WHEAT STRAW UTILIZATION WITH BEEF COWS

by

BRUCE L. PEVERLEY

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INTRODUCTION

Approximately 4,858,300 hectares of wheat are harvested annually in Kansas. The wheat harvest residue (wheat straw, cracked grain, and chaff) is available for livestock feeding, but only a small portion is used as feed. Because of low cost and availability, wheat residue could provide an economic saving to stockmen, especially in a cow-calf operation, where feed represents 50 to 75 percent of the costs of raising a calf. Incorporating wheat residue at the proper time will reduce feed costs and maintain production, especially for dry pregnant cows whose nutrient requirements the first two-thirds of gestation are low (N. R. C., 1976). Development of large package harvesting systems has made utilization of stored wheat residue more appealing and practical.

REVIEW OF LITERATURE

Yields

The energy required to produce the world's protein needs through ruminant animals could be provided if only five percent of the waste cellulosic materials could be economically collected and processed (Dyer et al., 1975). Cutting tests with wheat indicated that after leaving some residue on the field for erosion control and soil moisture penetration, about one kilogram of residue was available for livestock feeding per kilogram of grain harvested (Anderson, 1976). Kansas, which raises 4,858,300 hectares of wheat, produces 15.6 million metric tons of straw. This estimate of available cereal residue is based on yields and acreage harvested.

Nutrient Composition

Values often listed for wheat straw residues may be inaccurate because of a lack of recent analytical data. Introduction of new varieties, adoption of improved fertilization practices and changes in harvest methods could have brought about large changes in cereal residue composition. Work by Acock et al. (1978) showed wheat straw crude protein and in vitro organic matter digestibility varied more with location than variety. In vitro organic matter digestibility decreased as maturity increased. Cereal residues have low protein and high cell wall and lignin contents. The lignin and cellulose occur in the residue chiefly as a ligno-cellulose complex. Much of the residues protein is bound throughout the ligno-cellulose complex. Lignin interferes with rumen microbial attack on cellulose and protein. Straw residue to be effectively used should be analyzed. Analysis of local residue is the most useful since the analysis is characteristic of the material being fed (Anderson, 1976).

In chemical analysis, crude protein generally is used as an index of forage quality. Wheat straw residue is low in crude protein, with book values quoted as 3.5 percent and 4.0 percent (N. R. C., 1976 and Morrison, 1956). Wheat straw residue is made up of two major portions, straw and chaff. The nutrient composition of the chaff samples indicates a higher protein content than straw due to differences in botanical composition. Chaff is the primary residue utilized by ruminants (Anderson, 1976).

The estimated total digestible nutrients of wheat straw is estimated at 48 percent compared to 55 percent for mid-bloom alfalfa hay (N. R. C., 1976). The net energy of straw and alfalfa for beef cattle (Lofgreen and Christensen, 1962) by the comparative slaughter technique was 23.0 and 44.4 Mcal per 45.5 kg. Wilson et al. (1976) reported that the digestible, metabolizable, and net energy of wheat straw for maintenance and production were 74.9, 64.5 and 38.1 Mcal per 45.5 kg, respectively. The low energy values of wheat straw offers little reason for use of large amounts of straw in high production rations.

Mineral values for wheat straw vary greatly. Work by Boawn and Allmaras (1974) done in Washington and Oregon showed calcium content (.15 to .19 percent) to range 2 to 10 times the phosphorus level. Their work is similar to values listed in N. R. C. (1976) and Morrison (1956). The calcium level of wheat residue will meet the requirements of the dry pregnant cow, unless tied-up in an unavailable form. Phosphorus supplementation will probably be needed as the phosphorus content of wheat residue is low (.03 percent to .10 percent) (Boawn and Allmaras, 1974).

Analysis data indicates wheat residue is deficient in crude protein and phosphorus. It is adequate in calcium and energy to maintain a dry pregnant cow.

Utilization

As the wheat plant matures, its composition changes and nutrients are translocated from the upper leaves to the seed head.

Van Soest (1967) showed hemicellulose, cellulose, and lignin are the cell wall constituents of the plant. As the plant matures, lignin increases (Tomlin et al., 1965), crude fiber increases (Heaney et al., 1966 and Murdock et al., 1961), dry matter digestibility decreases (Heaney et al., 1966), and crude protein declines (Heaney et al., 1966; Mellin et al., 1963; and Meyer et al., 1960). The lignin content of cereal residue is high (McAnally, 1942; Ferguson, 1942; and Coombe and Preston, 1969). Lignin and cellulose occur in the plant mainly as a ligno-cellulose complex. Lignin acts as a physical barrier between cellulose and rumen celluloltytic bacteria so that cellulose degradation is decreased. Gray (1947) and Ferguson (1942) determined lignin was undigested by ruminants.

Limited published data show that digestibility of the energy in grass straw is low, primarily because of the high content of fibrous carbohydrates (cellulose, hemicellulose) and relatively high levels of lignin. Furthermore, this type of material is digested slowly by ruminant animals. The combination of low digestibility and slow digestion greatly restricts the amount of feed animals can consume and the nutritional value they can obtain from it (Church and Kennick, 1977).

Intake of Straw

As cell wall constituents increase, voluntary intake declines consistently (Van Soest, 1965). Van Soest also showed that intake of forages with high cell wall content is highly correlated with both their chemical composition and digestible dry matter. Voluntary intake is positively correlated with rate of passage (Coombe and Tribe, 1963). Blaxter et al. (1961) also showed a positive correlation between intake and digestibility. Campling et al. (1961) found that a low intake of long oat straw, relative to oat hay (given ad libitum to dry Shorthorn cows) was due to lower fiber digestibility and a longer retention time. Blaxter and Wilson (1962) reported that the ad libitum intake of oat straw was 43 percent below that of hay, and this was related to apparent digestibility of energy. Lyons et al. (1970) concluded that voluntary straw intake was limited at the lowest level of supplementary protein by a deficiency of absorbed protein. At higher levels of supplementary protein, intake was probably limited by the capacity of the alimentary tract. Weston (1967) concluded the primary factor limiting intake of wheaten hay diet (organic matter digestibility of approximately 57 percent and containing 4.4 percent crude protein) was a deficiency of nitrogen; the second limiting factor was the slow rate of passage from the rumen. The fact that cereal residues have low protein and high cell wall and lignin contents has important implications, especially if nutritive value is defined as a produce of consumption and digestibility (Anderson, 1976).

Processing

Poor quality roughage, such as straw, can be used in larger amounts when rations are pelleted. The reason for this is that roughage is more dense after pelleting, particle size is smaller, and the material passes through the stomach more rapidly allowing greater consumption (Church, 1976). Grinding reduces particle size and increases the rate of passage of undigested residues; therefore, there is less time for fermentation in the reticulo-rumen. As feed intake is increased the rate of passage of undigested residue becomes more rapid. As a general rule, as rate of passage increases, digestibility is somewhat decreased (Church, 1976). Rumen turnover rate is important as it has a controlling action on the amount of forage that can and will be ingested.

Campling and Freer (1966) found that voluntary intake of ground pelleted oat straw by cows was 26 percent greater than that of long straw. Minson (1963) concluded that grinding and pelleting reduced the digestibility of roughages, but no evidence was shown of any corresponding reduction of net energy values. His review showed the major effect of pelleting in most cases was an increase in feed intake, which led to greater liveweight gain. He also showed that the poorer the ration, in terms of intake and liveweight gain with ad libitum feeding, the greater the response in intake and liveweight gain to grinding and pelleting. Beardsley (1964) is in general agreement with this conclusion.

Nelson (1977) found that wintering beef cows on a ground half hay and half straw ration consumed 4.4 kg more forage than cows on the same unprocessed ration. Burt (1966) showed that when 12.1 kg of pelleted straw was substituted for long straw, liveweight gain was increased by 80 percent because of reduced time to consume feed, reduced energy expenditure of chewing and ruminating and a change in the proportion of rumen volatile fatty acids toward a lowered production of acetic acid. A 35 percent increase in feed efficiency was attributed to grinding and pelleting (Beardsley, 1964).

Mathison (1974) found no major changes in straw intake could be attributed to differences in length of straw cut or level of supplementary energy intake. He also noted molasses and a liquid non-protein nitrogen supplement based on sugar did not alter the voluntary intake of straw significantly when mixed with the straw. Sharma et al. (1972 a,b) found the addition of molasses to straw diets reduced protein and fiber digestibility, passage rate, and straw intake. Winter and Pigden (1971) found that when urea and sucrose were infused together, the sucrose was used as an energy source in preference of straw and depressed straw intake and dry matter digestibility.

Taylor et al. (1975b) found by adding water to sliced straw that it was eaten readily and without waste. Taylor's group also observed that cows on the wet straw diet maintained consumption better than cows receiving straw ground or run through a hammer mill or cows fed broken bales. Cows on the soaked straw consumed their daily feed much more rapidly than cows on an equal amount of dry straw.

Supplementation

To utilize its food, a ruminant depends on rumen microbial activity, which in turn depends on an adequate supply of nutrients. Wheat residues are insufficient in nitrogen to satisfy the microbial growth requirement (Shrewsbury et al., 1942 and Burroughs et al., 1950d). Supplementation is necessary to have maximum intake and digestibility with wheat residues. Burroughs et al. (1949a), Burroughs et al. (1950b), and Burroughs et al. (1950e) have shown alfalfa hay, high protein feeds and cereal grains have increased the digestibility of poor quality roughages. Lyons et al. (1970) reported that an increase in the crude protein of a supplement significantly increased the digestibility of crude fiber and crude protein of straw when fed in either restricted or unrestricted quantities. They also concluded voluntary straw intake was limited, at the lowest level of protein supplementation, by a deficiency of absorbed protein. Abou Akkada and El-Shazly (1958) pointed out efforts to increase roughage digestibility by nitrogen supplementation may be limited by the encrustation of cellulose by lignin in certain roughages. Work by Andrews et al. (1972) showed low protein, high energy combinations (6.4 percent crude protein in the whole diet) were frequently refused and gains on this treatment were low; at a higher protein level, when protein supply was adequate, straw intakes were less than on the lower energy level with adequate protein. Low levels of concentrates (up to 25 percent) increased the intake of straw, while high levels produced a substitution effect where roughage intake decreased as the level of concentrate increased (Crabtree and Williams, 1971).

Urea used as a supplement with residue material has given variable responses. Urea has been an effective source of supplemental dietary nitrogen in work by Coombe and Tribe (1962), Hemsley and Moir (1963), Weston (1967) and Faichney (1968). Their work showed urea to promote faster passage rates and increased straw intake and weight gains. Coombe and Tribe (1960) showed urea increased the digestion rate and total digestibility, while reducing retention time of oat straw in the digestive tract. Not all data agree with these responses. Joyce (1975) found the weight loss from a straight barley straw diet was reduced by adding barley or corn, but urea had no significant effect on performance. O'Donovan (1968) found that spraying urea on long straw did not significantly increase rate of gain or straw intake. Long straw intake and daily gain of growing bullocks were not significantly altered by providing a .5 percent urea solution ad libitum (O'Donovan, 1967).

Coombe and Tribe (1962) suggested that the response to nitrogen and energy supplements was dependent on the crude protein content of the roughage. It appeared the primary function of urea supplements was to enable the animal to maintain nitrogen equilibrium rather than store significant amounts of nitrogen in the body (Coombe and Tribe, 1963 and O'Donovan, 1968).

Maximum intake of cereal residues occurred when small amounts of starch-type carbohydrates were fed in addition to supplemental nitrogen, either urea or preformed protein (Crabtree and Williams, 1971; Fishwich et al., 1973; and Andrews et al., 1972). Mulholland et al. (1976) reported up to 10 percent starch had little effect on cellulose digestibility, but 30 percent caused a severe depression. This agrees with other workers (Burroughs et al., 1949b and Kane et al., 1959). Winter and Pigden (1971) found when urea and sucrose were infused together, the sucrose was used as an energy source in preference to straw and decreased straw intake and dry matter digestibility. A lack of a readily available energy supplement was concluded by Hemsley and Moir (1963) not to be a major limiting factor in the utilization of oat straw.

Performance

Controlled experiments using wheat residues in maintaining beef cows are very limited. Mathison's (1974) work with barley straw showed rations containing from 81 to 89 percent straw were adequate for wintering beef cows as indicated by feed consumption and weight gains. Weisenburger *et al*. (1976) confirmed Mathison's findings. Wintering cows fed diets of 100 percent straw ate the least amount of feed over the winter compared to cows on lower percentage straw diets; however, they lost essentially the same amount of weight as cows fed diets containing 95 percent straw (Mathison, 1976). Mathison noted cows on the 95 and 100 percent straw rations were very sluggish in their actions on cold days and had lower rectal temperatures and blood hematocrits than cows fed concentrate. Mathison stated that straw diets containing less than 15 percent supplemental concentrate could not be recommended for wintering beef cows.

No essential difference was shown in weight changes of cows fed diets containing baled or chopped straw (Mathison, 1976). Mathison felt chopping straw with a forage harvestor had little influence on cow weight changes, although less feed wastage occurred than when baled straw was fed. Nelson (1977) found a chopped two-thirds straw and one-third hay ration to be more desirable as a wintering ration to beef cows than the same ration being fed in the long form. Cows receiving the unprocessed ration consumed 4.4 kg less total feed per day and wasted substantially more straw, especially on mild winter days, as compared to a very minimal amount of waste and continued voluntary intake among cows fed chopped forage. Cows on the unprocessed forage experienced a slight weight loss, while cows on the chopped ration increased in weight over the wintering period. Acock et al. (1979) found a two-thirds wheat straw and one-third alfalfa ration to adequately maintain gestating mature cows. Hendrix et al. (1978) studied feeding large round bales *ad libitum* with feeding panels. They were able to maintain dry gestating cows on wheat straw with 3.96 kg of a 37 percent natural protein supplement. Cows in this study experienced only slight negative changes in weight and condition. Weisenburger et al. (1976) pointed out cows fed barley straw pellets gained more weight and ate more feed than those fed ground or chopped straw. Taylor et al. (1976) compared sliced wheat straw to sliced wheat straw soaked with water, both supplemented with cottonseed meal, with non-lactating cows. Eighty-one percent of the cows on wet straw gained weight compared to 59 percent on dry straw.

Taylor et al. (1975b) compared cottonseed hulls, milo stover, and wheat straw soaked with water with dry pregnant cows. Cows in each of the three forage treatments gained approximately .23 kg per day. Both calf weights and calf vigor at birth between treatments were not different.

Mathison (1974) showed when the protein level was raised from approximately 5 to over 6.5 percent the voluntary consumption of barley straw by cows was increased by 13 to 14 percent. This increased consumption was accompanied by greater weight gains. Little difference was found in cow feed intake on straw diets containing 5.7, 6.6, or 9.7 percent crude protein by Weisenburger et al. (1976). Winter gains, however, increased as protein level increased which is in agreement with Mathison (1976). Weisenburger also found cattle performed equally as well on predominantly barley straw diets when supplemented with either soybean meal or a slow release non-protein nitrogen supplement. Mathison (1976) showed urea to be useful as a crude protein supplement when used with straw diets to maintain cows.

In a study with nursing cows, Taylor et al. (1975a) compared a ration of alfalfa and wheat straw to one of alfalfa and cottonseed hulls. Cows on cottonseed hulls outperformed cows on wheat straw in cow gain, cow milk production, average daily calf gain, and conception rate by natural service. Taylor's work showed rations consisting primarily of straw were able to maintain dry cows, but cows nursing calves showed inadequate performance on such a ration.

Acock et al. (1979) found that wintering cows on crop residue could be supplemented with alfalfa hay fed two times per week as effectively as cows supplemented with alfalfa daily. This is in agreement with the findings of Pope et al. (1963), which concluded cows fed at two and three day intervals performed as well as those supplemented daily.

EXPERIMENTAL PROCEDURE

The basic roughage component of all six experiments rations was wheat crop aftermath. Wheat straw was collected in either large round bales or conventional, small square bales immediately after wheat harvest for all experiments. Wheat tailings were gathered with a Foster Dump Wagon.

Soaked straw used in experiments I, II, and VI was ground straw soaked with water. Soaked straw was allowed to set 12 hours prior to feeding. Average dry matter of soaked straw at feeding was 30 percent. In experiments I, II, III, IV, and V, alfalfa was fed from small square bales. In experiments I, II, IV, and V, as cows were weighed on and off test, each cow was visually appraised for condition by three people. Each cow was scored between 1 and 10; 1 = very thin; 10 = very fat. The three scores were averaged to give each cow a condition score.

In experiment III cow condition was determined by weight/height ratios (weight in kg is divided by height in cm).

Cow weights were taken, in all experiments, at the start and finish after cows were held off feed and water for 14 hours.

Cows used in the trials were Simmental-Hereford percentage cows. The cows, which were involved in all the experiments, are maintained continually in drylot at the Kansas State University Beef Research Unit.

MATERIALS AND METHODS

Experiment I

This experiment was designed to study the effect of feeding wheat straw, wheat tailings, and soaked wheat straw on the performance of lactating and non-lactating cows.

Ninety-one cows in early gestation were allotted by weight and condition into three groups, then divided into dry and lactating groups for a 106-day trial. Cows were weighed on (July 13, 1977) and off (October 27, 1977) trial. Calves were weaned on October 6, 1977 from the lactating cows. Cows ranged in age from 2 to 10 years.

The three roughage treatments were wheat straw, wheat tailings, and soaked wheat straw. All roughage was ground prior to feeding.

The rations were formulated and fed once daily. Cows were limited to a specific daily feed intake during the experiment. Rations fed per treatment and cow intake of rations are listed in Table 1.

Table 1. Daily intake of indicated rations by dry and lactating beef cows (Experiment I)

	Daily Ration (D.M.) Fed				
	Residue	Alfalfa	Milo	Cow Supplement*	Total Intake
Dry Cows					
Wheat tailings, kg	6.29	1.26	.85	.23	8.63
Wheat straw, kg	5.9	1.29	.85	.23	8.27
Soaked wheat straw, kg	5.9	1.38	.85	.23	8.36
Lactating Cows					
Wheat tailings, kg	5.5	1.58	2.38	.23	9.74
Wheat straw, kg	5.7	1.51	2.38	.23	9.83
Soaked wheat straw, kg	5.8	1.60	2.38	.23	9.99

* Cow supplement consisted of (kgs/metric ton) soybean meal, 486; rolled milo, 223; salt, 91; bone meal, 61; urea, 29; Z-10 trace mineral, 9; aurofac 10, 6.8; vitamin A, 2.7; wet molasses, 18.

Wheat straw and wheat tailings, both, were analyzed for crude protein, calcium, phosphorus, and acid detergent fiber (Table 2).

Table 2. Composition of roughage fed to cows (Experiment I)

	Dry Matter Basis			
	Crude Protein	Calcium	Phosphorus	Acid Detergent Fiber
	%	%	%	%
Wheat straw	4.00	.268	.114	59.74
Wheat tailings	5.85	.402	.145	57.77

Experiment II

This 59-day study (from November 7, 1978 to January 4, 1979) was designed to evaluate the effect of feeding dry ground versus water soaked wheat straw (30% D.M.) on the performance of gestating beef cows.

Fifty-four non-lactating cows in mid-gestation were allotted into two groups by weight and condition. During the trial cows were fed straw *ad libitum* and 2.27 kg of alfalfa hay per head per day.

Straw was ground to eliminate feed wastage and help measure consumption. Due to freezing weather in the latter part of the study, soaked straw was not allowed to set overnight prior to feeding.

Both straw treatments and alfalfa were analyzed for crude protein, calcium, phosphorus, and acid detergent fiber (Table 3).

Table 3. Composition of roughage fed to cows (Experiment II)

	Dry Matter Basis			
	Crude Protein	Calcium	Phosphorus	Acid Detergent Fiber
	%	%	%	%
Dry Wheat Straw	4.03	.306	.104	52.47
Soaked Wheat Straw	4.10	.288	.094	48.44
Alfalfa	15.20	1.72	.311	37.17

Experiment III

A 60-day experiment (August 4, 1978 to October 3, 1978) was conducted to study the effects of varying the percentage of wheat straw and alfalfa in the ration on the performance of cows in late lactation. Fifty-five cows ranging in age from 3 to 8 years of age were allotted by weight and condition to the experiment.

Three roughage treatments were used in the experiment: (1) all alfalfa hay, (2) two-thirds alfalfa hay/one-third chopped wheat straw, and (3) one-third alfalfa hay/two-thirds chopped wheat straw. Each experimental group of cows was fed approximately 12.3 kg (D.M.) of roughage and 1.8 kg (D.M.) of grain sorghum daily. All 3 treatments had crude protein and energy levels in excess of cow needs for their stage of production according to N.R.C. (1976). Calves had access to creep feed the entire trial period.

Straw was ground to eliminate feed wastage and to more accurately measure consumption, except for 13 days when straw was fed long due to a mechanical failure which prevented grinding. During this time period, straw was fed in big round bales by means of feeding panels.

Rations used in the trial were analyzed for crude protein, calcium, phosphorus, and acid detergent fiber (Table 4).

Table 4. Composition of roughage fed to cows (Experiment III)

	Dry Matter Basis			
	Crude Protein	Calcium	Phosphorus	Acid Detergent Fiber
	%	%	%	%
Dry Wheat Straw	4.03	.306	.104	52.47
Alfalfa	15.39	1.75	.301	36.84

Experiment IV

A 97-day experiment (November 11, 1978 to February 12, 1978) was designed to compare feeding ground versus long wheat straw with different sources of supplemental protein.

The three roughage-protein treatment groups were: (1) long wheat straw supplemented with a protein cube, (2) long wheat straw supplemented with alfalfa, and (3) ground wheat straw supplemented with alfalfa.

The ground or long straw was fed ad libitum throughout the experiment to all treatment groups. Cubes and alfalfa hay (provided from small square bales) were fed daily. The first 62 days of the trial, cows on the long straw + alfalfa and ground straw + alfalfa rations received 2.5 kg of alfalfa per day. During this same time period cows on the long straw + cube treatment were supplemented with a 1.64 kg of a 20% protein cube. The last 32 days of the trial, which coincided with the last one to two months of pregnancy, the level of supplement was increased. At this time alfalfa was increased to 2.91 kg per day with 1.36 kg of milo also fed/cow/day. Cows receiving cubes were fed 3.33 kg of a 16% protein cube during the same time period. Supplemental feed was formulated so the crude protein content received by the cows was equal during the trial. Supplemental rations are listed in Table 5.

Eighty-one cows, consisting of 60 cows in late gestation and 21 open cows, were allotted by weight, condition, and pregnancy to the three treatments. Open cows numbered 7, 6, and 8 for the long straw + cube, long straw + alfalfa, and ground straw + alfalfa treatments, respectively. The cows ranged in age from 1 to 11 years old.

Chemical analysis of wheat straw and alfalfa are identical to those in Table 4.

Table 5. Daily supplemental feed/cow (Experiment IV)

Supplemental Feed	Crude Protein	Estimated TDN
1st 62 days		
Alfalfa, 2.5 (kg)	.75	2.85
20% cube, 1.64 (kg)*	.72	2.77
Last 35 days		
Alfalfa, 2.91 (kg)	.96	3.65
Milo, 1.36 (kg)	.27	2.40
16% cube, 3.33 (kg)**	1.23	5.73

* 20% cube - consists of milo, 563.64 kg; soybean meal, 290.9 kg; molasses, 7.27 kg; binder, 27.33 kg; vit. pre-mix, 4.55 kg; per 909.1 kg.

** 16% cube - consists of milo, 669.55 kg; soybean meal, 181.82 kg; molasses, 45.45 kg; binder, 11.36 kg; vit. pre-mix, .91 kg; per 909.1 kg.

Experiment V

Fifty-four cows in late gestation were used in a 36-day trial (January 6, 1979 to February 10, 1979) to study the effects of daily versus interval feeding of supplemental alfalfa hay to wheat straw rations. Wheat straw was provided to the cows *ad libitum* in the form of long straw. Each cow received 1.36 kg of milo per day.

The treatments were 2.95 kg of alfalfa fed daily or an equal amount of alfalfa fed only twice per week. Intake by treatment is shown in Table 6.

Cows were allotted into the two treatments by weight and condition. Cows ranged in age from 3 to 9 years.

Chemical analysis of wheat straw and alfalfa are identical to those in Table 4.

Table 6. Estimated intake (D.M.) by treatment (Experiment V)

	Estimated Straw	Alfalfa	Milo	Total Estimated
	kg	kg	kg	kg
Alfalfa fed 2 times per week	8.84	2.95	1.36	13.15
Alfalfa fed daily	8.28	2.95	1.36	12.59

Experiment VI

In a 26-day study (August 12, 1978 to September 7, 1978) thirty-six cows in early gestation were used to measure intake of wheat residue processed in six different ways. The six wheat residue treatments were: (1) ground straw soaked with water, (2) dry ground straw, (3) long straw, (4) ground straw treated with cane molasses at the 4% level, (5) ground straw treated with a 32% protein urea-based liquid supplement at the 5% level, and (6) ground straw soaked with water and treated with anhydrous ammonia at the 5% level.

Cows were allotted to the six treatments by weight. All cows used in the trial were mature, ranging in age from 3 to 6 years, and in good condition going on test. For 12 days prior to the start of the trial, cows were fed a ration of ground straw. The cows were held off feed and water for 20 hours prior to weighing.

Cows were fed and maintained individually according to treatment throughout the trial. Supplemental rations fed are listed in Table 7. Each supplemental feed was designed to provide approximately .3 kg of crude protein per day. Supplemental feeds were fed once daily. All wheat residue was fed in the ground form. Wheat residue was fed three times per day to insure maximum intake. Feed refusals were weighed each morning.

Table 7. Supplemental cow rations fed daily in intake study (100% D.M.)

Feed	1	2	3	4	5	6
Cow Supplement,* kg	.68	.68	.68	.68	-	-
Milo, kg	1.36	1.36	1.36	1.14	1.60	1.8
Liquid molasses, kg	-	-	-	.29	-	-
32% liquid supplement, kg	-	-	-	-	.31	-
Trace mineral mix,** kg	-	-	-	-	.20	.20
Anhydrous ammonia, kg	-	-	-	-	-	.03

* Cow supplement consists of soybean meal, 486.36 kg; rolled milo, 223.18 kg; salt, 90.9 kg; bone meal, 60.9 kg; urea, 29.09 kg; Z-10 trace mineral, 9.09 kg; aurofac 10, 6.82 kg; vitamin A, 2.73 kg; wet molasses, 18.18 kg; per 909.09 kg.

** Trace mineral mix consists of salt, 21.8 kg; bone meal, 14.55 kg; Z-10 trace mineral, 2.18 kg; aurofac 10, 1.64 kg; vitamin A, 0.64 kg; wet molasses, 4.36 kg; per 45.45 kg.

Molasses and the 32% liquid supplemental were added to the straw by adding the desired amount of supplemental material to the proper amount of ground straw and mixed for 15 minutes in a Harsh Mobile Mixer. The material was then packaged in large plastic sacks and sealed to keep leaching to a minimum. The liquid supplemental contained 9% urea. Anhydrous ammonia treated straw was made up in the following manner. Ground straw was first soaked with water and mixed for 15 minutes. Water was added so the material was 30% dry matter and anhydrous ammonia added to the material with a Cold-Flo chamber. The Cold-Flo chamber flow rate was determined by allowing the ammonia to flow into a plastic tub that was placed on scales. The Cold-Flo chamber was then mounted on the Harsh Mobile Mixer. The hose off the chamber was buried in the soaked residue material. Liquid ammonia flowed through the hose into the mixer. After the proper amount of ammonia was added (15.9 kg/NH_3 to 227 kg straw), the residue material was mixed for 15 minutes. It was then placed in large plastic bags and sealed to prevent leaching. The ammoniated material was fed fresh.

Nutrient composition of wheat residue fed in intake trials is listed in Table 8.

Table 8. Composition of roughage fed to cows (Experiment VI)

	Dry Matter Basis			
	Crude Protein	Calcium	Phosphorus	Acid Detergent Fiber
	%	%	%	%
Liquid Supplement Treated Straw	4.20	.25	.102	52.83
Molasses Treated Straw	3.60	.25	.108	51.43
Long Straw	3.55	.21	.097	54.30
Dry Ground Straw	3.76	.197	.072	52.64
Water Soaked Straw	3.63	.205	.095	48.83
Anhydrous Ammonia Treated Straw	8.7	.154	.062	56.68

STATISTICAL ANALYSIS OF DATA

Cow weight change, ending cow weight, ending cow condition, total condition change, and calf gain were analyzed through analysis of variance (Kemp, 1972). The means were separated by Duncan's New Multiple Range Test (Steele and Torrie, 1960).

RESULTS AND DISCUSSION

Experiment I

Cow performance is shown in Tables 9 and 10. All cows in experiment I gained weight. Dry cows gained more ($P \doteq .095$) weight than lactating cows in all treatments. In all three treatments, the average daily gain for lactating cows was .17 kg per day compared to the dry cows average of .31 kg per day.

Treatment had no significant effect on cow weight change. Average daily gain (kg) for lactating cows on wheat straw, wheat tailings and soaked wheat straw was .15, .18, and .19, respectively. Average daily gain (kg) for dry cows on the same treatment was .21, .32, and .39, respectively. Though not significant, cows on soaked straw gained more (86% greater) weight than cows on dry straw. This trend in daily gain is similar to findings of Taylor et al. (1976). Gain for dry cows on all treatments were satisfactory (averaging .31 kg per day). These results show dry cows in early gestation can be maintained on rations consisting primarily of wheat straw as long as proper protein supplementation is provided.

Although treatment did not affect cow weight change, cows on soaked straw and tailings tended to outgain cows on dry straw, 12.74 kg and 7.60 kg, respectively. Why cows on tailings tended to outgain cows on dry straw is explainable, as tailings are higher in protein (2%) and energy value (ADF value for tailings averaged 57.77 compared to 59.74 for dry wheat straw). Why soaking of straw may increase cow weight gain is not understood. Possibly the heating process the straw

Table 9. Effects of type of wheat residue on cow performance (Experiment I)

	Wheat Straw		Wheat Tailings		Soaking Wheat Straw	
	Lactating	Dry	Lactating	Dry	Lactating	Dry
Number of cows	14	17	14	17	13	16
Average starting weight (kg)	459.2	450.9	454.5	458.7	456.7	463.8
Average ending weight (kg)	475.1	472.9	473.2	492.3	476.9	505.4
Total weight [a] change (kg)	15.9	22.0	18.7	33.6	20.2	41.5
Average starting condition score	5.5	4.9	5.1	4.8	5.3	4.8
Average ending condition score	4.7	4.0	4.7	4.3	4.4	4.5
Total condition [a] change score	-0.8	-0.9	-0.4	-0.5	-0.9	-0.3

a/ No significant ($P < 0.10$) difference was detected.

Table 10. Summary of effect of type of residue (Trial I)

	Wheat Straw	Wheat Tailings	Soaked Wheat Straw
Number of cows	31	31	29
Average weight change (kg) [a]	19.25	26.85	31.99
Average condition score change [a]	-0.85	-0.55	-0.60
Advantage compared to straw (kg) [a]		+7.60	+12.74

[a] No significant ($P < 0.10$) difference was detected.

undergoes 12 hours prior to feeding may be helpful in breaking down the ligno-cellulose complex of the residue allowing the rumen bacteria to more effectively utilize the nutrients of the residue.

Although all cows in the experiment gained weight, cows in all treatment groups decreased in condition score. Condition score at the start of the experiment had a highly significant ($P < .001$) effect on condition score at the end of the experiment. Cow condition score at the finish of the experiment was not significantly affected by stage of production the cow was in (dry or lactating). Treatment did not affect condition score significantly at the finish of the trial, but did approach significance ($P = .1319$).

The decrease in visual general appearance of the cows in the study probably indicates that additional energy and protein were needed in the cow ration.

Palatability of the rations varied. Cows on the dry straw and tailings took approximately seven hours to clean up their daily ration. Cows on the soaked straw would consume their rations in one-half their time. Taylor et al. (1976) noted similar palatability differences between soaked straw and dry straw.

Experiment II

Effects of ration on cow performance is shown in Table 11. No significant difference ($P < .05$) was seen in terms of cow weight change or cow condition change by treatment. Cows fed dry straw tended to show less weight change (-9.66 kg) than those fed soaked straw (-17.27 kg), however, cows on dry straw ate 11.35 kg (dry matter) of residue,

Table 11. Effects of ration on cow performance (Experiment II)

	Soaked Straw	Dry Straw
Number of cows	27	27
Average starting weight, kg	570.77	564.82
Average ending weight, kg	553.50	555.17
Total weight change, kg [a]	-17.27	-9.66
Average starting condition	5.24	5.59
Average ending condition	5.24	5.35
Total condition change [a]	.00	-.24
Straw intake (dry basis), kg	9.50	11.35
Alfalfa (dry basis), kg	2.27	2.27

[a] No significant ($P < .05$) differences were detected.

while those on soaked straw ate 9.50 kilogram. This may explain the difference in weight loss. These results disagree with our previous work (Experiment I, Tables 9 and 10) and that of Taylor et al. (1976).

That difference is probably explained by the fact that the trial was conducted during early winter. Extreme cold during the last 45 days (average mean temperature of $-1^{o}C$) of the trial caused numerous problems, including freezing of the soaked straw (30% D.M.) in the bunk. Due to the freezing, the soaked straw became quite unpalatable which caused a decrease in cow intake. During the first 30 days of the trial, cows on soaked straw consumed 9.50 kg (D.M.) of straw compared to 10.90 kg (D.M.) for those on dry straw. Cows on soaked straw consumed 9.50 kg (D.M.) per day the last 29 days of the trial while cows on dry straw consumed 12.27 kg (D.M.) during the same time period.

Experiment III

Cow performance is shown in Table 12. Cow weight changes the last 60 days of lactation were: alfalfa hay, +12.22 kg; two-thirds alfalfa hay/one-third ground wheat straw, +12.70 kg; one-third alfalfa hay/two-thirds ground wheat straw, -12.20 kilogram. There was a significant difference ($P < .05$) in weight gain between the one-third alfalfa hay and two-thirds straw and the other two treatments.

In a 163-day trial Taylor et al. (1975a) found a half alfalfa/half straw ration fed to lactating cows gave unsatisfactory performance.

There was a significant ($P < .05$) treatment change in weight/height ratio between cows on the two-thirds straw and one-third alfalfa ration and the other treatments. This, combined with the fact that

Table 12. Effects of ration on cow performance (Experiment III)

Ration	2/3 Straw 1/3 Alfalfa	1/3 Straw 2/3 Alfalfa	All Alfalfa
Number of cows	19	19	17
Average starting weight, kg	491.53	493.15	505.02
Average ending weight, kg	479.33	505.86	517.25
Total weight change, kg	-12.20[b]	12.70[a]	12.22[a]
Average starting weight/ height ratio	24.29	24.18	24.56
Average ending weight/ height ratio	23.68	24.81	25.14
Total weight/height ratio change	-0.61[b]	0.63[a]	0.58[a]
60-day average calf gain, kg	65.35	65.15	66.25

[a,b] Means in the same row with different superscripts differ significantly ($P < .05$).

cows lost weight on the same treatment, indicates cows were not receiving adequate nutrition for this stage of production from this ration.

Calf gains between treatments did not differ significantly (P = .979). Calf gains by treatment were 65.35, 65.16, and 66.25 kg for the all alfalfa hay, two-thirds alfalfa hay/one-third ground wheat straw, and one-third alfalfa hay/two-thirds ground wheat straw treatments, respectively. Similarity in calf gains can be explained as calves had access to creep for the entire trial period which could erase any possible effect of cow milk production.

The results from this study indicate that beef cows in drylot during late lactation can perform satisfactorily on two-thirds alfalfa hay and one-third wheat straw.

Experiment IV

Cows in all three treatments lost weight over the 97-day trial (Table 13). Cows on the long straw + alfalfa treatment lost significantly ($P < .05$) more weight (-53.36 kg) than cows in the other treatments. Performance of cows on long straw + cubes (-30.67 kg) and ground straw + alfalfa (-37.56 kg) were similar. Straw intake (Table 14) was the lowest for cows on long straw + alfalfa (8.37 kg) while cows on the ground straw + alfalfa consumed the most straw (12.66 kg), which is in agreement with work by Church (1977) , Campling and Freer (1966), and Minson (1963). Mathison (1974) saw no major intake changes, due to length of straw cut. The cubes used in the long straw + cube treatment probably provided a more digestible form of protein than was provided by the alfalfa in the long straw + alfalfa treatment. An

Table 13. Effect of ration on cow performance (Experiment IV)

	Long Straw + Cube	Long Straw + Alfalfa	Ground Straw + Alfalfa
Number of cows	27	27	27
Average starting weight (kg)	571.60	573.92	565.00
Average ending weight (kg)	540.93	520.55	527.44
Total weight change (kg)	-30.67[a]	-53.37[b]	-37.56[a]
Average starting condition score	5.55	5.43	5.59
Average ending condition score	5.00[ab]	4.83[b]	5.35[a]
Total condition	-.55[ab]	-.60[b]	-.24[a]

[ab] Means in the same row with different superscripts differ significantly ($P < .05$).

Table 14. Estimated daily intake (D.M.) of roughages/cow (Experiment IV)

	Long Straw + Cube	Long Straw + Alfalfa	Ground Straw + Alfalfa
Average straw intake (kg)	9.16	8.37	12.66
Average alfalfa intake (kg)	-	2.50	2.50
Total roughage intake (kg)	9.16	10.87	15.16

increased digestibility may also explain the slightly higher consumption of wheat straw for this treatment group. This would be in agreement with work by Lyons et al. (1970).

Cows on all treatments decreased in condition score during the trial period. Condition of cows on the ground straw significantly differed ($P < .05$) from cows on long straw + alfalfa, or for cows on long straw + cubes. Cow weight changes generally were proportional to the intake of straw (Table 14). Cows with the greatest straw intake had the lowest change in condition score. Condition scores at the end of the experiment of the open cows and pregnant cows were 5.6 and 5.5, respectively. As far as total condition change, pregnant cows lost more ($P < 0.05$) condition over the experiment than the open cows. The greatest part of the condition loss of pregnant cows occurred the last 35 days of the trial as they neared the end of pregnancy.

Experiment V

Feeding alfalfa hay as a source of supplemental protein twice weekly as compared to daily had no effect ($P < .05$) on cow weight change during the 36-day trial (Table 15). Cows with daily alfalfa supplementation lost 25.64 kg while cows fed alfalfa twice per week lost 30.33 kilogram.

Both treatment groups had similar decreases in condition scores, -.31 for cows fed alfalfa daily and -.25 for cows fed alfalfa twice per week.

This study, with interval feeding of alfalfa or a supplemental feed, is in agreement with the findings of Acock et al. (1979), and

Table 15. Results of daily feeding alfalfa versus interval feeding (Experiment V)

	Alfalfa 2 Times per Week	Alfalfa Daily
Number of cows	27	27
Starting weight (kg)	553.8	543.8
Ending weight (kg) [a]	523.5	518.2
Weight change (kg) [a]	-30.3	-25.6
Starting condition	5.19	5.11
Ending condition [a]	4.94	4.80
Condition change [a]	-.25	-.31

[a] No significant ($P < .05$) difference was detected.

Pope et al. (1963). Cows on crop residues (in this case wheat straw) can be supplemented with alfalfa hay twice weekly with results as good as with daily feeding of alfalfa hay.

Experiment VI

Cow performance and feed intake is listed in Table 16. During the 26-day intake study, consumption per cow varied greatly between wheat residue treatments. Cows on ground straw soaked with water had the greatest ($P < .05$) intake (9.23 kg) of residue over the trial period. Intake of dry ground straw (7.42 kg) was higher ($P < .05$) than the intake of long straw (6.49 kg) or straw treated with molasses (6.26 kg). There was no significant difference between the intake of cows on molasses treated straw (6.26 kg) or straw treated with a 32% crude protein urea-based liquid supplement (5.99 kg). The intake by cows on straw treated with anhydrous ammonia (4.37 kg) was significantly lower ($P < .05$) than all other treatments.

The addition of water to dry ground straw improved intake by 20% over that of dry ground straw. Due to the greater intake, cows on soaked straw tended to have less weight loss (-6.36 kg) than cows in other treatments. As all rations were designed to be adequate in nitrogen, the increase in intake of soaked straw was probably due to increased palatability. Work by Taylor et al. (1975b) and our previous work (Trial I) both noted cows would more willingly consume soaked ground straw than an equal amount (D.M.) of dry ground straw. In Table 8, water soaked straw is seen to have a lower acid detergent fiber (ADF) value than all other wheat residue treatments. The lower

Table 16. Effect of wheat straw processing on feed intake and cow performance (Experiment VI)

	Soaked Straw	Dry Ground Straw	Long Straw	Molasses Straw	Liquid Supplement Straw	Anhydrous Ammonia	Trial Mean
Intake/cow/day (kg)	9.23^{a}	7.42^{b}	6.49^{c}	6.26^{cd}	5.99^{d}	4.37^{e}	6.63
Gain/cow (kg)	-6.36^{a}	-10.08^{a}	-17.59^{a}	-19.77^{ab}	-13.86^{a}	-32.20^{b}	-16.64
Daily straw intake as percentage of average body weight	$.0162^{a}$	$.0131^{b}$	$.0116^{c}$	$.0111^{c}$	$.0107^{c}$	$.0078^{d}$	.0118
Daily straw intake as function of metabolic cow weight (Intake/average body $weight^{.75}$)	$.1749^{a}$	$.1414^{b}$	$.1241^{c}$	$.1191^{c}$	$.1147^{c}$	$.0839^{d}$	.1264

[abcde] Means in the same row with different superscripts differ significantly ($P < .05$).

ADF value indicates a larger amount of energy available due to soaking. That more available energy may explain why weight losses of cows fed this material was reduced as compared to other treatments.

The second highest intake (7.42 kg) and second lowest weight loss (-10.08 kg) occurred feeding dry ground straw. The dry ground straw intake was greater than dry ground straw treated with molasses or the 32% crude protein urea-based liquid supplement treated straw or straw fed in the long form. An advantage in intake of ground straw over long straw has been shown by Church (1977), Minson (1963), and Beardsley (1964).

Although molasses is often added to feed to increase palatability, the addition of molasses or the liquid supplement, which contained 65% molasses, did not improve feed intake over that of dry ground straw. Mathison's work (1974) is in agreement. Sharma et al. (1972a,b) found the addition of molasses to straw diets reduced protein and fiber digestibility, passage rate and straw intake. Winter and Pigden (1971) found when urea and sucrose were infused together, the sucrose was used as an energy source in preference to straw and depressed straw intake and dry matter digestibility.

The anhydrous ammonia treated straw in this study was poorly consumed (intake of 4.37 kg) and had the highest cow weight loss of any treatment (-32.2 kg). This may have related to utilization of too high a level of anhydrous ammonia. The anhydrous ammonia treated straw did not show any spoilage, although it was approximately 30% dry matter. That material did maintain a strong ammonia odor upon feeding.

Buettner *et al*. (1978) showed a different response to ammoniation of mature fescue hay. They found digestibility of dry matter and fiber constituents and intake of cattle and sheep were significantly increased by ammoniation.

SUMMARY

Six trials were conducted to evaluate the use and feeding value of wheat straw with lactating and/or gestating beef cows.

The soaking of straw prior to feeding tended to increase straw intake and cow weight changes. Soaked straw was found unsatisfactory to feed in cold weather. Cows fed straw tailings had a slight weight gain advantage over cows fed ground straw. Wheat tailings were found to be higher in crude protein and to have a lower acid detergent fiber content than wheat straw. Cows fed ground straw consumed more straw and gained more weight than cows fed long straw.

Cows in late lactation showed equal performance whether fed an all alfalfa ration or a ration of two-thirds alfalfa/one-third wheat straw.

Residue rations must be supplemented with protein. Supplementing cows with either protein cubes or alfalfa hay gave equal performance. Cows performed equally, whether supplemented with alfalfa daily or fed an equivalent amount of alfalfa hay fed twice weekly. The addition of a urea-based liquid protein, molasses, or with anhydrous ammonia to the straw did not increase straw intake.

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WHEAT STRAW UTILIZATION WITH BEEF COWS

by

BRUCE L. PEVERLEY

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($P < 0.05$) cow weight and condition loss but had no effect on calf gains.

In Trial IV, eighty-one percentage Simmental cows in mid-gestation were used to compare these treatments: (1) feeding ground wheat straw supplemented with alfalfa, (2) long wheat straw supplemented with alfalfa, and (3) long wheat straw supplemented with protein cubes. Ground straw was fed in feed bunks while long straw was fed from feeding panels. All alfalfa was fed long from small square bales. Straw was provided ad libitum to all treatment groups. Regardless of protein source, cows were fed equal amounts of supplemental protein throughout the trial. Straw intake, cow weight change and conditions change for each treatment were (1) 12.66 kg, -37.56 kg, -.24; (2) 8.37 kg, -53.36 kg, -.60; and (3) 9.16 kg, -30.67 kg, -.55. Weight loss for cows on the long straw plus alfalfa was significantly different ($P < .05$) from the other two treatments.

In Trial V, fifty-four percentage Simmental cows in late gestation were allotted to two treatments: (1) 2.95 alfalfa fed daily and (2) equivalent amount of alfalfa fed twice weekly. Wheat straw was fed ad libitum to both treatments from big round bales fed with feeding panels. In both treatments cows received 1.36 kg of grain sorghum per head per day. Cows in treatment 1 consumed 8.28 kg of wheat straw daily, while those in treatment 2 consumed 8.84 kg daily. Cows in both treatments lost weight and condition. Weight and condition losses were (1) -25.64 kg, -.31; (2) -30.33 kg, -.25.

Thirty-six percentage Simmental cows, in early gestation, were allotted to six treatments to measure the intake of wheat straw processed in different manners. Treatments were: (1) ground straw soaked with water (30 percent D.M.), (2) dry ground straw, (3) ground straw treated with a 32 percent protein urea-based liquid supplement at the 5 percent level, (4) long straw, (5) ground straw treated with 4 percent added molasses, and (6) ground straw soaked with water and treated with anhydrous ammonia at the 3 percent level. Cows were individually fed and maintained throughout the day trial. Rations were supplemented to be equal in protein and energy. Intake of the different straw treatment (kg per cow per day), cow weight change (kg), and metabolic weight percentage intake were: (1) 9.23, -6.36, .1749; (2) 7.42, -10.08, .1414; (3) 5.99, -13.86, .1147; (4) 6.49, -17.59, .1241; (5) 6.26, -19.77, .1191; (6) 4.37, -32.2, .0839. Cow intake per day and metabolic weight percentage intake for straw soaked with water was significantly higher ($P < .05$) than any other treatment and straw treated with anhydrous ammonia was significantly lower ($P < .05$) than any treatment in the trial. Cows on straw soaked with water had less weight change than any other treatment. Cows fed anhydrous treated straw lost significantly more weight ($P < .05$) than any other treatment. Soaking ground straw with water or grinding straw brought about higher intakes and lower cow weight losses than feeding it long. Other treatments did not improve straw intake or decrease cow weight losses over the performance of cows fed long straw.