. Likewise soil fertility and fertilization practices will attenuate environmental conditions to dictate pasture forage growth. There are direct relationships between forage availability and intake potential of cattle. Availability of forage to underpin supplementation practices is an important variable in the supplement decision making process. Abundant forage, even if it is low-quality, which can be utilized as a digestible fiber source offers many more supplementation options compared to a short supply of forage. Table 2 indicates the months in which a 1,100 lb mature Brangus type cow will need supplemental energy and/or protein to meet her requirements associated with maintenance, lactation, or gestation. The need for supplementation occurs as a result of the combination of forage nutrient concentration and forage dry matter availability. Additionally, low forage availability results in a greater proportion of the nutrients required by the cow to come from supplementation. The cheapest source of nutrients is almost always grazed forage. Coupled together the variation of nutrient content and intake potential can significantly affect the forage nutrient availability of grazing cattle.

Forage Supplement Interaction

Unfortunately, the implementation of supplementation to ruminant animals is not always a straight forward situation. Acknowledgement of that interaction should be addressed. One should refer to the work of Moore et al. (1999) to examine the interaction of a number of different supplement types and forage types on cattle intake. In their review, Moore et al. (1999) indicated that forage intake was both increased and decreased with supplementation. This differential response to supplementation can lead to the variable response that can be observed in practical situations. The authors reported that much of the negative effect on forage dry matter intake (substitution, negative associative effect) occurred when forage TDN:CP ratio was < 7. This indicates that high quality forages as indicated by protein content will be displaced by the consumption of supplements. Whereas a TDN:CP ratio > 7 likely indicates a nitrogen deficit in the forage. This nitrogen deficit likely affects forage intake, digestibility, and thus forage energy value. In this case appropriate supplements can have a positive effect (positive associative effect) on forage intake and forage digestibility. Marston and Lusby (1995) indicated that once protein requirements within the diet are met, increasing energy intake by feeding supplementation would be difficult without substitution. Consideration of the forage-supplement interaction needs to be fully addressed in practical feeding situations. This is especially imperative because often multiple by-product feedstuffs can be utilized in cattle supplements.

By-Product Feed Choices

An in-depth review of the vast array of by-product feed choices that cattle producers have to choose from are beyond the scope of this paper. However, by-product feeds that often utilized and those that will become increasingly accessible will be addressed. An obvious omission from this paper is liquid feeds. The author would refer readers to the large amount of work already published by the University of Florida, and other sources for a more complete discussion of molasses and other liquid products. Associated with each by-product feedstuff is some variation in the chemical composition. By nature these feedstuffs are by-products and at best co-products of a particular process for some other more valuable product. Quality control, consistency, and availability of by-product feedstuffs should always be considered before their use. As with many by-products balancing for mineral deficiency in the by-product is an important consideration. Additionally, by-product feeds should be compared with other feeds as to their appropriate use as a supplement to grazing cattle. The following are brief descriptions, feeding guidelines and considerations of selected by-product feedstuffs (Table 3).

Distillers Grains

Distiller's dried grains are the dried residue remaining after the starch fraction of corn is fermented with selected yeasts and enzymes to produce ethanol and carbon dioxide. After complete fermentation, the alcohol is removed by distillation and the remaining fermentation residues are dried. Historically, three types of residual co-products were produced: distiller's dried grains, distiller's dried solubles, and distiller's dried grains with solubles. Once the fermented mash was distilled, the soluble portion of the remaining residue was condensed by evaporation to produce condensed distiller's solubles. The coarse material remaining in the fermentation residues was the distiller's grains fraction. Both of these fractions were subsequently dried to produce either distiller's dried solubles (DDS) or distiller's dried grains (DDG). Today, ethanol plants blend and dry these two residues to produce distiller's dried grains with solubles (DDGS), which generally is the only form available to the feed industry. The DDS fraction has the highest concentration of nutrients compared to DDG and DDGS. It is a rich source of vitamins, and is the lowest in fiber and highest in fat, yielding a digestible energy value that is approximately 91% of that found in corn. Since DDGS is a blend of DDS and DDG, one would expect the nutrient composition of DDGS to be intermediate between DDS and DDG. This is generally the case with the following exceptions: CP, arginine, histidine, lysine, methionine, cystine, tryptophan, magnesium, sodium, sulfur, selenium, vitamin B_{12}, and folacin.

Dried distillers grains with solubles are an excellent source of protein, particularly by-pass protein. This by-pass protein of DDGS is approximately 50% of the CP content. The by-pass protein characteristic of DDGS offers an important source of metabolizable protein to reach the small intestine. As a percent of the by-pass protein value of soybean meal, DDGS are 230 to 260% greater, indicating the high by-pass value and potentially better source of protein (Aines et al., 1986). To complement the by-pass protein, DDGS are a very low starch and high digestible fiber by-product feed. The digestible fiber content of DDGS also makes DDGS a good source of energy for cattle. The energy content of DDGS can function to compliment the fibrous energy source in grazed forages or as a supplement to stretch the forage supply by displacing forage intake. The use of DDGS as either a protein or energy supplement is dictated generally by the level of feeding and production goals.

Feeding of DDGS would be a valuable addition to young cattle supplements. The by-pass protein value of DDGS would work to meet the metabolizable protein requirement of young growing cattle. In many feeding situations the metabolizable protein requirement of young cattle can be difficult to meet. Likewise, DDGS have an energy value of 109% of corn (Aines et al., 1986). This increased energy value is the result of the high digestibility of the corn bran which makes up most of the fiber fraction and greater concentration of fat in DDGS compared to corn. In addition, DDGS could work synergistically with urea to result in a valuable supplement. The DDGS would provide digestible fiber for energy, by-pass protein and amino acids, vitamins, and minerals. A small amount of urea could be included in the supplement to meet the degradable intake protein requirement of the rumen microbes.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	<1.0	15 - 20	10 - 15
Growing cattle	<1.0	50	5 - 10

Corn Gluten Feed

Corn gluten feed (CGF) is a by-product of the wet corn milling industry. Corn gluten feed actually contains no gluten but is a mixture of the corn bran and condensed solubles. The CGF product contains highly digestible fiber from the bran portion, and is a good source of degradable intake protein and energy. Approximately 50% of the CP of CGF is soluble with 70-75% of the protein being ruminal degradable (Shaver, 2004). Corn gluten feed is an excellent compliment to forage based diets because of the low starch-high fiber energy source. Additionally, CGF does contain some fat to increase the energy density. In certain production situations CGF may need to be augmented with a by-pass protein source to meet animal requirements for metabolizable protein. Corn gluten feed is low in calcium and potassium, but high in phosphorus concentration. An adequate mineral program is essential to maintain proper balance of calcium, potassium, and other minerals in production settings. The use of CGF should be limited to less than 25% of the total ration dry matter (Kubik and Stock, 1996) or 0.5% of BW (Davis, 1998) in high forage diets. Corn gluten feed is often coupled with soybean hulls in various proportions as a supplement for grazing cattle.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	<0.50	25	5 - 7
Growing cattle	<1.0	25	5 - 10

Soybean Hulls

Soybean hulls (SBH) are a by-product of soybean processing for oil. Soybeans hulls are the seed coat of the soybean that has been cracked to remove the seed and toasted to destroy the urease activity. The protein concentration of SBH is variable depending upon the amount of soybean seed that is included in the product. Soybean hulls are ground then pelleted to increase the bulk density of the feed and improve the SBH handling characteristics. Soybean hulls contain approximately 77% TDN, 12% CP, and less than 14% starch (Kunkle et al., 2004). The TDN of SBH arises from the highly digestible nature of the fiber in SBH. Soybean hulls are generally utilized to replace the grain concentrates rather than forage in the overall diet of cattle (Amaral-Phillips and Hemken, 1997). When fed to growing cattle SBH should be limited to less than 0.5% of BW (Davis, 1998). Soybean hulls have the equivalent TDN to corn grain, but when fed at high levels the TDN of SBH is reduced because of the high rate of passage associated with the fiber fraction. Some concern about SBH causing bloat has been expressed when feeding at levels greater than 1.5% of BW. Soybean hulls expand when they contact water or salvia giving cattle a full appearance, but gas bloat at high levels is possible. To prevent bloat, long stem roughage should always be assessable and/or feed additives or other feed sources can be blended with SBH to reduce the incidence of bloat. While SBH are nearly a "perfect" energy supplement for grazing cattle, the protein level in SBH would indicate an additional protein source to support rapid weight gains in young cattle.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	<0.50	50	5 - 10
Growing cattle	<0.50	25 - 50	3 - 10

Whole Cottonseed

Whole cottonseed (WCS) is one of the oilseeds that is commonly and effectively fed whole without further processing. Whole cottonseed is an excellent source of energy (90% TDN), protein (24% CP), and phosphorus. Whole cottonseed has several limitations to its use. The first limitation of use is the high oil content of WCS (24%), which provides much of the energy. The oil in WCS is slowly released through the chewing and re-mastication process of cattle. However, a high level of inclusion of WCS in the diet to result in a total dietary fat content of greater than 6% can reduce forage fiber digestion and feed efficiency. Once cattle become adapted to consuming WCS, the fat concentration in WCS can act as an intake limiter (Rankin, 2004). Secondly, WCS is low in calcium; therefore a mineral source with adequate calcium concentration should be supplied. Whole cottonseed also contains the ergot alkaloid gossypol which has been reported to cause infertility in bulls. Therefore, WCS should generally not be fed to bulls. If WCS is fed to bulls during the off-season, the WCS should be removed from the bull's diet a minimum of 60 days prior to the initiation of the breeding season to allow sufficient time for fertility issues to resolve. There appears to be two isomers of the gossypol molecule, one that causes the negative problems associated with gossypol, whereas the other appears to have little negative effects (Rankin, 2004). Upland cotton, the predominate cotton grown in the Southeast appears to contain a lower concentration of the toxic gossypol compared with Pima cotton.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cow	0.50	25	5 – 8
Bulls (not breeding season)	0.33	15	5 – 7
Growing cattle	0.30	10	1.5 – 3

Wheat Middlings

Wheat middlings (WM) are a by-product of the flour milling industry. Wheat middlings consist of the bran, germ, and some flour. Two forms of WM are generally available, pelleted WM or meal WM which can often be dusty and present some feed handling issues. Nutritionally, WM have a high TDN (82%), phosphorus (1%), and moderate protein (18%) because of the inclusion of the bran and germ components. Wheat middlings are generally not considered a fibrous by-product because of the low fiber (< 9.5% crude fiber). Wheat middlings are often utilized in many dry-pelleted supplements to augment the energy content without the use of high starch ingredients. The use of WM can be advantageous for any class of cattle. Supplementation of mature cows on low quality forage and growing cattle has been equally successful utilizing WM. Wheat middlings are often coupled with an oil-seed protein source to make a balanced cattle supplement. Supplementation of any class of cattle with high levels of WM will require attention to the calcium concentration in the mineral supplement to balance the high level of phosphorus.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	0.50	20	5 – 7
Growing cattle	0.30	15	1.5 – 2.5

Citrus Pulp

Citrus pulp is a by-product of the orange and grapefruit processing industry (Kunkle et al., 2004) that is commonly available in Florida. Citrus pulp is available in both wet and dry forms with the dry form as a pellet being the most readily available. Wet pulp is locally available to producers within economical trucking distance of processing plants. Wet and dry citrus pulp are nutritionally similar except for the water in wet pulp (Arthington and Pate, 2001). The difference in dry matter content between wet (20%) and dry (91%) is quite remarkable. Additionally, the amount of wasted product is drastically different between dry and wet pulp (5 vs. 30%; Arthington and Pate, 2001). Citrus pulp regardless of the type is high in TDN (79%) and low in CP (8%). The energy derived from citrus pulp come from digestible fiber and thus is an excellent energy supplement for forage based diets. Citrus pulp should be regarded as an energy supplement only. Therefore, all classes of cattle will likely need some additional protein in their diet. In the case of mature cattle, non-protein nitrogen sources may be adequate to compliment the digestible fiber of citrus pulp. In contrast, young growing cattle will need both degradable protein and by-pass protein to meet their protein requirements. Unlike other concentrate based by-products, citrus pulp is high in calcium because of the processing and low in phosphorus. The variation associated with dried citrus pulp will likely be lower compared with that of wet citrus pulp. Additional variation will come from the pulp type (orange vs grapefruit) and between processing plants.

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	0.50	<50%	3 - 7
Growing cattle	0.40	33%	2 - 3

Brewer's Grains

Wet or dry brewer's grains (WBG, DBG) are a by-product of the brewing or malting industry. Most often brewer's grains are available in the wet form. The WBG product can contain the spent grains, generally barley alone or barley mixed with other cereal grains, and spent hops. Typically WBG are low in dry matter, moderate in protein with the majority of the protein being by-pass, and high in TDN as a digestible fiber source. Because the majority of the starch has been fermented away, WBG can be considered a moderate source of fiber. Brewer's grains are low in both calcium and potassium, thus proper mineral supplementation is imperative. The variability associated with WBG, like many by-product feeds is an important consideration, particularly because of the amount of water in the product. Storage of WBG on the farm or ranch can present some management concerns. Piles of WBG should be utilized in two to five days during the summer and could last as long as five to seven days during the winter. However, the environmental conditions in Florida are not conducive to a long shelf-life of a wet-fermentable product. One alternative is to store WBG in silage bags. This storage method has been proven to extend the shelf-life of WBG considerably. The effective fiber (eNDF) content of WBG (eNDF = 0.33) is useful and in dairy rations has been utilized to replace some portion of the forage (eNDF = 1.0) in rations. Wet brewer's grains have been utilized in low moisture forage or low moisture silage diets and have increased consumption of the total diet. Overall, a large amount of WBG will need to be consumed to provide adequate nutrients because of the low dry matter content, and thus WBG may have limited usefulness (Rankin, 2004).

	DM, % of BW	DM % max. of total diet	DM lb/head/day
Mature cattle	0.50	<50%	3 - 10
Growing cattle	0.40	33%	3 - 15

Oilseed Meals

Oilseed meals; soybean meal (SBM), cottonseed meal (CSM), and peanut meal (PM), are the protein comparison standard for many other by-product feeds. These products are obtained after the removal of the oil from the seed through a solvent process or through mechanical processing. Variation in SBM and CSM nutrient content arises from the different processing methods. Solvent extracted meals generally have lower fat content and lower in by-pass protein (35% vs. 55%) compared with mechanically extracted meals. All oilseed meals are excellent sources of protein and energy. Differences exist between SBM, CSM, and PM for CP, TDN, and fiber fractions as a result of the different seed characteristics and processing procedures. Protein concentration differences in SBM (44 vs. 48%) are a result of processing the soybean with or without the hull intact. Oilseed meals are often the easiest way to incorporate degradable protein into the diets of forage fed cattle. Cattle on low-protein forages often exhibit an increase in forage intake and fiber digestibility (positive associative effect). The oilseed meals are often incorporated with higher energy supplements (wheat middlings, corn gluten feed) to balance pelleted supplements. In general, the differences between SBM, CSM, PM, and any other oilseed meals (sunflower, linseed) are small enough that use of an oilseed can be based on a $/weight basis rather than $/unit of CP or TDN. Supplementation rates of the oilseed meals are generally dictated by cost and amount to meet nutrient requirements rather than inclusion rates that may adversely affect animal performance.

Vegetable Waste

The large vegetable industry in Florida makes cull vegetables and vegetable by-products locally available. Vegetable waste can be highly variable in product makeup and nutrient content. Because of this great variability, analysis of the product should be performed periodically and if or when obvious changes in the product occur. Vegetable waste generally is very high in water content and low in dry matter. Generally, vegetable products can contain 15 to 30% CP and 10 to 20% acid detergent fiber on dry matter basis (Shaver, 2004). Storage life of vegetable waste products would likely be less than five days to prevent spoilage and heating. Vegetable waste should nearly be treated like a very wet forage product because of particle size, ash content, and potential energy content (Shaver, 2004).

General Considerations

There are several important considerations that should be evaluated for any by-product feed. Many of the by-products utilized by beef cattle have potentially high moisture content. The amount of water itself is not an issue, rather the effect of water diluting nutrients in the by-product feed. High water content of by-product feeds could potentially limit the intake of the feedstuff, the stability of the product should storage be a need, and the cost of transportation of the by-product. Also, utilization of wet by-product feeds in combination with other potential by-product feeds should be considered along with the overall diet dry matter content. Additionally, do not be fooled by the potential low cost of wet by-product feeds compared to dry feed by-product feeds. Comparisons between feeds should be done on a dry matter basis rather than as-fed for the price per nutrient unit. As pointed out in individual by-products some by-products have high or extremely low concentrations and of particular nutrients or minerals. Consideration should be given to these nutrients and the overall supply and nutrient balance of the total diet for the class of cattle being fed. Because these are by-products of a particular industry attention needs to be paid to the quality of the by-product when it is received. Consistent nutrient profiles are not necessarily guaranteed with by-product feeds. Additionally, the milling process of cereal grains will concentrate any potential for mycotoxins in the by-product feeds. Finally, the form that by-product feeds are produced (wet) can and does increase the potential for contamination from spoilage or contamination.

Conclusion

The extent of potential by-product feed use by beef cattle are only limited by availability of by-products and imagination. A great number of potential by-products were not covered by this paper. Regardless, consideration should be give to every by-product utilized as a feedstuff for cattle. The ability of our base forage to meet those requirements varies throughout the year and according to the cattle requirements. Given the differences in forage quantity and quality during the year, it is nearly impossible for one by-product to meet the nutrient requirements of all cattle all year-round. No one by-product feed will meet the needs of a single supplementation program especially when different classes of cattle need to be supplemented. Cattle of different ages, physiological status, and desired level of performance all have different nutrient requirements. Likewise it will often not be economical to supplement all cattle with a single by-product or blend of by-products because of potential imbalances of nutrients. Finally, just because a by-product is cheap in price does not equate to value in feeding. Consideration of the nutrient profile, handling characteristics, transportation, storage, and availability should be addressed when deciding upon the use of by-product feeds in forage diets.

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Table 1. Monthly energy and protein concentrations of bahiagrass in Florida. [a]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Energy												
TDN, %	49.6	51.3	58.5	56.8	57.5	56.7	57.0	56.1	55.3	53.5	52.2	52.0
NE_m, mcal/lb	0.40	0.43	0.54	0.58	0.53	0.51	0.52	0.48	0.49	0.47	0.44	0.44
Protein												
CP, %	6.6	9.2	11.3	12.1	11.5	11.0	9.8	8.9	8.2	8.1	7.5	8.5

[a] Bahiagrass diet mean of Brown and Kalmbacher (1998) and US Sugar Corp. bahiagrass data base.

Table 2. Months needing energy or protein supplementation to meet requirements based on January 1 calving date. [a]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maintenance	X	X										
Lactation	X	X	X	X								
Gestation			X	X	X	X				X	X	X

[a] Months indicated by a deficiency of NE_M or MP supplied by forage to meet maintenance lactation or gestational requirement.

Table 3. Nutrient composition of selected by-product feedstuffs. [a]

Feed	DM, %	TDN, %	NEm, Mcal/lb	NEg, Mcal/lb	CP, %	DIP, % of CP	UIP, % of CP	Rel. By-pass value [b]	Ca, %	P, %
Distillers grains, dry	91	99	1.13	0.75	31	26	74	2.0	0.09	0.66
Distillers grains, dry w/ solubles	90	99	1.13	0.75	30	27	73	1.5	0.20	0.80
Distillers grains, wet	30	101	1.15	0.77	30	46	54	2.0	0.09	0.66
Corn gluten feed	90	80	0.86	0.56	22	75	25	0.8	0.12	0.85
Soybean hulls	90	77	0.82	0.52	13	58	42	1.0	0.55	0.17
Soybean meal, solvent	90	84	0.98	0.64	49	70	30	1.0	0.38	0.71
Whole cottonseed	90	95	1.07	0.73	23	62	38	1.0	0.14	0.64
Cottonseed meal, solvent	91	78	0.82	0.53	48	58	42	1.0	0.22	1.25
Wheat middlings	89	82	0.89	0.59	19	78	22	1.0	0.15	1.02
Citrus pulp, dehydr.	89	73	0.91	0.61	7	43	57	1.0	1.81	0.12
Citrus pulp, wet	18	73	0.91	0.61	7	62	38	1.0	1.81	0.12
Brewers grains, dry	92	84	0.92	0.61	25	34	66	2.0	0.29	0.60
Brewers grains, wet	23	84	0.92	0.61	25	41	59	1.6	0.29	0.60
Vegetables	14	83	0.90	0.60	10	100	0	-	0.60	0.30
Bakery by-product	68	91	1.02	0.69	14	76	24	-	0.09	0.18
Distillers stillage, corn	7	92	1.03	0.70	22	45	55	-	0.14	0.72
Molasses, cane	78	75	0.79	0.50	6	100	0	-	0.97	0.10

[a] Tabular values from NRC, 1996 and Beef Magazine, 2006.
[b] By-pass value is relative to soybean meal with 30% bypass (Kubik and Stock, 1996).

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