THE EFFECT OF PELLETED WHEAT STRAW ON MILK PRODUCTION

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF ANIMAL SCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN ANIMAL SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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ACKNOWLEDGMENTS

The preparation of this thesis would not have been possible without the guidance and supervision of Dr. William H. Brown, Professor of Animal Science. The author wishes to express his sincere gratitude for all of the help he has received from Dr. Brown throughout his graduate studies.

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ABSTRACT

Twelve lactating dairy cows, in a double switchback feeding trial, were fed 115% of the National Research Council requirements for maintenance and production of a dairy ration containing 50% high-energy concentrate and the other 50% being roughage in the following combinations: 1) 50% alfalfa hay cubes; 2) 5% pelleted wheat straw (PWS), 45% alfalfa hay cubes; 3) 15% PWS, 35% alfalfa hay cubes; and 4) 25% PWS, 25% alfalfa hay cubes.

No significant differences due to the diet were detected in feed intake, milk composition, mean molar percentages of volatile fatty acids (VFA) in rumen, percents fat, protein, solids-not-fat or body weight gains. The mean concentration of VFA in rumen was not affected at any of the experimental rations, except for valerate which increased when the 15% PWS ration was fed. The digestibility of protein and combustible energy decreased with increased levels of PWS in the diet. Milk production was also negatively affected by the use of PWS at all levels, when compared with the control group.

INTRODUCTION

Wheat straw is a by-product obtained from wheat grain crops, and its importance as a roughage is considerable if we realize the fact that wheat is the second most important crop in the United States (52), and that more than 90% of the wheat acreage of the world lies in the northern hemisphere (27).

As wheat straw competes in price but not in nutrient value with other forages and feedstuffs of higher quality, various attempts have been made to make its use more profitable in livestock feeding without affecting performance and production. Wheat straw has been used in the ration of ruminant animals; however, such roughages as wheat straw are poorly digested due to its high fiber content, and its volume causes dilution of nutrient content when included in the rations of cattle.

Minson (34) reported that the process of pelleting and wafering of roughages increased food-conversion efficiency because of an increased food intake. Wheat straw also has been fed combined with urea (19,28), and in finishing rations for beef cattle (21), and fattening sheep (7). Other authors have reported an increase in performance of low quality roughages compared to high quality ones, when the pelleting process was exerted (7,10,36).

It is obvious that as the world demand for food is increasing, the forecast predicts that it will no longer be justifiable to use crop products suitable for human consumption for animal production. Hutton (24) has stated that more economical production of low-cost milk and meat occurs where less dependence is placed on feeding grain and oil seed supplements. Other investigators (9,60) dealing with the necessity of improving the utilization of wheat straw for animal production have used chemical treatments, and reported an increment in its nutritional value and subsequent role in ruminant nutrition.

Dairy cattle also offer a means for transforming the wheat straw included in their rations into milk. Thus, experiments have been made concerning the feasibility of using this by-product as a source of forage in the rations of dairy cows.

The objective of this experiment was to evaluate the effects and performance of pelleted wheat straw included in the rations of lactating dairy cows at 5, 15, and 25% levels.

LITERATURE REVIEW

Wheat Straw as Feed for Ruminants

Wheat straw is a by-product obtained from wheat crops, and thus it represents a feed source for ruminants throughout the country.

Because it has been used as a regular part of ruminant rations since the last century, the first experiments and reports dealing with its nutritional value and pracrical utilization come from that time. The first report was made in 1885 by the Connecticut Agricultural Experiment Station (16), in which it was found that the digestion coefficients for wheat straw fed to sheep and cows were: dry matter, 46%; protein, 17%; fat, 36%; nitrogen-free extract, 39%; and crude fiber, 56%. In another experiment in North Carolina, Emery and Kilgore (14) compared the digestibility of wheat straw with that of cottonseed hulls, and found the values for wheat straw to be 26% for protein, 27% for fat, 40% for nitrogen-free extract, and 52% for crude fiber. In this comparison with cottonseed hulls, wheat straw had a much higher digestibility of crude fiber and a much lower digestibility of ether extract.

In 1895 in Utah, Mills (33) reported that a ration of alfalfa and straw with grain was superior to one of alfalfa and grain. He concluded that the best way to use protein foods in ruminant feeding was by mixing them with some straw, which was cheap and abundant.

Foster and Merrill (20), at the Utah Experiment Station, found that complementation of two foods such as lucerne and straw would provide a good proportion between protein and carbohydrates. He conducted an experiment with three sets of four steers and concluded that for a certain portion of the ration, straw was almost equal in value to lucerne. From the cost of production, cheaper gain was made by using straw with lucerne and grain than was made with lucerne and grain. The price per pound of digestible dry matter was lowest for wheat straw. They also concluded that open yard feeding enhanced the consumption of the straw and enabled the ruminants to make more profitable use of it.

In both 1929 and 1931, Watkins (57) conducted feeding experiments with steers to find the nutritive value of wheat straw alone and combined with cottonseed meal. In the first trial, four steers were used and were fed only straw. Apparent digestibility of the ration was as follows: dry matter, 46.64%; protein, 25.42%; nitrogen-free extract, 53.87%; and crude fiber, 58.25%. In the second part of the experiment, the values for wheat straw fed as the only feed in the ration were slightly less with the exception of the nitrogen-free extract, which was higher. In both experiments, it was concluded that the digestibility of wheat straw increased because of the more nearly balanced ration when it was fed along with cottonseed meal. It was pointed out that the digestibility of the crude fiber remained almost the same during the entire experiment. They also concluded that a small amount of cottonseed meal fed as a supplement increased roughage consumption.

Other investigators gave digestibility values for straw based upon earlier works. Morrison (37) shows in his tables values of 40.6% for TDN as an average for cattle and sheep, with .3% digestible protein. In 1947, Schneider (47), using the results of the experiments in this and other countries, reported that wheat straw had values of 46.5% TDN for cattle and 45.5% for sheep. Digestible protein was .5% and .3% for cattle and sheep, respectively.

Thalman (48) conducted a test to determine to what extent wheat straw could be used in the ration for fattening steers. He fed two lots of nine steers either alfalfa hay and wheat straw, or wheat straw only as a roughage source. Both groups were full fed shelled corn and 1.5 pounds of cottonseed cake per head daily. They also had access to a mineral pre-mix. The efficiency in utilizing the feed was good in both groups and there were no problems in getting the animals to eat the wheat straw. The group receiving alfalfa and straw consumed seven pounds less corn than that required by the group receiving wheat straw as the sole roughage; however, the first group required more alfalfa per 100 pounds of gain. It was concluded that there was not a significant difference in the finish of the two groups and gains were satisfactory both in amount and economy.

Trowbridge and Moffett (50), also studying the use of wheat straw with other feedstuffs, found that a group of steers fed wheat straw and molasses consumed an average daily ration of 10.89 pounds of molasses, 2.72 pounds of cottonseed cake, 29.42 pounds of silage, and 1.42 pounds of wheat straw. This group gained 1.8 pounds per head daily and were fed 133 days. When the wheat straw was replaced with alfalfa hay, more roughage and less concentrates were consumed.

Athar et al. (2), in a fattening trial with yearling buffaloes, concluded that wheat straw can be fed in rations with molasses at 65, 45, 35, 25, and 15% levels without significant differences in body weight gains. The percentages of molasses were 0, 20, 30, 40, and 50%, respectively, and the rations were formulated to have wide differences in character.

In another experiment, Foot (19) studied the value of ethanol when added to sheep diets containing straw supplemented with urea and molasses. He found that the only significant effect was a faster rate of passage of food particles when ethanol was used.

In 1969, Monetti et al. (35), using non-castrated male calves, found it advisable to add 3% animal protein to a ration in which wheat straw was the only available ration.

In a study using urea as a protein supplement in the ration of buffalo steers, Ludri, Gupta and Pant (30) reported that a significant increase in the total volatile fatty acids (VFA) occurred in the rumen when urea was fed, and that digestibility of cellulose from wheat straw also increased, indicating that the addition of urea was stimulatory to the cellulolytic activity of the rumen bacteria. They also reported that urea can successfully meet 33% of the protein requirement of adult buffalo steers for maintenance.

Louca and Papas (28) studied the use of wheat straw and urea as substitutes for lucerne hay and protein supplement in barley diets of non-castrated friesien bull calves. They observed that in the first period of the experiment (80 days to 6 months), the calves fed wheat straw grew slower than those fed lucerne hay, but in the second period of fattening (6-12 months), the difference disappeared and no significant differences in average daily gain between the groups fed either urea or protein supplement were found. They concluded that diets of barley supplemented with urea and wheat straw were as good as those supplemented with lucerne hay and protein supplement. A similar report was made by Den Braver (11) when he found that approximately the same digestibility coefficients were obtained when straw was fed together with hay as when it was given as the only feed together with a mixture of urea and minerals.

In 1973, a year after the experiment of Ludri et al. (30), Ahuja et al. (1) found different levels of VFA in the rumen of buffalo bulls fed wheat straw and enough urea to replace 53% of the dietary nitrogen. An increase in the urea-nitrogen of blood plasma and ammonia-nitrogen of rumen liquor along with a decrease in total VFA in the rumen was found. When up to 28% of the dietary nitrogen was replaced with urea, a negative influence in total water intake, fecal water loss and urinary output was observed. With in vitro tests, the initial rate of release of ammonia from urea-soaked wheat straw was slower than that from urea mixed with dry wheat straw.

O'Donovan and Ghadaki (41) studied the effect of diets containing different levels of wheat straw on the performance of 6-7 month old uncastrated lambs, and found that a significant decrease in daily gain and an increase in feed per unit of gain occurred when the highest straw level (30%) was fed. They concluded that an almost linear increase in the digestibility of dry matter occurred when more concentrate was given.

In a complete switchback trial designed for 12 cows in mid-lactation, Halevi, Neumark and Amir (23) fed three different ratios of chopped wheat straw and concentrates (45:55, 30:70, and 15:85, respectively). Protein content was held constant for each group by adjusting protein in the concentrate. They found no significant differences in milk production or milk composition. They concluded that milk fat was relatively low even though molar percent acetic acid in the rumen was high in all groups. Plasma glucose concentration was similar in all groups, while total plasma-free fatty acids were highest in group 2 (30:70 wheat straw to concentrate). The composition of plasma-free fatty acids did not vary significantly. Digestibility of dry matter decreased slightly as percentage of wheat straw increased in the ration. This agrees with the work of O'Donovan and Ghadaki (41). Metabolizable energy per gram of dry matter increased as the wheat straw decreased in the ration. Halevi et al. (23) also concluded that processing of wheat straw would increase its intake and therefore obtain a higher milk production.

Principal Chemical and Physical Treatments of Roughages and Their Effect in Ruminant Nutrition

Using sodium hydroxide (NaOH) as a mean for improving straw quality, Beckman (3) reported that chopped straw soaked in a 1.5% solution at a 1:8 NaOH to straw ratio increased straw digestibility. The procedure was the same as that used for making paper out of straw, and involved 20-30% of dry matter loss during the washing process. Kellner and Kohler [as cited by Woodman and Evans (60)], used NaOH solution for treating rye straw under pressure and found that organic matter straw digestibility increased 38% and crude fiber 46%. In 1938, Nikolaeva (39) treated straw with ammonium hydroxide (NH_4OH) solution without heating and found that the bonds between lignin and cellulose were partially destroyed and that part of the lignin was dissolved. When straw was treated with either 5 or 15% NH_4OH for 15 days, 38% of the lignin was removed and the coefficient of digestion of straw peaked at 8 days. He also found no direct relationship between percentage of lignin removed and the coefficient of digestion.

Woodman and Evans (60) reported that wheat straw treated in a 6% NaOH solution for 7 hours using 70 psi of pressure gave a value of 74% for the digestibility of the dry matter when fed to sheep as 38% of the ration.

In 1954, Kehar (26) found that replacing alkali-treated wheat straw for untreated straw in the rations of young heifers enhanced growth. The increase in growth rate was nearly 50% when the initial plane of nutrition was poor, but only 10% with normally fed animals. There was a cost reduction of 13% with animals on a low plane of nutrition when alkali-treated wheat straw was included in the ration.

Sahai, Johri and Kehar (46) reported that using alkali-treated wheat straw in the ration of lactating cows improved the quality of the fodder, and that the palatability of treated and untreated straw was practically the same. However, treatment of the straw did not produce an increase in milk yield.

Goering et al. (22) reported the effect of sodium chlorite ($NaClO_2$) on digestibility of ensiled roughage materials by both in vitro and in vivo techniques. They found that cell wall content, generally hemicellulose and lignin, decreased with increasing rates of $NaClO_2$ treatment. In vitro results indicated that the mechanisms for improved digestibility involves a more specific attack on lignin than had been observed with alkali-treatment. Digestible organic-matter intake was improved by less than 4% by treatment with $NaClO_2$ in spite of a 13% increase in organic matter digestibility.

Cate et al. (7) found that in lambs, economy of feed utilization was increased by pelleting with the advantage increasing as the quality of the roughage in the ration decreased. They also found that satisfactory gains can be obtained on self-fed rations containing low quality roughage if the average daily feed consumption is high. Ronning, Meyer and Clark (45) found no detrimental effects on milk fat percentage when rations containing pelleted or chopped alfalfa hay were compared with and without concentrates. Cows receiving pelleted hay consumed more dry matter and produced more milk than those on chopped hay when no concentrates were fed. However, the supplementation of chopped hay with approximately 12% concentrates increased dry matter intake and production to about the same level as the pelleted hay rations.

Porter et al. (42) reported a greater actual milk production and a lower fat percentage when alfalfa hay was fed in the pelleted form as the sole source of roughage to dairy cattle when compared with alfalfa field-cured, field-baled, or artificially dried-ground. Ronning (44) also found depressed milk fat production when pellets containing finely ground alfalfa hay and a grain-type concentrate were fed to dairy cattle. The effect was more marked when no concentrate was fed or when only 15% was used instead of 30 or 45%. He also reported no detriment in the health of the cows during the 175 days when only pellets were fed.

No digestive disturbances or depression in the milk fat percent were reported by Putnam and Davis (43) when pelleted complete rations were compared to a conventional ration given to lactating cows. Flatt et al. (18) fed alfalfa hay (early-cut and late-cut) and grass hay pellets to non-pregnant cows and found that the apparent digestibility of dry matter, organic matter and gross energy decreased with advanced stage of maturity of the forages. In other studies with the same feed fed to growing heifers, it was found that pelleting significantly increased the consumption of the forages with the greatest effect shown with the poorer quality forages.

O'Dell, King and Cook (40) reported a milk fat change in dairy cows when different forms of forage were fed. Milk fat percentage decreased significantly when pelleted alfalfa was compared to baled alfalfa. In a second trial, feeding pellets from dehydrated coastal bermuda grass previously ground through either a .64, .32 or .16 cm hammermill screen resulted in a milk fat depression in all groups. In a third trial they fed dehydrated coastal bermuda as .64 cm ground, .64 cm ground and pelleted, .95 cm ground and pelleted, or .16 cm ground and pelleted hays. The results showed that .16 cm ground hay pellets increased the milk fat test. They concluded that the critical size in relation to milk fat depression is approximately .64 cm.

Thomas et al. (49), in an experiment conducted with dairy cows, observed that only finely ground hay depressed milk fat content (4.6-3.9%) decreased the percentage of rumen acetic acid (68.3-59.2) and increased the percent of propionic acid (16.2-24.6). They concluded that medium ground hay (39.8% of hay retained on Tyler sieves of size 16) depressed milk fat content only slightly when compared with unpelleted concentrates fed along with the same hay.

In a review survey, Van Soest (54) reported that restricted roughage diets, ground roughages, and the degree of fineness of the forage are related to low fat milk production by lactating ruminants. He summarized three theories to explain that fact: 1) deficiency of rumen acetic acid, 2) increases of propionic acid and other antiketogenic factors, and 3) endocrinological factors causing low milk fat. However, Brown et al. (6) found no decrease in total milk production or in percents fat, protein, solids-not-fat, or individual fatty acids in milk when pelleted cottonseed hulls were fed to lactating cows as a substitute of 10, 30, or 50% of the alfalfa hay cubes in a ration containing 50% alfalfa hay cubes and 50% high energy concentrate.

Other reports have shown a milk fat decrease when pelleted roughage was fed. Chalupa et al. (8) reported that feeding pellets as the sole forage decreased milk fat percent. Both Chalupa et al. (8) and Thomas et al. (49) also reported a decrease in rumen pH, protozoa numbers and molar percents acetate and butyrate. Chalupa et al. (8) further reported that molar percents propionate and valerate increased by pelleting. Milk fat was found to contain a lowered proportion of short-chain fatty acids.

Journet (25) found only a slight decrease in milk fat percent of dairy cows when alfalfa or grass hay was not ground too fine (3, 5 or 10 mm screens).

In an experiment with dairy goats, Fehr (17) noticed that the feeding and rumination time decreased by 25% in animals receiving alfalfa pellets. The intake of straw from either the pelleting or wafering process increased, concentrate intake decreased, and there was a tendency for milk fat percent to decrease.

Wainman and Blaxter (56) have reported a decline in crude fiber content of roughages after pelleting. They also found a loss of 9% organic matter, an 80% increase in intake, and an increase in the metabolizable energy. Later, in 1975, Van Der Honing (53) also reported an increase in the utilization of metabolizable energy when ground and pelleted forage was fed to dairy cows. There was a decrease in digestibility of energy. Whiting, Brown and Stull (59) support the finding of low digestibility of combustible energy when feeding high roughage diets (59.2%) containing coarse barley straw to dairy cows. They also found a lower digestibility of fiber when low roughage diets were fed.

Blair, Christensen and Manns (4) studied the performance of lactating dairy cows fed complete pelleted diets based on wheat straw, barley and wheat, and found an increase in energy digestibility as straw percentage in the diet increased. Yield of fat-corrected milk and solids-corrected milk tended to be lower on the low straw diet, while milk protein and solids-not-fat percents were elevated. Little variation was observed in serum amino acid concentration.

Moore (36) and Cunha (10) summarized some of the characteristics of pelleted feeds. Moore (36) compared chopped or long hay and concluded that when pellets are offered to dairy cows the following effects are expected:

1. A decrease in rumen pH.
2. An increase in the concentration of volatile fatty acids in the rumen 1-4 hours after feeding.
3. A decrease in the ratio of acetate to propionate.
4. An increased rate of digestion in the rumen.
5. An increased dry matter intake.
6. An increased rate of passage of feed particles from the rumen.
7. The feeding value of long hay appears to be improved with pelleting.

Moore (36) also concluded that the addition of concentrates to the pellets causes the differences in milk production to disappear, that pelleting in all rations results in an increased intake of dry matter and an increased milk production, that the feeding of ground or pelleted forage results in a decrease in fat percent of the milk probably related to a lower proportion of acetate to propionate in the rumen, and that feeding pelleted forage to dairy calves increases dry matter intake and rate of growth.

Cunha (10) concluded the following:

1. Pelleting increases intake of roughages, especially the low quality forages.
2. Pelleting does not seem to improve the digestibility of a roughage.
3. Pelleting improves low quality roughages more than high quality ones.
4. Roughage pellets can be more easily and accurately mixed with the concentrages in the ration.
5. Pelleting prevents the sorting out by animals of the more unpalatable parts of the feed.
6. Pelleting increases rate of gain and feed efficiency. This increase is greatest with low quality roughages as compared to low fiber feeds.

Cunha (10) also reported some disadvantages:

1. The extra cost from grinding and pelleting.
2. Fine grinding of roughages may decrease the butterfat content of milk produced by dairy cows.
3. Rumen parakeratosis may occur when high level of pellets are consumed.

EXPERIMENTAL PROCEDURE

Twleve Holstein cows near the peak of lactation were selected from the University dairy herd and randomly assigned to one of four groups in a double switchback feeding trial (29). A basic ration containing a 50:50 ratio of concentrate to alfalfa hay cubes was used to compare replacement of 10, 30 or 50% of the alfalfa cubes by weight with pelleted wheat straw (PWS). The straw was ground before pelleting and the resulting pellets were .95 cm in diameter. Ration analysis is given in Table 1.

Each trial consisted of three four-week periods with one week changeover intervals. Cows were penned by treatment and group-fed twice daily 115% of the National Research Council's standards for maintenance and production (38). All three ration components were placed in the manger at the same time, but were not blended. Since there was no weight-back, there was no problem maintaining the desired ratio of component intake.

Milk samples collected during four consecutive milkings at the end of each week were composited and analyzed immediately for each cow. Milk fat was determined by the standard Babcock method, percent protein by the Orange G method of Udy (51), and solids-not-fat (SNF) by the method of Watson (58). Weights of the four milkings were recorded and averaged to determine daily production.

Milk samples from the last week of each period only were frozen at $-14^{o}C$ until analyzed by gas-liquid chromatography for the component

Table 1. Composition of Concentrate Mixture, Alfalfa Hay Cubes and Pelleted Wheat Straw Fed Experimental Cows.

	% Dry Matter	% Crude Protein	% Ether Extract	% Fiber	% Kcal/g
Concentrate mixture*	93.91	16.06	5.02	19.56	3.96
Alfalfa hay cubes	94.23	19.30	2.77	29.56	4.07
Pelleted wheat straw	95.85	5.81	1.26	58.90	3.85

*Loose mixture containing: 22.5% whole cottonseed, 22.5% rolled barley, 22.5% rolled corn, 5.0% molasses and 27.5% pelleted supplement (United Producers and Consumers Cooperative, Phoenix, Arizona).

fatty acids of the milk fat. Fatty acids extracted from the milk fat were analyzed by the method described by Brown, Stull and Stott (5), with the only exception that a Perkin-Elmer Model 800 dual-flame gas chromatograph was utilized. The fatty acid methyl esters analyzed by gas chromatography were prepared by the method of Metcalfe, Schmitz and Pelka (32).

Body weight changes were calculated by difference between starting and finishing weights (average of three consecutive daily weighings) during each period. Fecal samples were collected by rectal removal twice daily (0600 and 1800) on three consecutive days at the end of each experimental period and composited for each animal. Dried composite feces (dried at $<50^{o}C$), roughage, and concentrate samples were analyzed for percent ether extract, fiber (55), and lignin (13). The lignin ratio technique (31) was utilized to estimate the apparent digestibility. Percent protein was determined by the standard Kjeldahl method and combustible energy by an adiabatic oxygen bomb calorimeter (Parr Instrument Co., Moline, Illinois).

Rumen fluid samples were taken by rumen tube on the last morning of each period. Samples were strained through two layers of cheesecloth, preserved by the addition of one part saturated mercuric chloride solution to ten parts of rumen fluid, and stored at $-14^{o}C$ until analyzed for volatile fatty acids (VFA) by the method of Erwin, Marco and Emery (15).

Variance was analyzed (29) and means for the treatments were compared by Duncan's Multiple Range Test (12).

RESULTS AND DISCUSSION

The condition and health of the cows remained satisfactory throughout the experiment, and no digestive or physiological disturbances were observed. There was no rejection of feed despite the relatively high level offered (115% of the NRC standard). Visual observations indicated that while there was some preference for the concentrate and alfalfa, the animals did consume the PWS without undo duress. These findings agree with several works (43,45,49), but not with another experiment (4), where cases of bloat and feed refusal were reported when pelleted forage rations were fed.

Even though no comparisons were made with long straw, it is probable that pelleting of the wheat straw enhanced feed consumption and improved its nutritional value (10). Pelleting does reduce transport and storage volume, allows the maintenance of a constant proportion of roughage in the forage mixture for high-yield dairy cows, and simplifies handling.

The effect of different levels of PWS on milk production and composition, and body weights is shown in Table 2. The addition of PWS caused a significant decrease ($P<0.05$) in milk yield, there being a significant decrease between the control ration and the rations containing 5 or 15% PWS. There was a further significant decrease in milk production when 25% PWS was fed. Percents fat, protein and solids-not-fat were not significantly affected by any level of PWS. Body weight changes were also not significantly affected. There were very large variations among

Table 2. Mean Yield and Composition of Milk and Body Weights of Cows Fed Different Levels of Pelleted Wheat Straw.

	Control	5% PWS	15% PWS	25% PWS	F	Standard Error
Milk production (kg)	29.86[a]	29.03[b]	29.08[b]	28.27[c]	15.99	.23
Fat (%)	3.34	3.35	3.36	3.60	2.95	.10
Protein (%)	3.00	2.99	2.95	2.95	.67	.05
Solids-not-fat (%)	8.72	8.67	8.73	8.61	2.58	.05
Body weight (kg)	689.00	704.00	705.00	690.00	3.83	6.36
Body weight gains (kg/day)	-.32	.17	.36	-.35	4.56	.23

[a,b,c]Values within a row of means with different superscripts indicate a significant difference ($P<.05$).

animals, and the groups receiving 5 and 15% PWS gained weight, while the other two groups lost weight.

Mean digestibility of ration components are shown in Table 3. Substitution of PWS for cubed alfalfa hay progressively depressed ($P<0.05$) digestion of protein and combustible energy. Previous works have reported the same (6,18) when using pelleted forage in the ration of dairy cattle.

Total VFA concentrations in the rumen are shown in Table 4, and molar percentages of VFA are indicated in Table 5. There was a significant increase caused by the use of PWS at the 15% level in the total concentration of valeric acid in the rumen (Table 4). There were no significant differences in the mean molar concentration of any of the VFA in the rumen. These results do not agree with those authors who have found milk fat depression (42,44) when lactating dairy cattle were fed pelleted forage in the ration, with or without being previously ground. However, in this experiment, the PWS was neither the only forage nor the only physical form fed since the alfalfa hay cubes were also present in all rations. The insignificant alteration in milk fat percentages in each of the rations is also supported by the fact that the ratios of acetate and propionate in the rumen did not vary, a situation that seems to be determinant in the reduction of the milk fat percentage as reported by others (8,36,49,54).

The analysis of the various milk fatty acids are indicated in Table 6. The percentages of the fatty acids were normal. Thus, PWS did not affect fatty acid composition of milk.

Table 3. Mean Digestibility of Rations from Cows Fed Different Levels of Pelleted Wheat Straw.

	Control	5% Plus	15% Plus	25% Plus	F Value	SE
	(% Digestibility)					
Protein	76.22^{a}	73.87^{a}	68.89^{b}	64.04^{c}	5.49	3.27
Fat	84.05	83.29	79.58	78.91	.98	3.70
Acid detergent fiber	40.86	36.13	30.41	32.76	1.47	5.30
Combustible energy	68.92^{a}	65.76^{b}	58.33^{c}	54.56^{d}	9.18	3.08

^{a,b,c,d}Values within a row of means with different superscripts indicate a significant difference ($P<.05$).

Table 4. Mean Concentration of Volatile Fatty Acids in Rumen Fluid of Cows Fed Different Levels of Pelleted Wheat Straw.

Volatile Fatty Acid	Control	5% PWS	15% PWS	25% PWS	F Value	SE
	(uM/ml)					
Acetate	44.68	36.61	65.20	41.38	2.00	11.87
Propionate	22.68	20.91	34.38	20.08	2.20	6.29
Isobutyrate	1.29	1.30	4.19	1.41	3.96	1.20
Butyrate	14.43	11.40	22.22	13.01	2.76	4.07
Isovalerate	2.00	.97	4.33	1.78	3.30	1.40
Valerate	3.74[a]	2.62[a]	6.56[b]	3.47[a]	8.20	.90
Total VFA	88.82	73.81	136.88	81.13	3.01	23.21

[a,b]Values within a row of means with different superscripts indicate a significant difference ($P<.05$).

Table 5. Mean Molar Percentages of Volatile Fatty Acids of Rumen Fluid of Cows Fed Different Levels of Pelleted Wheat Straw.

Volatile Fatty Acid	Control	5% PWS	15% PWS	25% PWS	F Value	SE
			(Molar %)			
Acetate	50.30	49.60	47.63	51.01	1.43	1.72
Propionate	25.53	28.33	25.12	24.75	1.26	2.05
Isobutyrate	1.45	1.76	3.06	1.74	1.35	.87
Butyrate	16.26	15.45	16.24	16.03	1.31	.57
Isovalerate	2.25	1.31	3.16	2.19	1.00	1.07
Valerate	4.21	3.55	4.79	4.28	.50	1.02

Table 6. Mean Percentages of Fatty Acids of Milk from Cows Fed Different Levels of Pelleted Wheat Straw.

Milk fatty acid	Control	5% PWS	15% PWS	25% PWS	F Value	SE
6:0	5.59	6.65	5.61	7.62	.77	1.56
8:0	6.08	7.25	5.69	7.43	.61	1.55
10:0	5.71	4.46	5.17	3.73	1.07	1.18
10:1	.17	.10	.15	.18	.79	.05
12:0	5.31	4.27	5.78	4.99	1.06	.87
12:1	.24	.22	.30	.24	.25	.09
14:0	10.79	10.30	10.97	9.72	.71	.94
14:1	1.36	1.35	1.24	.94	.37	.46
15:0	1.38	1.24	1.16	.58	1.11	.47
16:0	28.33	28.26	29.12	27.30	1.74	.80
16:1	2.01	2.04	1.77	1.96	.29	.32
16:2	.67	.73	.50	.66	.66	.17
17:0	.47	.46	.42	.31	.36	.17
18:0	8.08	9.57	8.74	8.12	.66	1.21
18:1	20.28	20.41	21.00	23.50	.84	2.32
18:2	3.10	2.43	2.09	2.42	.54	.82
18:3	.43	.26	.29	.30	.99	.10

It can be concluded that the addition of PWS to the ration of lactating dairy cows decreased total milk yield as well as protein and combustible energy digestibilities. However, fat percentages were not affected with the PWS at all levels used. Because the milk production decrease was only 5% between the control group and the group fed 25% PWS, there obviously could be times when the price differential between straw and alfalfa could be large enough so that feeding of straw would be economically advantageous.

LITERATURE CITED

1. Ahuja, S. P., K. C. Sharma, K. C. Chaudary and T. S. Bhatia. 1973. Enrichment of wheat straw with urea and effect of its feeding on rumen metabolism in buffalo bulls. Indian J. Anim. Sci. 43(2):103-109.

2. Athar, S. M., N. A. Khan, A. Q. Qazi and B. H. Schneider. 1966. Fattening trials with male buffalo calves to determine the level of protein and proportion of wheat straw and molasses. Agr. Pakistan 17(1):41-50.

3. Beckman, E. 1921. Conversion of grain straw and lupins into feeds of high nutritive value. Chem. Abstr. 16:765.

4. Blair, T., D. A. Christensen and J. G. Manns. 1974. Performance of lactating dairy cows fed complete pelleted diets based on wheat straw, barley and wheat. Can. J. Anim. Sci. 54(3):347-354.

5. Brown, W. H., J. W. Stull and G. H. Stott. 1962. Fatty acid composition of milk. I. Effect of roughage and dietary fat. J. Dairy Sci. 45:191.

6. Brown, W. H., F. M. Whiting, B. S. Daboll, R. J. Turner and J. D. Schuh. 1977. Pelleted and nonpelleted cottonseed hulls for lactating dairy cows. J. Dairy Sci. 60:919.

7. Cate, H. A., J. M. Lewis, R. J. Webb, M. E. Mansfield and U. S. Garrigus. 1975. The effect of pelleting rations of varied quality on feed utilization by lambs. J. Anim. Sci. 14(1):137-142.

8. Chalupa, William, Glen D. O'Dell, A. J. Kutches and Robert Lauker. 1970. Supplemental corn silage or baled hay for correction of milk fat depressions produced by feeding pellets as the sole forage. J. Dairy Sci. 53(2):208-214.

9. Chandra, S. and M. G. Jackson. 1971. A study of various chemical treatments to remove lignin from coarse roughages and increase their digestibility. J. Agric. Sci. 77:11.

10. Cunha, T. J. 1967. Pelleting feeds for beef cattle. Beef Cattle Science Handbook, Vol. 4:35.

11. Den Braver, E. J. 1974. Determination of metabolizable energy in straw for ruminants by in vivo and in vitro methods. Swed. J. Agric. Res. 4(2):53-59.

12. Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

13. Ellis, G. H., G. Matrone and L. A. Maynard. 1946. A 72 percent H_2SO_4 method for the determination of lignin and its use in animal nutritional studies. J. Anim. Sci. 5:285.

14. Emery, F. E. and B. W. Kilgore. 1891. Digestion experiments. III. Comparison of composition and digestibility of wheat straw and cotton seed hulls. North Carolina Agr. Exp. Sta. Bull. 80C.

15. Erwin, E. S., G. J. Marco and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

16. Farrington, E. H. and E. H. Jenkins. 1885. II. The digestibility of feeding stuffs. Connecticut Agr. Exp. Sta. Annual Report.

17. Fehr, P. M. 1971. Utilization of pelleted forages by dairy goats. Ann. Zoot. (Paris) 20(3):305-320.

18. Flatt, W. P., C. E. Coppock, L. A. Moore and R. W. Hemken. 1965. Energy balance studies with dry, non-pregnant dairy cows consuming pelleted forages. in: Energy metabolism: Proceedings of the third symposium, Troon, Scot. Academic Press: New York City. Europe Ass. Anim. Prod. (11):131-144.

19. Foot, J. Z. 1966. The value of ethanol as a supplement to a diet of straw (wheat), urea and molasses for sheep. Australian J. Exp. Agr. Anim. Husb. 6(22):317-319.

20. Foster, L. and L. A. Merrill. 1897. Cattle feeding. I. A comparison of Utah feeding stuffs. Utah Agr. Exp. Sta. Bull. 54.

21. Frischknecht, W. D. 1977. Finishing cattle with maximum amounts of forage and by-product feeds. Beef Cattle Science Handbook, Vol. 14:473.

22. Goering, H. K., L. W. Smith, P. J. Van Soest and C. H. Gordon. 1973. Digestibility of roughage materials ensiled with sodium chlorite. J. Dairy Sci. 56(2):233-240.

23. Halevi, A., H. Neumark and S. Amir. 1973. Straw in different proportions as sole roughage in diets for cows in mid-lactation. J. Dairy Sci. 56(11):1424-1428.

24. Hutton, J. B. 1970. Comparative efficiency of pastures and crops. Proc. 11th Intern. Grassland Congr., Queensland, Australia, p. A78-100.

25. Journet, M. 1970. Use of pelleted feeds for dairy cows. Ann. Zoot. (Paris) 19(1):85-87.

26. Kehar, N. D. 1954. Effect of feeding alkali-treated cereal straws on the growth of young cattle. Indian Jour. Vet. Sci. and Animal Husb. 24(4):189-216.

27. Leonard, W. H. and J. H. Martin. 1963. Cereal crops. The MacMillan Company, New York.

28. Louca, A. and A. Papas. 1970. The use of barley, urea, lucerne and wheat straw for fattening friesian calves. Cyprus Agr. Res. Inst. Tech. Bull. (7):3-13.

29. Lucas, H. L. 1955. Switchback trials for more than two treatments. North Carolina Agr. Exp. Sta. Paper No. 662.

30. Ludri, R. S., K. L. Gupta and H. C. Pant. 1972. Urea as a protein substitute in the ration of adult buffalo steers: I. Dry matter intake, ruminal pH, TUFA and ammonia levels and the cellulolytic activity of rumen microbes. Agri. Univ. J. Res. Sci. 19(2):39-46.

31. Maynard, L. A. and J. K. Loosli. 1962. Animal Nutrition. 5th ed. McGraw-Hill Book Co., Inc., New York.

32. Metcalfe, L. D., A. A. Schmitz and J. R. Pelka. 1966. Rapid preparation of fatty acids esters from lipid for gas chromatographic analysis. Anal. Chem. 38:514.

33. Mills, A. A. 1895. Alfalfa or lucerne. Utah Agr. Exp. Sta. Bull. 44.

34. Minson, D. J. 1963. The effect of pelleting and wafering on the feeding value of roughage: A review. Jour. Brit. Grassland Soc. 18(1):39-44.

35. Monetti, G., A. Mordenti, L. Barbieri and P. Santoro. 1969. The influence of the protein quality of basic ration (alfalfa and wheat straw) on steer production. Zootechnia 18(3):151-166.

36. Moore, L. A. 1964. Symposium on forage utilization: Nutritive value of forages as affected by physical form. Part I. General principles involved in ruminants and effect of feeding pelleted or wafered forage to dairy cattle. J. Anim. Sci. 23:230.

37. Morrison, F. B. 1956. Feeds and feeding. 22nd ed. The Morrison Pub. Co., Clinton, Iowa.

38. National Academy of Sciences, National Research Council. 1971. Nutrient requirements of dairy cows. 4th ed. Rev. Washington, D.C.

39. Nikolaeva, L. T., 1938. Ammonium hydroxide treatment of straw. Chem. Abstr. 35:817.

40. O'Dell, G. D., W. A. King and W. C. Cook. 1968. Effect of grinding, pelleting, and frequency of feeding of forage on fat percentage of milk and milk production of dairy cows. J. Dairy Sci. 51(1):50-55.

41. O'Donovan, P. B. and M. B. Ghadaki. 1973. Effect of diets containing different levels of wheat straw on lamb performance, feed intake and digestibility. Anim. Prod. 16(1):77-85.

42. Porter, G. H., R. E. Johnson, H. D. Eaton and F. S. Elliott. 1953. Relative value for milk production of field-cured and field-baled, artificially dried-ground and artificially dried-pelleted alfalfa when fed as the sole source of roughage to dairy cattle. J. Dairy Sci. 36(10):1140-1149.

43. Putnam, P. A. and R. E. Davis. 1961. Effect of feeding pelleted complete rations to lactating cows. J. Dairy Sci. 44(8):1465-1470.

44. Ronning, M. 1969. Effect of varying alfalfa hay-concentrate ratios in a pelleted ration for dairy cows. J. Dairy Sci. 43(6):811-815.

45. Ronning, M., J. H. Meyer and G. T. Clark. 1959. Pelleted alfalfa hay for milk production. J. Dairy Sci. 42(8):1373-1376.

46. Sahai, K., P. N. Johri and N. D. Kehar. 1955. Effect of feeding alkali and water treated cereal straws on milk yield. Indian Jour. Vet. Sci. and Animal Husb. 25(3):201-212.

47. Schneider, B. H. 1947. Feeds of the world. Their digestibility and composition. Jarret Printing Co., Charleston, W. V., 299 pp.

48. Thalman, R. R. 1935. Wheat straw as a roughage for fattening cattle. Nebraska Agr. Exp. Sta. Circ. 152.

49. Thomas, G. D., E. E. Bartley, H. B. Pfast and R. M. Meyer. 1968. Feed processing: III. Effects of ground, steam heated, and pelleted hay, with and without pelleted grain, on milk composition and rumen volatile fatty acid ratios. J. Dairy Sci. 51(6):869-875.

50. Trowbridge, E. A. and H. C. Moffett. 1940. Blackstrap molasses in rations for fattening yearling steers. Missouri Agr. Exp. Sta. Bull. 413.

51. Udy, D. A. 1956. A rapid method for estimating total protein in milk. Nature 178:314.

52. U. S. Department of Agriculture. 1976. Agricultural Statistics. U. S. Government Printing Office, Washington, D.C.

53. Van Der Honing, Y. 1975. Intake and utilization of energy of rations with pelleted forages by dairy cows. Agr. Res. Rep. 836:1-156.

54. Van Soest, P. J. 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. A review. J. Dairy Sci. 46:204.

55. Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Agr. Chem. 46:829.

56. Wainman, F. W. and K. L. Blaxter. 1972. The effect of grinding and pelleting on the nutritive value of poor quality roughage for sheep. J. Agr. Sci. 79(3):435-445.

57. Watkins, W. E. 1931. The digestibility of cottonseed meal as a supplemental feed for range cattle in New Mexico. New Mexico Agr. Exp. Sta. Bull. 194.

58. Watson, P. D. 1956. A lactometer method for determining the solids in milk. U.S.D.A., A.R.S., Pubs. ARS-73-10.

59. Whiting, F. M., W. H. Brown and J. W. Stull. 1976. Coarse barley straw in dairy rations containing alfalfa hay cubes. J. Dairy Sci. 59(4):764-766.

60. Woodman, H. E. and R. E. Evans. 1947. The nutritive value of fodder cellulose from wheat straw. I. Its digestibility and feeding value when fed to ruminants and pigs. J. Agr. Sci. 37:202.