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An Evaluation of High Protein Oat Forage for Dairy Cattle

Thomas Lee Schroeder

AN EVALUATION OF HIGH PROTEIN OAT FORAGE FOR DAIRY CATTLE

BY

THOMAS LEE SCHROEDER

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Thesis Adviser Date

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I thank my wife Sandy, and my son Jason, from them I obtain life, for them I live.

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AN EVALUATION OF HIGH PROTEIN OAT FORAGE FOR DAIRY CATTLE

ABSTRACT

Thomas Lee Schroeder

Under the supervision of Professor Howard H. Voelker

A 2 consecutive yr study evaluated Spear, a high protein oat (HPO) variety, for forage dry matter yields, and for feeding value when fed as a silage to heifers, steers, and lactating cows. In yrs 1 and 2 the HPO yielded 7% and 13% less DM per hectare, respectively, than Burnett, a medium protein oat (MPO) variety.

In yr 1, 15 Holstein heifers were randomly assigned to either alfalfa-brome hay (ABH), HPO or MPO for a growth study with average daily gains higher for ABH and the same for HPO and MPO. A total collection digestion trial using 6 cows was also conducted comparing ABH, HPO, and MPO fed ad libitum with concentrate fed at 1 kg per 2.5 kg milk produced. Digestibilities for HPO were lower than ABH or MPO.

In yr 2, HPO and MPO silages were fed ad libitum without a concentrate mixture to 7 Holstein heifers each. Average daily gains were higher with MPO. Steers fed HPO silage had lower digestibilities than MPO with nitrogen utilization similar. A swithchback design lactation trial with 5 cows per group were individually fed a ration of HPO or MPO silage supplemented with a concentrate at 1 kg per 3 kg milk produced. Dry matter intakes, milk yield, and composition were similar as were ruminal volatile fatty acids, pH, and ammoniacal nitrogen levels.

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INTRODUCTION

As world population climbs toward the 6 billion mark predicted for the turn of the century, it becomes of grave importance that we meet the challenge of human food production. In developed nations, urban sprawl is devouring land once used for agricultural purposes, while in underdeveloped nations, malnutrition is commonplace. The technology of the 21st century will need to develop new methods and means whereby grains can be increasingly used to provide the nutritional needs of humans. Therefore, animal scientists must work toward even more efficient utilization of roughages by ruminant animals.

Efficient conversion of roughages to high quality human food is an ability unique to ruminants, and of the domesticated ruminants, the most efficient is the dairy cow. Sixty-four percent of the feed consumed by dairy cattle is forage (40), the remaining portion consists of feed products not fit for human consumption. Dairy cattle convert 25% of the protein and 17% of the energy consumed as feed nutrients to edible products (15). The challenge is twofold: 1) to increase the production of high quality forage, and 2) to improve utilization of that forage through more efficient use of ruminants.

Amino acid composition is the prime determinant of protein content and nutritive value in cereal grains. The most limiting essential amino acid of cereal grains is lysine, followed by methionine and threonine. Of the cereal grains, oat grain contains these three essential amino acids in the greatest concentration with threonine and methionine second only to lysine. This means oat grain is nutritionally superior to other cereal grains.

In the early 1970's, plant breeders adopted a systematic approach to breeding oats for increased protein content, which resulted in the release of 2 high groat protein cultivars (53). Both varieties were found to contain 5% more protein than the 289 common cultivars of the World Oat Collection (53).

In South Dakota, Spear, a high groat protein spring oat variety, was developed in 1974 from a Neal x Clintland 64 cross. When young pigs were fed a diet containing 40% Spear oats, weight gains were equal to those of an equivalent ration of corn and soybean oil meal (48), indicating a substantial reduction of protein supplement is possible when Spear oats are fed to pigs. However, forage production of high protein Spear oats, and utilization of the oat silage by ruminants has not been investigated. The major objective of this study was to determine the feeding value of high protein Spear low-moisture oat silage for growing and lactating dairy cattle.

LITERATURE REVIEW

Nutrient Composition

The biological value of rolled oats is intermediate to whole wheat and corn (30). However, oat groats are nutritionally superior to other cereal grains (53) and one of the most economical sources of high quality protein..

The amount of soluble nitrogen in oats is about twice that of corn due to the main storage form of amino acids in oats being the water soluble protein fraction, the globulin (51). Peterson (33) reported that increased oat protein levels were associated with an increased globulin fraction. In addition, the sum of lysine, threonine, and methionine fractions were significantly correlated with protein content (35). However, the lysine content of oats was inversely correlated with glutamic acid which is the main storage amino acid found in the prolamin and glutelin fractions. Methionine and lysine were found equally limiting in growing cattle with methionine the foremost limiting amino acid in forage feeding programs (34).

Total, water soluble, ammonia, amino, and nitrate nitrogen fractions in oats all decreased with increased maturity (42). This follows the trend for crude protein. The amino nitrogen fraction constitutes the major portion of the water soluble nitrogen fraction. Nitrogen application to fields increased forage yield per hectare (42, 45) while depressing total plant crude protein percentage more at later stages of maturity than non-fertilized counterparts. Total plant crude protein and digestible protein declines with increased maturity (2, 7, 8, 16, 18, 23, 28, 39, 41, 42, 44). Stallcup (42) reported that crude protein decreased in the vegetative portion of the plant with an accompanied crude protein increase in the head as maturity increased. Thus, at dough stage, the head contains 73% of the total plant protein.

An experiment (9) comparing green oats and mixed pasture indicated cows fed green oats produced more milk of higher solids-not-fat (SNF) content. The authors concluded that composition of the diet influenced solids-not-fat when digestible energy and digestible crude protein intakes were similar. However, Bartsch (2) found no significant difference for digestible crude protein intake or milk protein percent for cows grazing oats.

Oat silage contains higher crude protein (6, 20) and a higher percent of digestible protein (13, 20) than corn silage, sorghum silage, and barley-pea silage. However, corn silage is superior to oat silage on the basis of total digestible nutrients (TDN) and digestible energy (13, 20, 34, 41). Comparisons of oat silage at different stages of maturity were conducted by Hutjens et al. (16) and Stallcup et al. (41) and both reported that TDN was greater with boot stage oat silage. Hutjens et al. (16) reported greater net energy for milk with boot stage oats, while Stallcup et al. (41) reported milk and dough stages to be equal for TDN. Stallcup et al. (42) further reported gross energy of oat forage to be lowest at milk stage and then increase to hard dough stage. Voelker et al. (47) reported early dough oat silage contained less digestible energy than oats-barley-wheat silages.

Crude fiber and nitrogen free extract have long been used in the determination of nutritive value. Crude fiber remains the accepted method of forage fiber determination by the Association of Official Analytical Chemists (AOAC) (1); however, procedures have been developed by which the total fiber, cellulose, hemicellulose, and lignin fractions of forage can be determined (14). In addition, the total fiber fraction or cell wall constituents (CWC) is inversely related to dry matter intake. The acid detergent fiber (ADF) fraction, consisting of cellulose, lignin, and insoluble ash, is negatively correlated with dry matter digestibility (37).

Thurman et al. (44) and Martz et al. (23) reported that oat silage crude fiber reached a peak at milk stage and then declined to hard dough stage. Crude fiber digestibility decreased as maturity increased while nitrogen free extract digestibility decreased from boot to milk stage, then increased to hard dough stage (44). Acid detergent fiber (ADF) increased with stage of maturity (10) and with wilting of oat silages.

A further investigation (42) of crude fiber at hard dough stage showed cellulose to be the predominant fraction of crude fiber and to make up a greater percentage of the crude fiber as maturity increased. Thus, a positive correlation between crude fiber and cellulose was noted. Highly negative correlations between protein percentage and crude fiber, cellulose, and nitrogen free extract percentages were also noted. Lassiter et al. (20) reported oat silage crude fiber to be higher and nitrogen free extract to be lower than corn silage. Digestibility of nitrogen free extract tended to be lower also, while no consistent trend was noted for crude fiber digestibility. In a comparison of oats, barley, wheat, and corn silage, Burgess et al. (8) noted oat silage contained the highest acid detergent fiber percentage, thus contributing to a higher rumen acetate value found with oat silage. Voelker et al. (47) reported low moisture early dough stage oat silage contained greater crude fiber and significantly greater acid detergent fiber than low moisture oats-barley-wheat combination silage in both years of a 2 yr study. Acid detergent fiber digestibility was also greater with oat silage than with the combination.

Nutritive Quality

Nutritive quality of silage is affected by 1) the crop itself, 2) the stage of maturity at harvest, and 3) the moisture content. Unlike the type of crop, which is determined at planting time, stage of maturity at harvest and moisture content can be regulated by harvest date and method of harvesting (direct-cut, wilted, low moisture, etc.). Forage composition is affected by various factors such as crop variety, soil type, fertilization rate, weather conditions, and geographical location. Compositional components as previously noted are also related to stage of maturity.

Oats pass very rapidly from early milk to dough, thus, time of cutting is a critical factor in the production of good oat silage if large tracts are to be harvested (18). Very succulent, high moisture oat forages will usually have high seepage losses thereby reducing the amount of dry matter preserved (7). Silo reinforcements may be necessary to hold the additional pressure of these silages (18). Higher moisture silages, as would be expected with early stage of maturity, are easier to pack in a silo and may compound the need for silo reinforcements.

Harvesting oats for silage in the boot to milk stage of maturity provides silage with higher protein content, lower crude fiber, and increased digestibility when compared to later stages of maturity silage (8, 10, 36, 41, 44). One research group (44) noted that milk stage yielded more nutrients per hectare; however, this was not conclusive (8, 22). It has been suggested that preservation of maximum protein and dry matter can be obtained by growing late maturing varieties and then cutting at late milk to mid-dough stage (18). This practive decreases the possibility of lodging and increases soil moisture conservation and opportunity for nurse crop growth (8, 23).

In an experiment (10) compared direct-cut prebloom, wilted prebloom, direct-cut, and wilted soft dough oat silages for daily dry matter intakes (DMI), DM content, acid detergent fiber (ADF), and DDM. Daily DMI was lowest for the direct-cut prebloom silage while similar DMI were found for the direct-cut and wilted soft dough and highest for the wilted prebloom stage. The wilted silages were notably lower in DDM and higher in ADF and DM than the prebloom silages.

McCullough et al. (28) conducted an extensive 2 yr study of oat silages ensiled at 4 different stages of maturity using ground snap corn or sodium metabisulfite as preservatives. All silages were classified excellent when evaluated for type of fermentation, color, odor, and pH. Dry matter preservation increased as stage of maturity increased, within preservative treatment until dough stage. Poor compaction of the dough stage silage was reported, thereby increasing spoilage and leading to lower preservation of dry matter. This occurred even though DM percentages were similar for all silages. As stage of maturity increased, oat silage consumption also increased in both yrs of the experiment. The feed value of each forage was evaluated in a 28 day trial using 4 or 5 cows per treatment. Milk persistency was the main parameter for comparison. Only boot stage produced satisfactory milk production when preserved with sodium metabisulfite. Disease conditions in the forage produced a 50% decrease in grain yield for the milk stage oat silage in yr 2, decreasing feed value of that silage in that year. Prebloom silage did not exhibit this problem and therefore, stage of maturity was felt to be an important criteria in the selection of harvest time. Normal milk production was not achieved in either yr when cows were fed milk or dough stage silage, thus, prebloom stage of maturity was felt optimum for feeding value and preservation of nutrients. The authors concluded milk production was affected little by stage of maturity, providing harvesting occurs prior to milk stage.

Brundage (6) reported milk stage oat-pea silage had a higher moisture content, was consumed at equal levels on DM basis, and yielded similar daily 4% milk production to barley-pea silage. Chemical analyses of the late milk oat-pea and barley-pea silages were similar with the exception of pH which was 4.3 and 5.9 for the respective silages.

Energy content expressed by TDN percentage remains relatively constant after milk stage. The utilization of TDN for milk production was equal for boot, early milk, and soft dough stage oat silage (23). Martz et al. (22) compared oat silage harvested at three stages of maturity to grass-legume silage and noted only boot stage oat silage was utilized as well as grass-legume silage for milk production. Silage DMI was greatest with dough stage oat silage (22, 23), as was DM consumed per kg milk produced (23). However, Martz and Associates (22) reported moisture level, as such, was not the limiting factor of DMI, rather the type of fermentation which occurred. A later study by Martz et al. (23) indicated body wt changes favored boot stage oat silage while a highly significant difference was noted between boot and early milk stages for fat-corrected-milk (FCM). This difference was reported to be related to decreased TDN with increased maturity. Thus, boot stage or shortly thereafter, would be best from a milk production standpoint, although acceptable oat silages can be made at all stages of maturity (22, 23, 49).

Lassiter et al. (20) compared the feed value of early dough stage oat silage to early dent corn silage for lactating dairy cows. The oat silage contained more crude protein and crude fiber than did corn silage, but TDN was lower in the oat silage, both yrs. Cows fed oat silage produced significantly more milk, had greater body wt gains, and consumed significantly more forage, while little difference was noted in butterfat test in yr 1. The second yr an opposite trend was noted, with oat silage yielding significantly less milk, and body wt gain. Lower DM consumption and lower TDN values obtained in yr 2 for the oat silage were used to explain the lower milk production and body wt gain. These factors contributed to significantly lower average daily gain and DM consumption with dairy heifers in yr 2.

Further investigations by Lassiter et al. (19) showed TDN content of early dough stage oat silage to be less than that of dent stage corn silage. When cows received 4.5 kg alfalfa hay and 6.8 kg from the respective silages, the oat silage group produced significantly more milk and gained more wt.

Marx (24) noted no significant differences in feed consumption or body wt when dough stage oat silage, and boot stage barley silage at 2 DM levels (41.4 and 56.2%) were compared to the controls; low moisture alfalfa silage and boot stage oat silage. The higher dry matter barley silage produced significantly lower milk than either control. A similar experiment (26) revealed boot stage oat silage to compare favorably with bud stage alfalfa haylage for DMI, 4% FCM, total milk fat, solids-not-fat produced and body wts in a 122 day lactation trial.

Low moisture oat silages yielded less DM per hectare than oats-barley-wheat (OBWS) silages as reported by Voelker et al. (46, 47). It was reported (46) that oat silage contained less protein, higher ADF, and pH, while OBWS was higher in acetic and propionic acids. Similar digestibilities were reported for both silages (47). Milk production and body weight gains were similar in the first experiment (46) with milk composition similar in the second experiment (47). Dry matter intake was comparable for both silages in each experiment. Voelker (47) reported significantly greater milk per day with OBWS in yr 1, while no difference was noted in yr 2. Greater DMI of OBWS with heifers was noted by Voelker (47). Heifer average daily gain, DMI per kg wt gain, and DM per 100 kg body wt were similar for both silages in each experiment (46, 47).

Burgess et al. (8) conducted a comprehensive study of direct-cut forage oat, barley, wheat, and corn silages. The oat and barley silages were included in both yrs of the study, while corn and wheat silages were included in yrs 1 and 2, respectively. Variation was noted for DM and crude protein between years, with the largest variation of crude protein found with the forage oat silage. Silage treatments in yr 1 did not affect total DMI, solids-not-fat (SNF) or milk fat percent. It was observed that significantly less corn silage DM as percent of body wt was consumed while greater actual milk, 4% FCM, body wt gains, and milk protein was produced. In yr 2 opposite results were obtained, with 4% FCM, body wt gains, total DMI, and milk protein not affected by silage treatment. Higher crude fiber content attributed to the lower performance of oat silage. The high fiber content contributed to significantly higher rumen acetate values in yr 1. No significant difference was found in yr 2 for rumen acetate values. Propionate concentration remained relatively constant between silage treatment in both studies.

It was concluded in this investigation that the additional protein found in the oat silage did not compensate for the higher milk production efficiency of the corn silage.

Factors of Fermentation

Forages are ensiled to preserve maximum nutrients through fermentation with optimum preservation achieved through anaerobic conditions. This silage making process has been well reviewed (4, 12, 17, 29). Prevention of clostridia growth can be attained by ensiling forages at a dry matter greater than 28%. At dry matters above 28%, lactic acid bacteria proliferate and pH is lowered to 4.0 to 4.5 where clostridia development is inhibited (29). Lactic acid bacteria are relatively non-existent on living plant material, however, upon chopping and ensiling of plant material lactic acid bacteria multiply and are transported throughout the mass by plant fluids thereby promoting a rapid increase in bacterial numbers. However, optimum silage fermentation depends not only on the type of bacteria present, but also on available water soluble carbohydrates, buffering capacity of the mass, speed of fermentation, and moisture content of the forage (27).

During fermentation plant carbohydrates are utilized by anaerobic microorganisms for the production of organic acids (4, 27). The main water soluble carbohydrates found in grasses are sucrose, fructose, fructans, and glucose, with sucrose and fructans hydrolyzed to glucose and fructose which are the major microbiological substrates for organic acid productions. The end products produced from these substrates are dependent upon the type of bacteria present and determine fermentation efficiency.

The desired end products are organic acids, of which lactic acid should comprise greater than 60% of the total with acetic acid being the main volatile organic acid (17). Organic acids account for the major portion of the total buffering capacity within the pH range of 4 to 6 (12). The buffering capacity of silage has been shown to decrease with wilting of forages (29), while highly buffered silages have been reported to decrease feed intake (50).

Liberated amino acids undergo changes due to plant and microbial activity during fermentation. The major amino acid changes are produced by clostridia via oxidation - reduction, deamination and decarboxylation, or decarboxylation reactions while lactic acid bacteria have been reported to attack only L-serine and L-arginine (29). Proteolysis does not change protein composition, thus, the amino acid composition of silage protein is similar to that of the forage prior to ensiling (29). The extent of proteolysis is dependent on dry matter content and pH value. Thus, pH and extent of deamination are closely related. Extensive degradation of lysine, histidine, and arginine along with lesser degradations of aspartic acid, threonine, serine, and tyrosine occur in the pH range of 4.87 and 5.77 (11). Thus, preservation of amino acids requires a rapid decrease in pH during fermentation.

This literature review points to the need for further research with oat silage, particularily the utilization of high protein varieties.

MATERIALS AND METHODS

Year 1

A 7.33 hectare plot of Spear, a high protein spring oat variety (HPO) and a 7.46 hectare plot of Burnett, a medium protein spring oat variety (MPO) were planted to provide sufficient forage for yield determination, heifer growth, and a digestibility study. The oat forages were harvested at early dough stage of maturity and ensiled in oxygen limiting silos after wilting to approximately 50% dry matter. Alfalfa-brome hay (ABH) was used as a control.

Heifer Trial

Fifteen Holstein heifers ranging in weight from 89 to 197 kg were randomly assigned to 1 of 3 treatment groups: 1) alfalfa-brome hay (ABH), 2) Spear oatlage (HPO), or 3) Burnett oatlage (MPO), for a 162 day period. Forages were group fed ad libitum and a 13.7% crude protein concentrate mixture (Table 1) was fed at 2.25 kg per heifer daily. In addition, a 1:1 mixture of dicalcium phosphate and trace mineral salt was offered ad libitum.

Amounts of forages, grain fed, and feed refusals were weighed daily. Feeds were sampled weekly, frozen, and composited for later analyses. Total nitrogen content of forages was conducted on a wet basis by Kjeldahl method (1) and the remainder was oven dried at 65^{o} C for 48 h, ground in a Wiley[1] mill and analyzed for fiber components (14). The concentrate mixture was analyzed for crude protein by AOAC

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[1]Arthur H. Thomas Co., Philadelphia, PA.

TABLE 1. Composition of concentrate mixture fed during year 1 heifer trial.

Ingredient[a]	%
Rolled shelled corn	63
Rolled oats	32
Soybean meal, (50% CP)	4
Trace mineral salt	.5
Dicalcium phosphate	.5

[a]Vitamin A, 3637 IU/kg; Vitamin D, 363 IU/kg added to concentrate ration.

(1) and moisture was determined by oven drying at 65° C for 48 h.

After a 2 wk preliminary period the heifers were weighed 3 consecutive days, every 14 days thereafter and 2 consecutive days at the end of the trial. Skeletal growth measurements were taken on each wt day and included: ht at withers, chest depth, chest circumference, withers to hips, and withers to pins. Average daily gain and growth measurements were analyzed by least squares analysis of variance (43).

Digestion Trial

Six lactating cows were used in a 5 day total collection digestion trial to compare alfalfa-brome hay (ABH), Spear oatlage (HPO), and Burnett oatlage (MPO). In addition to the ad libitum forages, a concentrate mixture (Table 2) was fed twice daily at 1 kg per 2.5 kg of milk produced.

TABLE 2. Composition of concentrate mixture fed during year 1 digestion trial and year 2 lactation trial.

Ingredient[a]	%
Rolled shelled corn	80
Soybean meal, (50% CP)	17
Trace mineral salt	1.5
Dicalcium phosphate	1.5

[a]Vitamin A, 8800 IU/kg; Vitamin D, 2200 IU/kg added to concentrate ration.

Feed and weighback of feeds were sampled once daily, and frozen until composited later for analyses. Feed analyses were conducted as in the heifer trial.

Milk wts and samples were taken twice daily and composited for analyses. Milk protein was determined by Kjeldahl method (1), total solids by the Mojonnier method (32) and milk fat by Milko-tester[2].

Urine was collected via sterile Bardex Foley catheter[3] into 19 liter containers to which 2 ml of toluene had been added. Urine was measured and sampled once daily, then frozen. Daily urine samples were composited on a percent of the total 5 day excretion and analyzed for total nitrogen by Kjeldahl method (1). Feces were weighed once daily, sampled and frozen. Daily fecal samples were analyzed for total nitrogen by Kjeldahl method (1) with the remainder

[2]MK-II, N. Foss Electric Hillerod, Denmark.

[3]C. R. Bard, Inc., Murray Hill, NJ.

oven dried (65^{o} C for 48 h) and fiber analysis conducted (14). Energy values of feed and feces were determined using a Parr[4] oxygen bomb calorimeter.

Year 2

A 7.46 hectare plot of Spear, a high protein spring oat variety (HPO) and a 7.33 hectare plot of Burnett, a medium protein spring oat variety (MPO) were planted to determine forage yields, lactional performance, heifer growth and digestibility. The Burnett served as a control. As in yr 1, the oat forages were harvested at early dough stage, wilted to 45 to 50% dry matter and ensiled in oxygen limiting silos[5].

Heifer Trial

Spear (HPO) and Burnett (MPO) were fed ad libitum to seven Holstein heifers each for 15 wk after a 2 wk preliminary period. Feeding programs, sampling schedules, and analyses were as in yr 1. Body wts were taken at the initiation and completion of the trial with average daily gains analyzed by least squares analysis of variance (43).

Digestion Trial

Twelve Holstein steers were randomly assigned to either Spear (HPO) or Burnett (MPO) for a 5 day total collection digestibility study. A 2 wk preliminary period was employed. Steers were weighed

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[4] Parr Instrument Co., Moline, IL.

[5] A. O. Smith Harvestore Products, Inc., Arlington Heights, IL.

before being placed in the digestion stalls and upon completion of the trial. Once in the digestion stalls an additional 5 day period was utilized for proper adjustment to stalls.

Forage intake during the collection period was limited to 90% of the ad libitum intake of the previous 8 days. Sampling procedures, feed analyses, and energy determinations were conducted as in yr 1.

Urine was collected in 19 liter containers to which 2 ml of toluene had been added. Urine and fecal samples were composited and analyzed according to yr 1 procedures.

Lactation Trial

Ten Holstein cows between peak lactation and mid-gestation were utilized in a 3 period, 5 wk per period switchback design (21) lactation trial. After a 2 wk preliminary the HPO and MPO forages were individually fed ad libitum with a concentrate mixture (Table 2) fed at 1 kg per 3 kg of milk produced. Cows were weighed at the start of the preliminary period, 3 consecutive days at the start of each of the subsequent periods and at the end of the trial. Body wts were analyzed according to Li (21).

Concentrate and forage samples were taken weekly, frozen, and composited later by periods. Analyses of concentrate and forage were conducted as in yr 1.

Milk wts were recorded daily and sampled 1 day, each of the last 3 wk of each period. Milk fat was determined by Milko-tester[6], milk

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[6]MK-II N. Foss Electric, Hillerod, Denmark.

protein by Kjeldahl method (1), and total solids by Mojonnier (32). Statistical analysis was conducted according to Li (21).

Rumen fluid samples were taken via stomach tube 3 h postfeeding once during the last wk of each period. One ml of mercuric chloride, to stop bacterial action, was added to sample bottles prior to sampling. Samples were analyzed for pH, volatile fatty acids by gas-liquid chromatography (3) and ammonia (38).

RESULTS AND DISCUSSION

Year 1

The yields and composition of the forages fed during yr 1 are presented in Table 3. Dry matter yields per hectare were 7% greater for MPO than for HPO. Nitrogen, cell wall contents, cellulose, and lignin were all lower for MPO, while hemicellulose was higher than either HPO or ABH.

TABLE 3. Yields and compositon of alfalfa-brome hay (ABH), Spear (HPO), and Burnett (MPO) oat silages fed during year 1.

	Forage			
Component	ABH	HPO	MPO	SEM[1]
Dry matter yield, kg/ha	---	2554	2733	
Dry matter %	92.18[a]	48.45[b]	58.30[c]	4.42
Nitrogen, % of DM	2.94	2.48	2.36	.54
Cell wall contents, % of DM	48.17[a]	45.76[b]	44.66[b]	.50
Cellulose, % of DM	20.10[a]	18.91[c]	15.48[b]	.52
Hemicellulose, % of DM	19.58	19.30	20.74	.86
Permanganate Lignin, % of DM	7.10[a]	6.00[b]	5.77[b]	.20

[1]Standard error of mean.

[abc]Means in the same row with unlike superscripts are different (P<.05).

Heifer Trial

Growth performance data (Table 4) shows heifers fed the control (ABH) gained more weight (P<.05) than heifers fed either of the oatlages. This agrees with Marx (25). However, skeletal growth changes were not significantly different.

TABLE 4. Growth performance of heifers fed alfalfa-brome hay (ABH), Spear (HPO), and Burnett (MPO) oat silages in year 1.

Item	Forage			SEM[1]
	ABH	HPO	MPO	
Initial wt., kg	151	156	151	
Average daily gain, kg	.96[a]	.82[b]	.82[b]	.04
Kg forage dry matter consumption per day	4.80	4.30	4.50	2.20
Skeletal growth changes, cm				
Height at withers	19.40	20.40	22.40	1.00
Chest depth	14.00	11.60	12.00	.86
Chest circumference	39.80	35.00	38.20	1.51
Withers to hips	17.40	16.60	18.20	1.69
Withers to pins	23.80	23.00	24.20	1.67

[1]Standard error of mean.

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

Digestion Trial

Data from the digestion study are presented in Tables 5 and 6. Total DMI (Table 5) were similar for all rations as were DMI (% BW). Forage DMI (% BW) and per day were lower for the MPO and not significantly different between rations.

Digestibilities (Table 5) for all parameters measured were

TABLE 5. Digestion data for cows receiving alfalfa-brome hay (ABH), Spear (HPO), and Burnett (MPO) oat silages during year 1.

Item	Forage			SEM[1]
	ABH	HPO	MPO	
Total DMI, kg/day	19.96	19.38	20.81	2.25
Total DMI, % BW	3.39	3.36	3.39	.47
Forage DMI, kg/day	13.05	13.34	11.78	1.69
Forage DMI, % BW	2.21	2.32	1.90	.31
Concentrate DMI, % BW	1.17	1.05	1.47	.23
DM digested, %	74.80[a]	65.40[b]	69.95[c]	1.06
Gross energy digested %	60.27	51.68	59.37	1.89
CWC digested, %	56.50	41.59	48.88	2.76
Cellulose digested, %	52.59[a]	42.24[b]	44.92[b]	1.73
Hemicellulose digested, %	64.10	48.32	55.58	4.23
Permanganate lignin digested, %	51.73[c]	23.13[d]	32.12[d]	4.68

[1]Standard error of mean.

[abcd]Means in rows with unlike superscripts are different at (P<.05).

lowest and highest for the HPO and ABH, respectively with cellulose and permangante lignin significantly (P<.05) higher for the ABH.

Nitrogen utilization data (Table 6) shows that nitrogen intake was higher for ABH, primarily because of higher nitrogen content in the forage. A negative retained nitrogen balance was noted, due to lower nitrogen intake and nitrogen absorbed on the HPO.

Year 2

The composition of the oat silages fed during yr 2 are presented in Table 7. As in yr 1, dry matter yields favored MPO and were 13% greater than the HPO. This 2 yr trend agrees with the results of Bonnemann (5) for grain yields. Forage dry matter yields in both yrs for both varieties were lower than those reported by Voelker et al. (46, 47). Dry weather conditions prevailed during both yrs and contributed to the lower yields reported. In addition, yr 2 oatlages received hail damage which contributed to a loss of grain from the heads. This was more prevalent with the HPO due to more advanced maturity. Loss of grain also contributed to higher CWC values reported in yr 2, although similar values have been reported (6, 7). Cellulose was significantly (P<.005) higher for the HPO in yr 2, as in yr 1. In yr 2 significantly (P<.005) lower hemicellulose was noted for the HPO and is the opposite of yr 1 findings. An opposite trend between yrs was also found for CWC. Nitrogen percentages were similar for both oatlages each yr and while HPO has a higher oat groat protein percentage in the grain, this is not evidenced on a forage basis.

TABLE 6. Nitrogen utilization by cows receiving alfalfa-brome hay (ABH), Spear (HPO), and Burnett (MPO) oat silages during year 1.

Item	Forage ABH	Forage HPO	Forage MPO	SEM[1]
N intake, g/day	526.22	476.80	503.03	55.31
N absorbed, g/day[a]	308.94	251.80	295.16	30.21
N excreted, g/day				
feces	217.28	224.99	207.87	26.57
urine	194.88	176.40	138.50	28.82
milk	98.11	91.10	116.40	14.92
retained N	15.91	-15.70	40.26	36.05
productive N[b]	114.02	75.40	156.66	40.16
N % intake				
feces	41.30	47.27	41.24	1.36
urine	36.81	38.72	27.74	7.37
milk	18.56	19.01	23.12	1.39
productive N	21.86	13.99	31.02	6.92
N % absorbed				
urine	72.89	73.55	46.89	11.13
milk	31.61	36.05	39.44	2.52
productive N	37.34	26.40	53.10	12.98
Digested N intake, kg/day	.31	.25	.29	.02
Apparent N digested, %	58.69	52.72	58.76	1.36

[1]Standard error of mean.

[a]absorbed = N intake - N in feces

[b]productive N = N in milk + N retained

TABLE 7. Yields and composition of Spear (HPO) and Burnett (MPO) oat silages fed during year 2.

Component	Forage HPO	Forage MPO	SEM[1]
Dry matter yield, kg/ha	4144	4681	
Dry matter %	47.76	47.50	1.31
Nitrogen, % DM	2.50	2.47	.03
Cell wall content, % DM	48.47	49.35	.56
Cellulose, % DM	23.26	20.16*	.63
Hemicellulose, % DM	15.26	20.40*	.55
Permanganate lignin, % DM	6.64	6.29	.23

[1]Standard error of mean.

*Different from HPO (P<.005).

Heifer Trial

Total body weight gains, average daily gains, and daily forage DM consumption are shown in Table 8. Average daily gains and total body weight gains were significantly greater (P<.05) with the MPO. Forage DM intake was also greater with the MPO, however, it was 14% more efficient in producing body weight gains.

TABLE 8. Growth performance of heifers fed Spear (HPO) and Burnett (MPO) silages during year 2.

Item	Forage		
	HPO	MPO	SEM[1]
Initial wt., kg	196	192	
Average daily gain, kg	0.58	0.67*	.00
Kg forage dry matter consumption per day	6.70	6.80	.49

[1]Standard error of mean.

*Different from HPO (P<.05).

Digestion Trial

Data from the digestion study are presented in Tables 9 and 10. No difference (P>.05) was noted in daily DMI (Table 9) or DMI (% BW) although, silage DMI favors MPO and agrees with the findings of yr 1. While only percent CWC digested was significantly (P<.05) different, the digestibility coefficients for all parameters measured were lower for the HPO. This agrees with yr 1 findings. The lower digestibility of the HPO may be due to the silica content of the forage, as reported by Van Soest et al. (52). The digestibilities of the MPO were similar to those previously reported (31, 47).

Lactation Trial

No difference (P>.05) was noted in DMI (Table 11) for the oatlages. Similar results were reported by Voelker et al. (46, 47). Daily yields of milk and 4% fat-corrected-milk (FCM) (Table 12) did not differ significantly between rations. This is inconsistent with

TABLE 9. Digestion data for steers receiving Spear (HPO) and Burnett (MPO) oat silages in year 2.

Item	Forage		SEM[1]
	HPO	MPO	
Silage DMI, kg/day	4.37	4.94	.19
Silage DMI, % BW	2.33	2.59	.08
DM digested, %	63.93	66.84	1.58
Gross energy digested, %	60.64	63.85	1.63
Cell wall contents digested, %	70.51	78.15*	1.64
Cellulose digested, %	61.82	65.97	1.81
Hemicellulose digested, %	56.34	65.27	3.06
Permanganate lignin digested, %	46.98	61.15	6.09

[1]Standard error of mean.

*Different from HPO (P<.05).

TABLE 10. Nitrogen utilization by steers receiving Spear (HPO) and Burnett (MPO) oat silages during year 2.

Item	Forage		SEM[1]
	HPO	MPO	
N intake, g/day	124.25	127.13	5.49
N absorbed, g/day[a]	90.71	94.92	3.34
N excreted, g/day			
feces	33.53	32.21	2.91
urine	51.32	53.91	3.27
N balance[b]	39.39	41.01	3.43
N, % intake			
feces	26.71	25.26	1.41
urine	41.49	42.37	2.08
N, % absorbed			
urine	56.59	56.89	3.10
Digested N intake, kg/day	0.90	0.94	.00
Apparent N digested, %	73.29	74.72	1.41

[1]Standard error of mean.

[a]N absorbed = N intake - N feces

[b]N balance = N absorbed - N urine

TABLE 11. Daily dry matter intakes (DMI) of cows receiving Spear (HPO) and Burnett (MPO) oat silages during year 2.

Item	Forage HPO	Forage MPO	SEM[1]
Total DMI, kg	20.95	21.29	5.55
Silage DMI, kg	13.85	14.28	4.64
Concentrate DMI, kg	7.10	7.01	.85
Body wt, kg	577.30	591.73*	5.12

[1]Standard error of mean.

*Different from HPO (P<.05).

TABLE 12. Daily yield and composition of milk from lactating dairy cows receiving Spear (HPO) and Burnett (MPO) oat silages during year 2.

Item	Forage HPO	Forage MPO	SEM[1]
Milk yield, kg	23.15	23.07	4.23
Fat-corrected-milk per day, kg	22.42	22.54	.00
Fat, %	3.79	3.85	.15
Protein, %	2.99	3.05	.07
Total solids, %	12.28	12.47	.22

[1]Standard error of mean.

the findings of Voelker et al. (47) for actual milk yield. Milk fat, protein and total solids percentages were not significantly different, although they were slightly greater for the MPO. Similar fat, protein, and total solids percentages have been reported (8, 26, 46, 47).

Rumen pH, along with rumen ammonia and rumen volatile fatty acids concentrations are presented in Table 13. No significant difference was noted between rations for rumen pH or rumen ammonia. Rumen ammonia concentration was higher than reported by Burgess et al. (8), however, these values might be expected due to the nitrogen level of the oatlages and the time at which samples were taken. Rumen VFA's were not significantly different between rations. Rumen acetate values favored the HPO, possibly due to the higher cellulose content of the forage (8).

TABLE 13. Rumen volatile fatty acids (VFA), pH, and ammoniacal nitrogen concentrations for cows fed Spear (HPO) and Burnett (MPO) oat silages during year 2.

Item	Forage		SEM[1]
	HPO	MPO	
Acetic acid, uM/ml	28.82	27.70	7.23
Propionic acid, uM/ml	9.50	9.18	2.37
Butyric acid, uM/ml	6.50	6.26	1.56
Total VFA's, uM/ml	47.74	46.20	10.78
pH	6.86	6.88	.25
Ammoniacal nitrogen, mg/100 ml	18.10	17.64	5.37

[1]Standard error of mean.

CONCLUSIONS

The conclusions that can be drawn from the results of these investigations are:

1. Forage dry matter yield may be 13% higher with the Burnett oatlages.
2. Although Spear oatlage has a higher oat groat protein percentage than Burnett, the forages have similar nitrogen percentages. In addition, the Spear nitrogen is not utilized as well as Burnett by lactating cows.
3. Digestibility of fiber varies from yr to yr, but the digestibility of Spear is usually lower.
4. Milk yield and composition are similar for both oatlages, as are rumen pH, volatile fatty acid, and ammoniacal nitrogen concentrations.
5. Body wt gains were higher for heifers and cows fed Burnett than Spear.

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APPENDIX

APPENDIX TABLE 1. Least-squares analysis of variance of year 1 heifer trial.

Source	Degrees of Freedom	Variable: Average daily gain	Height at withers	Chest depth	Chest circumference	Withers to hips	Withers to pins
		---- Mean squares ----					
Total	14						
Treatment	2	.03*	8.60	8.26	29.86	3.20	1.86
Error	12	.008	5.03	3.76	11.46	14.43	13.96

*F - test significant (P<.05).

APPENDIX TABLE 2. Least-squares analysis of variance of dry matter intakes (DMI), year 1 digestion trial.

Source	Degrees of Freedom	Total DMI kg/day	Total DMI % BW	Forage DMI kg/day	Forage DMI % BW	Concentrate DMI % BW
		Mean squares				
Total	5					
Treatment	2	1.02	.00	1.38	.09	.09
Error	3	10.17	.45	5.73	.19	.11

APPENDIX TABLE 3. Least-squares analysis of variance of digestibility coefficient for year 1 digestion trial.

Source	Degrees of freedom	Variable					
		DM digested %	Gross energy digested %	CWC digested %	Cellulose digested %	Hemicellulose digested %	Permanganate lignin digested %
		- - - - - - - - - - - - - - Mean squares - - - - - - - - - - - - - - - - - - -					
Total	5						
Treatment	2	44.19*	44.60	111.09	57.69**	124.76	427.77**
Error	3	2.24	7.18	15.32	6.04	35.94	43.90

*F - test significant (P<.025).

** F - test significant (P<.05).

APPENDIX TABLE 4. Least-squares analysis of variance of nitrogen utilization of year 1 digestion trial.

Source	Degrees of freedom	N intake g/day	N absorbed g/day	N excreted, g/day feces	urine	milk	Retained N g/day	Productive N	N % intake Feces	Urine	Milk	Productive	N % absorbed Urine	milk	productive	Digested N intake kg/day	Apparent N digested %
		Mean squares															
Total	5																
Treatment	2	1222.71	1778.08	147.11	1652.45	340.99	1574.83	145.20	24.00	68.89	12.62	145.92	462.22	30.84	360.44	.00	24.00
Error	3	6119.80	1826.10	1411.97	1661.22	445.37	2599.20	95.92	3.74	108.76	3.90	95.92	248.12	12.75	337.18	.00	3.74

APPENDIX TABLE 5. Least-squares analysis of variance of heifer trial year 2.

Source	Degree of freedom	Variable Average daily gain
Total	13	
Treatment	1	.029*
Error	12	.005

*F - test significant (P<.05).

APPENDIX TABLE 6. Least-squares analysis of variance of year 2 digestion trial.

		Variable							
Source	Degrees of freedom	Silage DMI, kg/day	Silage DMI % BW	DM digested %	Gross Energy digested %	CWC digested %	Cellulose digested %	Hemi-cellulose digested %	Permangan-ate lignin digested %
Total	11								
Treatment	1	.96	.20	25.37	30.97	175.03*	51.79	.00	602.22
Error	10	.23	.04	15.02	16.08	16.27	19.73	.00	222.64

*F - test significant (P<.01).

APPENDIX TABLE 7. Least-squares analysis of variance of nitrogen utilization year 2 digestion trial.

Source	Degrees of freedom	N intake g/day	N absorbed g/day	N excreted g/day feces	N excreted g/day urine	N Balance	N, % intake feces	N, % intake urine	N, % absorbed urine	Digested N, intake, kg/day	Apparent N digested, %
		Mean squares									
Total	11										
Treatment	1	25.02	53.13	5.22	20.12	70.73	11.96	25.99	54.55	.00	6.20
Error	10	180.91	67.07	50.95	64.26	7.88	6.32	2.31	.25	.00	11.94

APPENDIX TABLE 8. Least-squares analysis of variance of daily dry matter intakes and body weight for year 2 lactation trial.

Source	Degrees of freedom	Total DMI kg/day	Silage DMI kg/day	Concentrate DMI kg/day	BW, kg
		Mean squares			
Total	9				
Treatment	1	532.90	305.25	14.40	846.4*
Error	8	154.45	107.67	3.65	131.15

*F - test significant (P<.01).

APPENDIX TABLE 9. Least-squares analysis of variance of daily milk yield and composition of milk in year 2 lactation trial.

Source	Degrees of freedom	Variable: Milk yield kg	Fat, %	Protein, %	Total solids %
		- - - - - - - - - - - Mean squares - - - - - - - - - - -			
Total	9				
Treatment	1	57.84	.14	.11	1.37
Error	8	89.68	.06	.02	.26

APPENDIX TABLE 10. Least-squares analysis of variance of rumen volatile fatty acids, pH, and ammoniacal nitrogen of year 2 lactation trial.

		Variable					
Source	Degrees of freedom	Acetic acid uM/ml	Propionic acid uM/ml	Butryric acid uM/ml	Total VFA's uM/ml	pH	Ammoniacal nitrogen mg/100 ml
		- - - - - - - - - - - - - - - -	- - -	- - - Mean	squares - - -	- - - - - -	- - - - - - - - - - - - -
Total	9						
Treatment	1	50.76	4.29	2.53	479.01	.041	8.61
Error	8	261.91	28.16	12.24	581.57	.330	144.65