Commodity Feedstuffs in Cow/Calf and Stocker Rations

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Introduction

Nutrition is the largest non-ownership cost associated with beef production. The beef industry's Standardized Performance Analysis (SPA) data on one million cows from 500 herds estimates that nutrition is responsible for 54% of total cash costs and 38% of total costs (Weaber, personal communication). Several options exist for astute managers intent on minimizing feed input costs. For example, if readily accessible and competitively priced, traditionally used byproducts such as soybean (SBM) or cottonseed meal, highly digestible fiber byproducts such as corn gluten feed (wet or dry; WCGF, DCGF), soybean hulls (SBH) and wheat middlings (WM) are a few of the many types available that efficient-minded producers can use to reduce feed costs.

Byproducts of this nature originate from various milling industries in which the grain or oilseed undergoes extensive processing to extract the starch or oil for human or industrial use.

The annual production of WM, DCGF and WCGF, and SBH in the US approximates 7.4, 5.7 and 3.3 million tons, respectively. Other byproducts that are highly digestible include distillers dried grains, beet pulp and rice millfeed. In general, the protein and energy contents of these byproducts are complementary to low-quality forages and predominant forage-based growing rations when compared to traditional oilseed byproducts and grain.

Historically, grain processing industries such as wheat flour mills have marketed their byproducts primarily to commercial feed companies. As a general rule, the processing center derives approximately 10 - 15% of gross revenues from byproducts destined for livestock feeding[4,5] hardly a significant reason for allowing the production and/or demand of byproducts to drive the entire process. However, increasing production costs and declining margins along with the opportunity to add value to the purchased crop commodity has encouraged grain and oilseed processors to rapidly adopt the notion of pelleting and directly marketing the resulting byproducts to beef producers. Pelleting byproducts at many grain processing and oilseed extraction centers has effectively reduced dust pollution, short term on-site storage concerns and accelerated the acceptance of byproducts by livestock producers through ease of transport and enhanced storage characteristics.[42]

Several factors should be considered first before byproducts are incorporated into an existing feeding program. First, the location of the processing facility must be well within the marketing radius of other competitively priced feedstuffs. Second, the nutrient composition of the byproducts should complement the intended animal's nutrient requirements. Third, besides unit cost and availability, the nutrient composition of the byproduct should be relatively consistent from load to load. This review article will address the factors which affect nutrient utilization, feeding guidelines and storage concerns with byproducts of this nature.

Nutrient Content of Highly Digestible Fiber Byproducts

As a result of focusing extraction efforts on the endosperm or meat fraction of grains and oilseeds for starch and oil, substantially higher levels of crude protein (CP; except SBH), ether extract, fiber and minerals (macro and trace) result from the concentration of the bran and/or hull fractions into the byproduct-destined stream (Table 1). Unlike CGF and WM, the nutrient content of SBH is derived predominantly from the seed coat or hull with some soybean meats which escape extraction efforts. Consequently, nutrients such as CP and minerals are not elevated to the extent that is observed with CGF or WM. The CP content may be increased from 7 to 200% in CGF and WM relative to corn and wheat, respectively. In general, the CP is highly degradable in the rumen.

Concentrating the bran and/or hull fraction into the byproduct results in a significant increase in the fiber (NDF and ADF), ash and mineral content. With the exception of SBH, costly macromineral (such as phosphorus, potassium and magnesium) and trace mineral (such as copper, manganese and zinc) levels dramatically increase in CGF and WM. Because of high sulfur levels, diets containing 100% WCGF have been reported to cause outbreaks of polioencephalomalacia.[43] Thus, supplemental thiamine should be added to diets containing higher levels of WCGF as a preventative measure.

Table 1. Nutrient content of parent grains/oilseed and associated byproducts[a]

Nutrient	Corn	Wet corn gluten feed	Dry corn gluten feed	Soybean	Soybean hulls	Wheat	Wheat middlings
Dry matter, %	88	42-44	90-92	92	91	89	87
Crude protein, %	10.1	14-22	21-22	40	9.4	16.9	18
UIP, %[b]	55	22	22	35	25	26.05	23
Crude fiber, %	2.9	7.0-8.4	8.0-8.4	5.8	35	2.8	11
NDF, %[b]	9	38	42	15	74	8	39
ADF, %[b]	3	14	10	11	47	11.7	13.5
Nem, Mcal/lb	1.02	.96-.99	0.87	1.04	0.82	0.97	0.83
Neg, Mcal/lb	0.7	0.65	0.57	0.71	0.53	0.66	0.5
TDN, %	90	90	78	93	77	89	73
Fat, %	4.2	3.0-5.0	2.0-3.3	19.4	2.5	2	3.7
Total starch, %	70	26	18	-	-	71	26
Ash, %	1.4	7.2-9.0	7-7.2	5.5	5	1.9	5
Calcium, %	0.02	0.1	.1-.2	0.27	0.6	0.05	0.14
Phosphorus, %	0.35	.45-1.00	.80-1.00	0.64	0.22	0.43	1.1
Potassium, %	0.37	.90-1.60	1.3-1.50	2	1.7	0.41	1.3
Magnesium, %	0.13	.15-.50	.42-.50	0.29	0.22	0.17	0.5
Sodium, %	0.02	0.2	0.12	0.02	0.01	0.02	0.035
Sulfur, %	0.14	.35-.40	.16-.30	0.24	0.09	0.15	0.21
Aluminum, ppm	-	-	-	-	-	-	45
Cobalt, ppm	0.04	-	0.09		0.12	0.16	0.2
Copper, ppm	4	6	6-9.9	20	18	6.5	13
Iron, ppm	26	41-165	165-304	91	324	35	140
Manganese, ppm	6	12-26.4	22-26.4	39	11	33	155
Molybdenum, ppm	-	-	0.8	-	-	-	1.45
Selenium, ppm	-	-	0.22	0.12	-	0.45	0.35
Zinc, ppm	16	45-114.4	88-114.4	53	24	50.8	80

[a]1995 Feed Industry Red Book
United States - Canadian Tables of Feed Composition, 1982
Blasi et al[5,6]
NCR-88[38]
Hutjens et al[26]
Cargill Website
Minnesota Corn Producers Website
NRC, 1996
[b]UIP = undergraded intake protein; NDF = neutral detergent fiber; ADF = acid detergent fiber

Corn Gluten Feed: A byproduct of the wet milling industry, corn gluten feed (CGF), represents about 12 - 13 lb from one bushel of corn after extraction of starch, gluten and germ. After the initial cleaning step and in preparation for the milling and separation process, shelled corn is soaked (steeped) in water and sulfur dioxide in order to swell the kernel. During this process, many essential nutrients are absorbed into the steep water. After several hours, the water or liquor is drawn off and concentrated (condensed corn steep water). The grain is then systematically separated from the bran (exterior portion of the kernel) into several fractions for further refinement to yield ethanol and fructose from starch, oil from germ meal and gluten meal from corn protein. DCGF is manufactured by combining corn bran with steep liquor and (and corn germ meal in some facilities) dried in a rotary drum dryer. After grinding the mixture through a hammer mill, the product is pelleted to increase bulk density, facilitate handling and enhance storability. WCGF is made by pressing the wet corn bran to approximately 35% dry matter (DM) so that when combined with corn steep liquor the final product contains about 40% DM.[10]

Normally, the ratio of bran to steep liquor is 2/3 to 1/3 in the final CGF product. However, significant deviations from this often quoted ratio can and do occur quite often depending upon the final intended ratio by the manufacturer. CGF can vary in color from golden to brown and the steep liquor adds a pleasant molasses-like caramel odor. A lighter colored product is usually preferred as a darker color may be indicative that heat damage has occurred during the drying process. Furthermore, as more steep water is added, the product will become darker as well. Invariably, CGF nutrient variation can be considerable. For example, the crude protein,[13,33] neutral detergent fiber (NDF)[27,13] and ether extract[40] has been reported to range from 17 to 26%, 26 to 54% and 1 to 7%, respectively. As with all byproducts, potential nutrient variation must be considered when formulating diets. Thus, it is imperative for the user to either conduct chemical analyses on each purchased load or purchase product with a guaranteed analysis.

CGF is a viable protein and energy source for cattle when grazing low and moderate quality forages,[9,16,17,51] feeding roughage-based growing diets[48,51] or finishing diets.[45] The crude protein in CGF is of high quality[12,15,29] and is about 26 % of DM of which approximately 75% is ruminally degraded (degradable intake protein = DIP). When feeding low quality forages, feeding corn has lead to a reduction in forage intake and decreased forage (fiber) digestion. This observed phenomenon is commonly referred to as a negative associative effect and oftentimes occurs when a grain such as corn is fed with forage. This presumably is a result of favoring starch-fermenting microbes over fiber digesters, thereby reducing overall fiber digestion. Alternatively, including corn grain in the diet may lead to a deficiency of DIP, which also could limit fiber digestion. When compared to SBM/corn mixtures and SBM as a supplement for beef cows fed corn stalklage[52] or native grass hay,[17] DCGF was shown to be an effective source of energy and protein for cows grazing low quality forage diets. As a protein source, CGF is approximately equal to SBM if diets are formulated to meet NRC protein requirements of cattle and are isocaloric.[12,29]

The energy value of CGF is dependent upon the amount of forage fed in the diet,[4,25,51] the physical form (wet vs dry) fed,[19,38] and the ratio of corn bran, solvent-extracted germ meal and steep liquor blends that are used to create CGF.[20,21] Researchers have determined that CGF could be fed up to approximately 50% of the ration dry matter with no reductions in cattle performance. Green *et al*[19] determined that CGF is highly digestible and feed efficiency is similar to corn when WCGF and DCGF is fed up to 50 and 25% of the grain component, respectively. Whitham *et al*[51] conducted a 99 day study where 216 beef heifers (average 524 lb) were fed traditional roughage-based diets at 2.75% of body weight or limit-fed high-concentrate diets fed at 2.0% of body weight to determine the effects of diet type on WCGF feed value. WCGF was essentially equal to

Table 2. Performance of heifers fed roughage-based or high-concentrate diets with corn or corn gluten feed.[a]

Treatment	Dry Matter Intake, lb/day	Daily Gain, lb/day	Feed:Gain
Days 0-99[e]			
Roughage + Corn	18.96[b]	2.52[b]	7.52[b]
Roughage + CGF	19.81[c]	2.57[b]	7.72[b]
Limit-fed Corn	13.73[d]	2.54[b]	5.42[c]
Limit-fed CGF	13.69[d]	2.27[c]	6.02[d]
SEM	.18	.08	.60

[a]Whitham *et al*[51]
[b,c,d]Means in a column with different superscripts are different (P<.05).
[e]Heifers were fed a common series of set-up rations; includes a 15-day post-trial period on common diets.

corn when included in roughage-based diets, but produced lower gains and poor feed efficiencies when used to replace corn (Table 2). Subsequent work with finishing rations has demonstrated that the energy value of WCGF or DCGF declines as increasing amounts replace corn in a grain feedlot ration.[48]

Researchers from the North Central Region[38] have summarized the differences between WCGF and DCGF with 31 experiments involving 2,700 cattle from seven states. Corn silage-based diets represented the predominant diet base from which CGF type was evaluated. For ease of interpretation, the data set was divided into groups fed low silage diets (5 - 20% of DM), medium silage diets (30 - 50 % of DM) and high silage diets (60 - 80% of DM). When low and medium silage levels were evaluated, feed efficiency was higher for cattle fed corn than for cattle fed CGF. At the high silage level, feed:gain ratios were similar among all energy sources. WCGF-fed cattle gained 14% more efficiently than cattle fed DCGF in diets containing no forage. However, the differences became much smaller between corn and CGF as the amount of forage in the diet increased. In general, DM and NDF digestibility is usually 5-10% higher in diets containing WCGF vs DCGF. Several postulates have been suggested as to why WCGF is superior to its dry counterpart. Because WCGF particle size is larger than DCGF, some researchers have suggested longer ruminal retention times and, hence, digestibility rates are improved.[15] Others have theorized that the digestibility of the ADF fraction is especially vulnerable to heat damage during the drying process.[50] However, Oliveros 1987[39] was unable to consistently observe between batches the negative effects of drying on DM digestibility.

Soybean Hulls: The estimated yield of SBH from a 60 lb bushel of soybeans is about 3 lb, or approximately 5% of the original soybean weight. In preparation for the oil extraction step, all soybeans are passed across a screen to separate all foreign material and fine particles prior to being cracked with a roller to break the whole beans into smaller pieces. This facilitates the removal of hulls as well as reduces the size of the bean meat, so that proper flaking can occur. The beans are cracked to a size of 1/6 to 1/8 inch, small enough to facilitate the release of the hull but coarse enough to limit the amount of meat fines. All of the hulls and a fraction of the meat fines are removed via aspiration after the initial cracking step. The hull fraction then passes over a sifter and is separated into three categories: (1) large hulls and meats, (2) small hulls and meats, and (3) fines. The fines are returned to the primary soybean stream, while the SBH and meat fractions go to the secondary dehulling step. During this process, the hulls are removed from the soybean meats and passed to the hull toaster to destroy urease activity. Following toasting, the remaining hull fraction is ground to the desired particle size and either pelleted or sold as bulk. The bulk density of whole SBH is extremely low and must be increased to lower the transportation costs, and thus increase the marketing radius of this byproduct. In general, pelleting increases bulk density 3 to 3.7 times and does not affect intake or dry matter or NDF digestibilities.[36]

As with CGF, the nutritional value of SBH is heavily dependent upon the nature and composition of the entire diet, and thus standardized book values are almost meaningless. Moreover, the chemical composition of soybean hulls can vary widely among sources. A large portion of this variation is due partly to the occasional erroneous classification of soybean mill feed and soybean mill run as SBH.[47] Both soybean mill feed and soybean mill run contain a portion of the soybean meat as well as the hull. SBH, when well cleaned, typically contains 9.4% crude protein and 74% NDF.[2] However, products classified as SBH have been observed to contain up to 19.2% crude protein with only 53.4% NDF.[3] These results further emphasize that livestock producers who incorporate SBH into diets should accept the challenges of nutrient variation and know the nutrient content of the byproduct.

The results of several beef cattle studies clearly demonstrates that SBH are a comparable energy source to corn for beef cattle when grazing low and moderate quality forages.[2,7,14,18,23] Martin and Hibberd[35] conducted an intake and digestibility study whereby cattle were fed low quality native grass (3.7% crude protein) with increasing increments (0, 2.2, 4.4, or 6.6 lb) of SBH daily. Maximum hay intake was observed with 2.2 lb SBH. Moreover, a low substitution rate of SBH for hay was observed when SBH were fed at the higher level (hay intake was decreased only 1.5 lb compared to control) which supported their conclusion that SBH enhanced the energy status of animals (Table 2). Subsequent work by Chan *et al*[8] revealed total energy intake was similar between corn and SBH when fed in combination with low quality native hay despite the large TDN difference which exists between corn and SBH (91 vs 77 %, respectively). In a feeding environment containing low quality forages feeding corn has lead to a reduction in forage intake and decreased forage (fiber) digestion, as discussed previously.

SBH have been successfully incorporated into supplementation programs for cattle grazing higher quality forages as well. Cravey *et al*[11] compared high-starch (corn) to high-fiber (SBH/WM) supplements for fall-weaned steer calves grazing wheat pasture fed at approximately 0.65% of body weight. Performance was similar for steers receiving either supplement (P>.45). Supplement conversions (feed:gain) were 5.4 and 5.0 for the high-starch and hull-based supplements, respectively In addition to increasing stocking rate by one-third, supplementation also increased daily gains by 0.33 lb.

Because SBH are recognized as an excellent source of readily available energy in forage-based diets, their usage in backgrounding and replacement heifer diets seems logical. Several studies conducted previously with growing beef cattle have yielded consistent results with SBH.[34,53] Hibberd *et al*[22] evaluated self-fed rations for 443 lb growing calves that consisted entirely of SBH or with 30% replaced by ground sorghum. During the 51-day trial, the SBH-fed and SBH/sorghum grain-fed calves gained 1.40 and 1.69 lb/day, respectively. Ration consumption averaged 13.8 lb/day for both groups (2.6% of body weight, DM basis). The feed efficiency (feed:gain) of calves fed soybean hulls was 9.8 vs 8.6 when 30% sorghum was added to the diet. Moreover, a subjective bloat scoring system was employed because fibrous feeds such as SBH swell and rapidly ferment. Producers should not be surprised if cattle fed large amounts of SBH exhibit some ruminal distension.

Limited research has been conducted evaluating SBH as a major component of high-concentrate limit-fed diets. Pelleted SBH are excellent candidates as the predominant energy source in feedlot diets for limit-fed, growing calves because (1) they are nearly as easy to transport and handle as grain; (2) they are highly digestible, reducing manure productions especially when compared to forage-based diets; and (3) they have a fairly stable fermentation pattern when compared to grain. Two hundred and thirty crossbred beef heifers were used in a 98 day trial to compare the growth performance of cattle fed roughage-free SBH diets to more traditional roughage-based or corn-based diets.[28] A traditional roughage-based diet (29% corn, 45% alfalfa, 20% prairie hay and 6% molasses and supplement) was fed at

2.75% of body weight and used as a control. A high-concentrate corn diet (77% corn, 15% alfalfa and 8% molasses and supplement) was fed at 1.5% or 2.25% of body weight. Similarly, a SBH diet (92% SBH and 8% molasses and supplement) was fed at 1.5% or 2.25% of body weight. Calves fed SBH when fed at 2.25% of body weight, showed gains comparable to those of cattle fed the more traditional roughage-based diet at 2.75% of body weight (Table 3). Feed efficiency was improved by approximately 12% in comparison to the roughage-based diet. SBH diets yielded gains that were approximately 73% of those obtained with the limit-fed corn diets, presumably because of lower digestibility. SBH can be used effectively as the primary ingredient in limit-fed diets. However, restriction of feed intake will not lead to appreciable improvements in SBH digestion for diets that contain insignificant quantities of forage.

Wheat Middlings: Often referred to as wheat millfeed, wheat mill run or midds, WM represent a sizable and economically important byproduct obtained during the process of milling wheat for flour. Flour milling byproducts arising from a fairly homogeneous parent grain can vary greatly depending upon the objectives of the milling process. During the wheat milling process, approximately 72 - 75% of pre-cleaned wheat becomes white flour with the remaining 25 - 27% representing wheat byproducts. Typically, 2.3 bushels of wheat are required to produce 100 lb of flour, resulting in 38 lb of wheat byproducts consisting primarily of bran, shorts and red dog (WM represent all wheat byproducts combined). Typically, bran and shorts each form approximately 40% of the WM produced with red dog composing the remaining 20%.[37]

Table 3. Performance of cattle fed roughage-, corn-, and soybean hull-based diets.[a]

	Day 0 to 98 Performance		
Treatment[b]	Intake, lb/d	Daily Gain, lb/d	Feed:Gain
Roughage	16.79[c]	1.80[d]	9.35[de]
Corn (1.5%)	9.29	1.13	8.20[d]
Corn (2.25%)	14.36[d]	2.34[c]	6.13[c]
Soyhull (1.5%)	9.07	.84[ef]	10.87[e]
Soyhull (2.25%)	13.97[d]	1.71[d]	8.20[d]

[a]Löest et al[28]
[b]Roughage = roughage-based diet fed at 2.75% of body weight (BW), Corn 1.5 = corn-based diet fed at 1.5% of BW, Corn 2.25 = corn-based diet fed at 2.25% of BW, SH 1.5 = soybean hull-based diets fed at 1.5% of BW, SH 2.25 = soybean hull-based diets fed at 2.25% of BW.
[cdef] Means within the same column differ (P<.01).

The most important nutritional consideration with flour-milling byproducts is that no practical way exists for commercial milling operations to produce flour to the buyer's specification(s) and simultaneously produce a standardized WM. The quality and consistency of WM can be affected by several factors. First, the nutrient content of WM can be influenced by wheat type and variety, and environmental factors experienced during production and storage of the wheat crop. Second, the production of various grades of flour for individual baker specifications may alter the amount of second clear fraction (low grade flour) included in the WM-destined stream.

When priced competitively, WM are an excellent source of crude protein, energy and important minerals for beef cows and heifers grazing low quality forages. WM contain approximately 40 to 45% NDF which is highly digested in the rumen. Sunvold *et al*[45] evaluated mixtures of WM, soybean meal (SBM) and grain sorghum formulated to contain 15, 20 and 25% crude protein, and fed at the same level. While dormant forage intake increased quadratically, they found that NDF digestibility increased linearly with increasing crude protein concentration. They concluded WM-based crude protein supplements were most effective with dormant bluestem forage when formulated to contain at least 20% crude protein. Moreover, Lusby and Wettemann[32] concluded the lower apparent energy content of WM compared to corn was offset by beneficial changes in forage intake and/or digestibility that resulted in similar levels of total digestible energy intake. Several trials at Oklahoma State University have evaluated the use of WM as a source of crude protein and/or energy for fall- and spring-calving beef cows grazing dormant, native range. In short, Lusby *et al*[31] concluded: 1) WM protein and energy is well utilized to increase precalving cow weight and could be used to replace SBM when the cost per lb of crude protein is favorable; and 2) that 5 to 6 lb of WM/day can be used to replace 3 lb/day of SBM.

Growing cattle respond very favorably to WM as a replacement for grain and SBM in backgrounding rations.[1,41] A recent study conducted by Blasi *et al*[5] evaluated the performance of stocker heifers fed WM in tradional full-fed, sorghum silage-based rations and in limit-fed, high concentrate rations. Diets were formulated without WM or with WM replacing 33, 67 or 100% of rolled corn plus SBM. Over the spectrum of WM evaluated in either the silage or limit-fed diets, a similar linear decline (P<.01) in daily gain occurred as the proportion of WM was increased (Figure 1). The heifers' dry matter intake of the silage-based 100% WM diet was approximately 10% less (P<.10) than intakes of the other silage diets. With full-fed silage diets, feed efficiency changed little (P>.30) as WM increased. However, with the limit-fed diets, efficiency decreased (P<.01) as WM replaced corn and SBM (Figure 2). Based on the results of this study, WM possessed a feed value almost equal to that of corn and SBM when used in full-fed sorghum silage-based rations but had a value of 83% when used in limit-fed diets. WM also have been used successfully in winter cereal pasture supplements.[26] These results suggest that the feeding value of WM is comparable to that of protein equivalent mixtures of grain and SBM in high forage, growing programs.

Storage challenges of byproducts: Quite often because of reduced demand, byproduct prices slip in relationship to their feed value in the spring and early summer months before strengthening (relative to their feed value) in the fall and winter months. Astute producers have considered and even purchased byproducts during periods of low prices and stored them on-farm until needed with limited success. Blasi *et al*[6] conducted a survey of beef producers who used WM and determined that over 30% of the respondents encountered problems

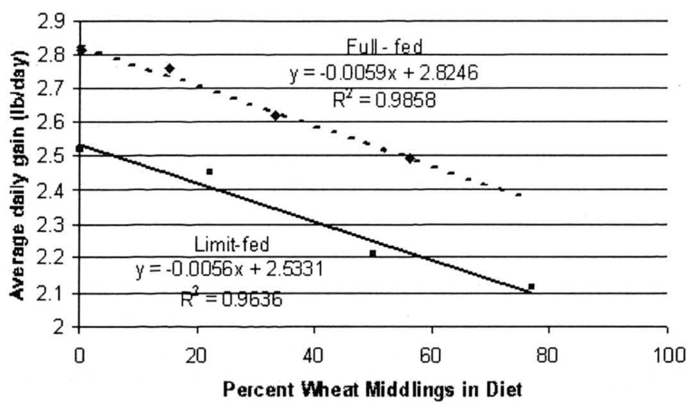

Figure 1. Effect of increasing levels of wheat middlings on daily gain of growing heifers fed either a sorghum silage or a limit-fed diet.[a]
[a]Blasi *et al*[5]

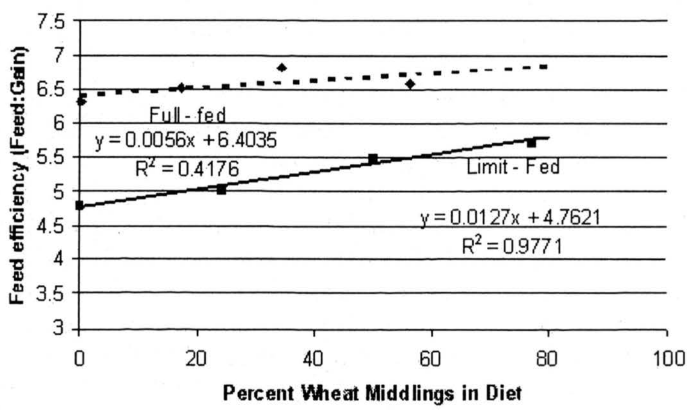

Figure 2. Effect of increasing levels of wheat middlings on feed efficiency of growing heifers fed either a sorghum silage or a limit-fed diet.[a]
[a]Blasi *et al*[5]

associated with storage. Subsequent research conducted by Reed *et al*[42] has determined that pelleting effectively reduces the level of mold to about 4% of unpelleted WM after a period of storage. Furthermore, drying the pellets by means of near-continuous summer aeration prevents mold growth to a large extent and reduces the effects of aggregation.

The handling characteristics of WCGF is somewhat similar to that of silage.[26] With no provision for long-term storage, WCGF can be stored for 12 to 14 days in cold weather and up to 7 days in hot weather before the appearance of an apparently harmless white mold and the onset of spoilage. WCGF can be stored on the ground, in a pit or even mixed with forages or grain and blown into a silo for fermentation. Relative to pelleted WM, DCGF appears to store well. However, reports regarding the difficulty of unloading after settling via transit has been reported to be a problem.

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