AN ABSTRACT OF THE THESIS OF

WILLIAM ALAN SCHURG for the degree of DOCTOR OF PHILOSOPHY

in ANIMAL SCIENCE presented on July 21, 1981

Title: EVALUATION OF RYEGRASS STRAW IN RATIONS FOR PONIES

Redacted for privacy

Abstract approved: _____
Dr. D.W. Holtan

A series of in vivo digestibility and maintenance studies were conducted to: 1) determine the nutritive value of ryegrass straw (RGS) fed to mature ponies at 0 to 90% of their diet; 2) evaluate total fecal collection (TFC) and the acid insoluble ash (AIA) or permanganate lignin (PL) indicators for determining digestibility; and 3) investigate water consumption and excretion patterns in ponies.

In the first phase, two digestibility trials and a 78-day maintenance trial were conducted. For cubed diets daily intake was similar ($P>.05$) averaging 2.9 kg/pony/day. Cubes containing up to 70% RGS were similarly digested, while greater than 70% RGS showed lower ($P<.05$) protein and energy digestibilities. Treatment of RGS with NaOH enhanced ($P<.05$) digestibility of the fiber fractions over untreated RGS when fed at 90% of the diet. Ponies fed pelleted diets containing 0, 50 or 68% RGS maintained similar ($P>.05$) mean body weight (170 kg) and feed intake (4.5 kg/day) during a 78-day maintenance trial. Dry matter and protein digestibility were not different ($P>.05$) between treatments, however digestion of the energy and fiber fractions

declined as the level of RGS increased in the diet.

In the second phase of these experiments, digestibility was determined in a comparison of the TFC and the AIA or PL indicator methods. When AIA was used as an indicator, deviations from TFC digestibility were not different ($P>.05$). Furthermore, random grab or subsampling from the TFC were not different from the TFC digestibility values when calculated by AIA indicator ratios. The PL method underestimated digestibility determined by the TFC and AIA methods by an average of 13.0% ($P<.01$).

The last phase of these studies evaluated water consumption and excretion. Water consumption in the pretrial averaged 12000, 13500 and 10396.0 ml/pony/day when consuming grass hay, alfalfa or hay-grain diets, respectively. Water intake averaged 3.2 ml/g of daily feed intake during the pretrial. Animals confined to digestion crates consumed less ($P<.01$) water when fed cubed (8190.0 ml/day) or pelleted diets (7450.0 ml/day) when compared to pretrial consumption (11965.0 ml/day). During the feeding of cubed or pelleted diets, drinking water represented 95% and dietary water made up 5% of the total daily water consumed. Urine excretion accounted for 43.8% and fecal water contributed 56.2% of the daily water output measured.

EVALUATION OF RYEGRASS STRAW IN RATIONS FOR PONIES

by

William Alan Schurg

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed July 21, 1981

Commencement June 1982

APPROVED:

Redacted for privacy

Assistant Professor of Animal Science in charge of major

Redacted for privacy

Head of Department of Animal Science

Redacted for privacy

Dean of Graduate School

Date thesis is presented July 21, 1981

Typed by Cheryl Schurg for William Alan Schurg

ACKNOWLEDGEMENTS

It is impossible to thank everyone associated with this project personally, however many persons contributed greatly to this project and without their support, help and constant encouragement it could not have successfully been completed.

Sincere thanks are extended to Dr. D.W. Holtan, my major professor, for his assistance and advice throughout this project. Also, appreciation is extended to Dr. J.E. Oldfield for his constant encouragement and support throughout my graduate program. Thank you's must also be extended to the other members of my graduate committee: Drs. P.R. Cheeke, G.A. Klein and D.O. Chilcote. Also, many thanks are extended to my fellow graduate students' assistance. The help received from laboratory, secretarial and horse center personnel is also acknowledged.

To my wife, Cheryl, love, gratitude and appreciation are expressed for her endless understanding and sacrifices. Finally, to my parents and in-laws for giving me the inspiration, motivation and love that has kept me going to reach this goal.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

EVALUATION OF RYEGRASS STRAW IN RATIONS FOR PONIES

CHAPTER I

INTRODUCTION

The horse and feed industries have been increasing their efforts to develop alternative rations and feeding methods for horses as the light horse industry in the United States expands. The total U.S. horse population is now estimated at 9 million head, which has an estimated 13 billion dollar impact on the industry. Feed prices are at an all time high as inflation continues to rise. It is estimated that the average horse owner will spend about $700 per year on feed for the average American horse. The importance of developing modern economical diets for horses through equine research is further illustrated by an ever increasing competition for the nation's grain supply between non-meat producing pleasure animals like the horse and those species of livestock used for food and fiber.

Environmental pollution problems related to field burning of such things as the ryegrass straws has prompted interest in development of alternative uses of the straws in the Pacific Northwest. These ryegrass straws have potential as feedstuffs for ruminant animals and horses, however, this practice has not been widely accepted by horseowners because these low quality roughages are inefficiently utilized by animals relative to higher quality forages. The inefficiency is due to low digestibility and poor nutritive value associated with the ryegrass straws. Manipulation of straw diets (Anderson, 1972; Jones, 1978), mechanical reduction of particle size (Schurg, 1976) and chemical treatment (Church and Champe, 1980; Solaiman et al., 1979) have proven effective in improving the animal's ability to utilize ryegrass and

cereal straws.

Only limited reports of using ryegrass straw in diets of horses have been published (Schurg, et al. 1978). Therefore, the work reported herein is proposed. The objectives of these trials were: 1) to determine the nutritive value of cubed ryegrass straw fed to ponies at various levels in combination with concentrates, alfalfa hay and with or without chemical treatment; 2) to evaluate the maintenance and digestibility of various completely pelleted diets containing varying levels of ryegrass straw fed to mature pony mares and geldings; 3) to evaluate total fecal collection, acid insoluble ash or permanganate lignin techniques for determining digestibility of ryegrass straw based diets for pony mares and geldings; and 4) to investigate water consumption and excretion in ponies fed various quantities and forms of ryegrass straws.

CHAPTER II

Evaluation of Ryegrass Straw in Pony Diets I. Maintenance and Digestibility of Completely Cubed or Pelleted Ryegrass Straw Diets fed to Ponies.[1,2]

W.A. Schurg[3] and D.W. Holtan[4]
Oregon State University, Corvallis 97331

Key Words: Cubed Ryegrass Straw, Pelleted Ryegrass Straw, Maintenance, Digestibility, Ponies, Sodium Hydroxide.

---

[1] Oregon Agricultural Experiment Station Technical Paper No. _____.

[2] Appreciation for providing the ryegrass straw is expressed to the Willamette Valley Grass Seed Growers Association and to Mr. Tom Miles Jr., Beaverton, OR.

[3] Current Address: Animal Sciences Department, University of Arizona, Tucson 85721.

[4] Department of Animal Science.

SUMMARY

In Experiment 1, seven mature (170 kg) pony geldings were randomly assigned to a 7x7 Latin square design (49 digestion trials) to determine the digestibility of various quantities of cubed ryegrass straw. Dietary treatments consisted of the control Diet A (50% hay-50% concentrates); Diet B (90% plain straw); Diet C (90% straw containing 3% NaOH); Diet D (70% straw-20% alfalfa); Diet E (45% straw-45% alfalfa); Diet F (20% straw-70% alfalfa); and Diet G (68% straw-32% concentrates). Daily intake (kg) was similar ($P>.05$) for all diets averaging 2.9 kg/pony/day. Digestibilities for dry matter (DM) were similar ($P>.05$) for all diets containing straw, however the control diet was higher ($P<.05$). Diets containing greater than 70% straw had significantly ($P<.05$) lower crude protein (CP) and gross energy (GE) digestibilities, however, incorporating NaOH treatment increased digestibility of the fiber fraction ($P<.05$). There also was a tendency for the CP and GE fractions to be increased when 90% straw was treated with NaOH as compared to 90% untreated plain straw. In Experiment 2, 21 mature (165 kg) pony mares and geldings were used in a series of feeding and metabolism trials to determine the maintenance and digestibility potential of completely pelleted diets containing various levels of ryegrass straw. Treatments consisted of a control diet (CD) 50% hay-50% concentrates; experimental I (EI) 50% straw-50% concentreates; and experimental II (EII) 68% straw-32% concentrates. Diets were formulated to be isonitrogenous and isocaloric containing 8.5% CP and 2.2 mcal/kg of DE. Following 20 day adaptation periods, one animal

from each treatment was assigned to the digestion crates in a 3x3 Latin square design for determination of digestibility. Generally, all ponies adapted to the all pelleted diets without depression of intake or incidence of digestive upset. Average daily feed intakes and final body weights (kg) were similar (P>.05) averaging 4.4 and 170.7, respectively, for the duration of the 78 day trial. Digestibility of DM and CP were not different between treatments, however GE and acid detergent fiber (ADF) digestibilities for CD (62.1 and 43.6); EI (57.8 and 27.9); EII (50.4 and 18.6), respectively, were lower (P<.05) as the level of ryegrass straw increased in the diets. Data indicate that mature ponies may be adequately maintained on diets containing up to 68% ryegrass straw without adversely affecting feed intake when incorporated into cubed or pelleted forms with additions of concentrates, alfalfa and chemical treatment.

INTRODUCTION

As the human population continues to expand and the possibilities of food shortages suggest smaller supplies of available cereal grains for livestock feeding, the need is critical for developing more economical alternative feeds and feeding methods through research. Horse production for pleasure and profit may well depend on the ability of these animals to utilize materials which are now regarded as waste products. Horses, like ruminants, possess a high capacity for digesting the cellulose and hemicellulose of plant cell walls.

Low quality roughages such as ryegrass straw represent a large potential source of feed energy that is regionally available in the Pacific Northwest, especially the Willamette Valley of Oregon. The ability of the horse to utilize these potential energy sources may have definite economic impact on the livestock industries in the future. Currently, these crop residues contribute only a small part of their potential to the livestock feeding industry.

The ryegrass straws are produced in fairly large quantities in Oregon, but are not generally well utilized as a feedstuff for horses. The low economic value attached to ryegrass as well as cereal straws is primarily related to such factors as: low protein, mineral and vitamin levels, with high levels of fiber and lignin (Anderson and Ralston, 1973; Pigden and Heaney, 1969; Van Soest and Jones, 1968). In addition, extreme bulkiness, lower digestibility of nutrient fractions and generally limited consumption makes straws undesirable (Church and Champe, 1980). Studies evaluating the nutritive value of diets using ryegrass

straws as a major ingredient for feeding horses have been limited (Schurg et al., 1978). Use of chemical treatment on straws is not new for ruminants (Hart et al., 1981; Lesoing et al., 1980; Berger et al., 1980; and Solaiman et al., 1979). However, data on feeding of chemically treated straws to equines is lacking (Williamson, 1941; and Slagsvold et al., 1979). The report herein was designed to determine the nutritive value of cubing and pelleting various levels of ryegrass straw (with and without sodium hydroxide treatment), alfalfa, and concentrates when fed to support maintenance in pony mares and geldings.

MATERIALS AND METHODS

Experiment 1. In this experiment, seven mature (170 kg) ponies were used in a 7x7 Latin square design (Steel and Torrie, 1960) to evaluate the acceptability, feed intake and nutrient digestibility of various quantities of cubed ryegrass straw. Ponies were randomly allotted to the seven treatments (table 1) initially and followed the order described in Appendix table 2. Chemical analyses of diets are shown in table 2. Animals were maintained individually in box stalls for a 7-day adaptation period and were subsequently placed in individual metabolism crates for a 4-day collection period each week. All animals were previously adapted to the metabolism crates prior to the start of the digestion trials. Animals were fed twice daily at 0700 and 1900 hr. Water was offered ad libitum three times daily. The ryegrass straw used in this experiment was obtained from a demonstration processing mill operated by the Willamette Valley Grass Seed Growers Assocation. The straw was chopped

TABLE 1. INGREDIENTS AND PERCENTAGE COMPOSITION OF CUBED DIETS FED TO PONIES -- EXPERIMENT 1

Ingredients	International Ref. No.	Diet						
		A	B	C[a]	D	E	F	G
Oats	4-07-999	21.25	-----	-----	-----	-----	-----	-----
Barley	4-07-939	21.25	-----	-----	-----	-----	-----	10
Mill run		2.50	-----	-----	-----	-----	-----	-----
Beet pulp	4-00-669	2.50	-----	-----	-----	-----	-----	-----
Molasses	4-04-696	2.50	10	10	10	10	10	10
Grass hay	101-939	50.00	-----	-----	-----	-----	-----	-----
Perennial ryegrass straw		-----	90	90	70	45	20	68
Soybean meal	5-04-604	-----	-----	-----	-----	-----	-----	12
Alfalfa hay	1-00-063	-----	-----	-----	20	45	70	-----
		100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Diet C has a 3% sodium hydroxide treatment added.

TABLE 2. CHEMICAL COMPOSITION OF CUBED RYEGRASS STRAW BASED DIETS FED TO PONIES -- EXPERIMENT I

	Diets[a,b]						
	A	B	C	D	E	F	G
Dry Matter (%)	91.3	91.9	90.4	91.5	90.8	91.3	91.9
Crude Protein (%)	10.0	4.0	4.3	7.6	11.7	15.0	7.4
Acid Detergent Fiber (%)	24.3	41.6	43.0	39.6	41.2	38.5	34.5
Cell Wall Constituents (%)	44.2	65.9	67.9	63.0	60.6	54.8	58.3
Acid Detergent Lignin (%)	4.1	8.0	8.7	8.9	9.9	11.7	7.0
Cellulose (%)	18.2	30.2	30.9	27.6	28.0	24.0	24.5
Hemicellulose (%)	19.9	24.3	24.9	23.4	19.4	16.3	23.8
Acid Insoluble Ash (%)	2.0	3.4	3.4	3.1	3.2	2.8	3.0
Gross Energy (Kcal/g)	3.9	4.0	3.8	3.8	3.9	3.9	3.6

[a] Dry matter basis.

[b] A (50% hay-50% concentrates); B (90% plain straw); C (90% straw-3% NaOH); D (70% straw-20% alfalfa); E ((45% straw-45% alfalfa); F (20% straw-70% alfalfa); G (68% straw-32% concentrates).

in a tub grinder, mixed with varying proportions of alfalfa or concentrates, then processed into cubes approximately 3 cm square. A trace mineralized salt block was available at all times. Maximum voluntary consumption of a previously adjusted feed intake was monitored daily. During each 4-day collection period, daily aliquots (10%) of feces were taken, refrigerated during the collection period and frozen until analyzed. Digestibility of nutrients were calculated using conventional total fecal collection procedures. The feed and feces were dried in a conventional air draft oven at 70C for 72 hr and ground in a Wiley Mill through 60 mesh screen in preparation for further analyses.

Chemical analyses for dry matter and crude protein were carried out in accordance with A.O.A.C. (1970) procedures. Acid detergent fiber, cell wall constituents and acid detergent lignin were obtained by following the modified micro procedure of Waldern (1971). Gross energy was measured with a Parr oxygen bomb calorimeter.

Experiment 2. Twenty-one Shetland-type mature mare and gelding ponies of about 165 kg in weight were utilized in this experiment. The ponies were randomly divided into three groups of seven animals and kept in 50x100 m dirt pens. All experimental diets were processed into .45 cm pellets in an attempt to alleviate feed refusal or dietary ingredient sorting. A salt block with trace minerals was supplied in each pen. All animals had free choice access to water and exercise. All three diets were calculated to be isonitrogenous and isocaloric containing 8.5% crude protein and 2.5 mcal/kg of gross energy. Ingredient composition and chemical analyses of the diets are shown in tables 3 and

TABLE 3. INGREDIENTS AND PERCENTAGE COMPOSITION OF PELLETED DIETS FED TO PONIES -- EXPERIMENT 2,3 (MAINTENANCE AND DIGESTIBILITY)

Ingredients	International Ref. No.	Diets[a]		
		Control	Exp. 1	Exp. 2
Barley	4-07-939	43.5	23.0	8.5
Corn	4-02-931	----	14.5	8.0
Molasses	4-04-696	5.5	5.5	5.5
Perennial ryegrass straw		----	50.0	68.0
Grass hay	101-939	50.0	----	----
Soybean meal	5-04-604	----	6.0	9.0
Limestone	6-02-632	.5	.5	.5
Salt (Morton's TM)		.5	.5	.5
		100.0	100.0	100.0

[a] Vitamin A added at 2.27 kg/ton of diet to supply 5500 IU/kg.

TABLE 4. CHEMICAL COMPOSITION OF PELLETED RYEGRASS STRAW BASED DIETS FED TO PONIES -- EXPERIMENT 2,3

Nutrients[a]	Diets[b]		
	CD	Exp. 1	Exp. 2
Dry Matter (%)	91.9	92.4	93.1
Crude Protein (%)	9.9	9.1	8.9
Acid Detergent Fiber (%)	21.6	25.8	32.6
Cell Wall Constituents (%)	43.1	49.3	55.7
Acid Detergent Lignin (%)	3.1	5.2	6.7
Cellulose (%)	16.7	18.5	23.2
Hemicellulose (%)	21.5	23.5	23.1
Acid Insoluble Ash (%)	1.8	2.1	2.6
Gross Energy (Kcal/g)	3.9	3.9	3.9

[a] Dry matter basis.

[b] Control diet (50% hay-50% concentrates); Experimental 1 (50% straw-50% concentrates) and Experimental 2 (68% straw-32% concentrates).

4, respectively. Ponies were individually fed at 0700 and 1900 hr daily. Individual daily feed intakes were monitored. All animals were weighed and measured initially and at weekly intervals.

Data were analyzed using a randomized split plot analysis of variance. The whole plot consisted of three treatments of ryegrass straw and the split plot consisted of eight weekly determinations. The data were analyzed to determine the effects of treatments, weeks and the interaction of treatment times weeks.

Experiment 3. Three mature Shetland pony geldings were used in a 3x3 Latin square design experiment to evaluate the digestibility of three levels of ryegrass straw fed in a complete pelleted diet. Ponies were each assigned to one of the three experimental groups and diets as seen in table 3, Experiment 2. Animals were fed the diets for a 20 day period prior to each digestibility experiment and after previously being adapted to the crates, animals were on a five day period of total fecal collection. Animals, feed, feces and urine were all handled in the same manner as previously described in Experiment 1. Data were analyzed by a 3x3 Latin square (Steel and Torrie, 1960) with the ponies randomly allotted to the three treatments initially and following the order described in Appendix table 3 for the metabolism trial.

RESULTS AND DISCUSSION

Experiment 1. All ponies adapted from preliminary long stem hay and grain rations to the complete cubed rations quite readily during a 10-day transition period. The general health was normal and no digestive disturbances were observed among the ponies during the trial. Mean

body weight data and daily feed intake are presented in table 5. All ponies maintained body weight and had similar (P>.05) daily feed intakes. There was, however, a tendency for ponies to eat less of the 90% plain straw (B) and 90% sodium hydroxide (NaOH) treated straw (C) diets as these diets may have been less palatable and were somewhat higher in bulk than the other diets.

Data on digestibility (table 6) indicate that dry matter (DM) digestibilities were similar (P>.05) for all diets containing straw, however, the control diet was higher (P<.05). Diets containing 70% or greater straw, diets B and C, had significantly lower crude protein (CP) and energy (E) digestibilities. Between the fiber constituents, digestibility coefficients were similar (P>.05) to each other except for the NaOH treatment which increased digestibility of the acid detergent fiber (ADF), cell wall constituents (CWC) and acid detergent lignin components (P<.05) over the untreated plain straw. The digestibility coefficients are similar to values for mature horses and ponies reported by Hintz et al. (1971), Schurg et al. (1978), Slagsvold et al. (1979) and Williamson (1941). Many workers suggest that the use of chemical treatments such as NaOH or anhydrous ammonia is only maximized when significant amounts of the chemical make contact with the straw fibers. This can be accomplished through a soaking or a spraying and soaking technique. Therefore, the chemical treatment can effectively increase the nutritional availability of the fiber fraction of mature forages and render greater utilization of the low quality residue by the animal (Anderson and Ralston, 1973; Lesoing et al., 1980; Schurg, 1981; and Slagsvold et al., 1979).

TABLE 5. MEAN BODY WEIGHT AND DAILY FEED INTAKE OF PONIES FED VARIOUS LEVELS OF CUBED RYEGRASS STRAW -- EXPERIMENT I

Item	Dietary Treatments[a]						
	A	B	C	D	E	F	G
Mean Body Weight (kg)	177.8	176.5	170.3	170.4	167.4	166.6	171.6
Daily Feed Intake (kg)	3.1	2.7	2.7	2.9	2.9	3.0	3.1

[a] A (50% hay-50% concentrates); B (90% plain straw); C (90% straw-3% NaOH); D (70% straw-20% alfalfa); E (45% straw-45% alfalfa); F (20% straw-70% alfalfa); G (68% straw-32% concentrates).

TABLE 6. MEAN APPARENT DIGESTIBILITY COEFFICIENTS OF VARIOUS LEVELS OF CUBED RYEGRASS STRAW FED TO PONIES -- EXPERIMENT I

Diets[d]	Percentages					
	Dry Matter	Energy	Crude Protein	Acid Detergent Fiber	Cell Wall Constituents	Acid Detergent Lignin
A	63.0[a]	66.3[a]	74.4[a]	35.0[a]	41.0[a]	17.2[a]
B	55.6[b]	59.1[b]	73.3[a]	33.7[a]	39.4[a]	15.8[a]
C	53.9[b]	54.7[b]	69.9[a]	32.0[a]	39.0[a]	15.4[a]
D	54.6[b]	52.1[b]	53.6[b]	34.7[a]	40.3[a]	16.3[a]
E	52.7[b]	49.1[b,c]	39.9[c]	43.3[b]	49.2[b]	20.2[b]
F	47.4[b]	48.3[b,c]	35.6[c]	29.5[a]	38.6[a]	15.3[a]
G	56.7[b]	58.3[b]	61.7[b]	31.0[a]	38.8[a]	15.4[a]

[a,b] Means with different superscripts in same column are different ($P<.05$).

[c] Means with different superscripts in same column are different ($P<.01$).

[d] A (50% hay-50% concentrates); B (90% plain straw); C (90% straw-3% NaOH); D (70% straw-20% alfalfa); E (45% straw-45% alfalfa); F (20% straw-70% alfalfa); G (68% straw-32% concentrates).

Experiment 2. Average daily feed intake and body weight data are presented in table 7. Results indicate that all ponies maintained body weight across all dietary treatments. Feed intake data supports a similar trend through the 78 day feeding period. It does appear that as the trial lengthened, both body weight and feed intake are beginning to decline as the level of straw increases in the diet, however the decreases are not different ($P>.05$) over time. The interaction of treatment x time likewise showed no differences.

It does appear that ponies fed and watered ad libitum with free choice exercise support a higher feed intake than ponies positioned in metabolism crates in Experiment 1. The unnatural environment without exercise that is imposed upon an animal confined to a metabolism crate alters animal performance (Pulse et al., 1973; Schurg et al., 1977; Sutton et al., 1977).

Experiment 3. Ponies used in the 3x3 Latin square digestibility study maintained body weight and had adequate feed intake as shown in table 8. However, as discussed earlier in Experiment 2, feed intake across dietary treatments were lower while animals were confined to the crates. Apparent digestibility coefficients (%) for pelleted diets can be observed in table 9. There were no statistical differences between treatments ($P>.05$) for DM and CP digestibility. Gross energy and all fibrous component digestibilities were significantly lower ($P<.05$) as the level of ryegrass straw increased in the diets.

In a cost comparison (table 10) diets containing nearly 70% ryegrass straw were cheaper per hundred weight (CD-$4.27 vs. EII-$4.05).

TABLE 7. MEAN BODY WEIGHT AND DAILY FEED INTAKE OF PONIES FED VARIOUS LEVELS OF PELLETED RYEGRASS STRAW -- EXPERIMENT 2 (MAINTENANCE)

Item	Control Diet (50% hay-50% conc.)	Experimental I (50% straw-50% conc.)	Experimental II (68% straw-32% conc.)
Initial Body Weight (kg)	165.7	164.7	164.1
Final Body Weight (kg)	172.4	171.9	167.7
Daily Feed Intake (kg)	4.7	4.4	4.1

TABLE 8. MEAN BODY WEIGHT AND DAILY FEED INTAKES OF PONIES FED VARIOUS LEVELS OF PELLETED RYEGRASS STRAW -- EXPERIMENT 3 (DIGESTIBILITY)

Item	Control Diet (50% hay-50% conc.)	Experimental I (50% straw-50% conc.)	Experimental II (68% straw-32% conc.)
Initial Body Weight (kg)	171.5	173.0	173.0
Final Body Weight (kg)	169.1	171.1	173.3
Daily Feed Intake (kg)	3.7	3.9	3.9

TABLE 9. MEAN APPARENT DIGESTIBILITY COEFFICIENTS OF VARIOUS LEVELS OF PELLETED RYEGRASS STRAW FED TO PONIES -- EXPERIMENT 3

	Percentages					
	Dry Matter	Energy	Crude Protein	Acid Detergent Fiber	Cell Wall Constituents	Acid Detergent Lignin
Control Diet (50% hay-50% conc.)	62.0	62.1[a,d]	70.5	43.6[d]	50.2[d]	21.7[d]
Experimental I (50% straw-50% conc.)	59.2	57.8[b]	70.9	27.9[e]	38.4[e]	17.2[e]
Experimental II (68% straw-32% conc.)	61.4	50.4[c,e]	67.0	18.6[f]	26.8[f]	13.6[e]

[a,b,c] Means with different superscript in same column are different ($P<.05$).

[d,e,f] Means with different superscript in same column are different ($P<.01$).

TABLE 10. RYEGRASS STRAW DIETS VS. CONTROL DIET; COST COMPARISON[a] -- EPXERIMENT 2

	Cost/ cwt.	Cost/ Head/Day	Cost/ 30 Days
Control Diet (50% hay-50% conc.)	$4.27	44¢	$13.25
Experimental I (50% straw-50% conc.)	$5.06	49¢	$14.69
Experimental II (68% straw-32% conc.)	$4.05	36¢	$10.95

[a] Economic feasibility is based upon availability, processing, transportation, animal performance and longevity and the human element.

Economic feasibility, however, is based upon availability, processing, transportation, animal performance, animal longevity and the acceptance and use by horse owners.

The results of these experiments indicate that the pony can effectively utilize up to 70% ryegrass straw without adversely affecting intake or maintenance of body weight, however digestibility decreases as the level of straw is increased in the diet. Furthermore, the mechanical processing of straw based diets were quite acceptable to ponies. The use of a chemical treatment such as sodium hydroxide appears to have potential in effectively rendering straw more useful, however, further research should be done to better understand the optimum usefulness chemical treatment of straw will provide. The amount of chemical treatment applied as well as the duration of treatment should be further investigated. Lastly, the horse public should be educated in the usefulness of lower quality roughages in equine diets as an alternative to the higher cost traditional roughages currently on the market.

CHAPTER III

Evaluation of Ryegrass Straw in Rations for Ponies, II. Total Fecal Collection, Acid Insoluble Ash or Permanganate Lignin as Techniques to Determine Digestibility of Pony Rations. [1,2]

W.A. Schurg[3] and D.W. Holtan[4]
Oregon State University, Corvallis 97331

Key Words: Digestibility, Digestibility Indicators, Pony Rations, Ryegrass Straw.

---

[1] Oregon Agricultural Experiment Station Technical Paper No. _____.

[2] Appreciation for providing the ryegrass straw is expressed to the Willamette Valley Grass Seed Growers Association and to Mr. Tom Miles Jr., Beaverton, OR.

[3] Current Address: Animal Sciences Department, University of Arizona, Tucson 85721.

[4] Department of Animal Science.

SUMMARY

Rations containing various levels of ryegrass straw (0-90%), concentrates, grass hay and alfalfa hay with or without chemical treatment and fed in either cubed or pelleted forms were used to feed mature pony mares and geldings in a series of digestibility trials. Animals were at a maintenance level of intake and digestibility of ration dry matter and gross energy were determined by using the total fecal collection (TFC), acid insoluble ash (AIA) or permanganate lignin (PL) techniques.

The nutrient digestibility coefficients estimated by the AIA natural marker technique were not different ($P>.05$) from the values determined by the TFC method. Furthermore, there were no differences in using a random grab sample method or by subsampling from the total fecal output when the AIA technique was used. The permanganate lignin method underestimated digestibility determined by both TFC and AIA by an average of 13 percentage units ($P<.01$). The PL method showed mean recovery rates of only 65.0% which was significantly ($P<.01$) lower than those found using the AIA indicator (98.0%). It is apparent that the use of PL as an indicator to determine digestibility coefficients is not acceptable, since the low recovery rate suggests a portion of the lignin is digested by the animal. The use of the AIA method provides a desirable technique of determining digestibility which reduces time and more efficiently uses labor as compared to the TFC procedures. From the data, it appears that AIA natural indicator methods may be used in equine digestibility experiments where various levels and forms of ryegrass straw based diets are fed.

INTRODUCTION

For many years, the most applicable and practical method for determining digestibility coefficients of nutrients in feeds was to use the conventional total fecal collection techniques. The use of this procedure involves a laborious and time consuming recordkeeping of the nutrients consumed and the collection of all feces. Many workers have designed and put into practice equine metabolism stalls and harness bag type collectors which removes the animal from his natural environment (VanderNoot et al., 1965; Knapka et al., 1967; and Stillions and Nelson, 1968).

A review of internal and external markers for use in digestibility studies has been published by Kotb and Luckey (1972). They indicate that marker systems may be employed successfully, but one should be aware of the limitations of each technique. Of the marker systems used for equine studies, chromium oxide has provided the most successful determinations of digestibility coefficients, and many workers have reported successful use of this technique (Haenlein et al., 1966; Knapka et al., 1967; Pulse et al., 1973; and Schurg et al., 1978).

There is considerable conflict of opinion concerning the use of lignin as an internal indicator (Ellis et al., 1946; Kane et al., 1949; and Thonney et al., 1979). Furthermore, the use of acid insoluble ash, a natural marker for determination of digestibility in equine animals has not been studied extensively (Sutton et al., 1977; and Schurg et al., 1977).

Therefore, the first objective of the study reported herein is to

evaluate total fecal collection (TFC), acid insoluble ash (AIA) and permanganate lignin (PL) techniques for determining digestibility of ryegrass straw based diets for pony mares and geldings and secondly to determine if differences occur in digestibility coefficients using natural markers when feces are either subsampled from the total collection or if a random fecal grab sample system is used.

MATERIALS AND METHODS

In Experiment 1, seven mature pony geldings were randomly assigned to digestibility crates in a 7x7 Latin square design. The seven rations contained 0, 20, 45, 68, 70 or 90% ryegrass straw with the balance being combinations of alfalfa hay and concentrates. One 90% straw group was treated with sodium hydroxide (NaOH) such that approximately 3% of the straw weight was added as NaOH. All diets were ground in a tub grinder and processed into approximately 3 cm square cubes. Ration ingredients, chemical composition and total collection determined digestibilities are described in an earlier report by Schurg and Holtan (1981). Ground samples of feed and feces were subsampled and assayed for PL and AIA. The PL analysis was obtained by following the procedures of Goering and Van Soest (1970) and the modified microprocedure of Waldern (1971). The AIA was assayed by the 2N HCl method of Van Keulen and Young (1977). Differences in digestibility due to method of determination were tested by analysis of variance (Steel and Torrie, 1960).

In Experiment 2, 21 pony mares and geldings were used to evaluate

completely pelleted ryegrass straw rations containing 0, 50 or 68% straw with the remainder being concentrates. One gelding was selected from each treatment group for confinement in digestibility crates for determination of digestibility by the total fecal collection technique. During the last six days of the maintenance trial with the 21 ponies, random fecal grab samples were taken for the PL and AIA assays. Methodology and details of ration composition are available in a previous paper by Schurg and Holtan (1981). The assay methods for PL and AIA are noted in Experiment I above.

The percentage of indicator in the feed that was recovered in the feces was computed and the Student's t-test was used to determine the probability that recovery of an indicator differed from 100. An analysis of variance of the 3x3 Latin square (Steel and Torrie, 1960) was used to test variation associated with pony, period and diet.

RESULTS AND DISCUSSION

Permanganate lignin and acid insoluble ash values of feed and feces are listed in table 11. As the percentage of straw increased in the diet, PL and AIA values tended to increase. The PL values associated with the feces likewise tended to increase, however the fecal AIA values showed no obvious pattern.

The percentage of feed indicator that was recovered in the feces is shown in table 12. Recovery of AIA was found to be 98.0%, and was not significantly different from complete recovery. The recovery of PL was only 65.0% in the feces, which was lower ($P<.01$) than TFC recovery. Furthermore, comparisons of recovered PL values were lower ($P<.01$)

TABLE II. MEAN VALUES OF PERMANGANATE LIGNIN (PL) AND ACID INSOLUBLE ASH (AIA) FOR CUBED AND PELLETED FEEDS AND FOR FECES. EXPERIMENT 1,2, RANDOM GRAB AND SUBSAMPLE

	PL %		AIA %		Subsample PL %	Subsample AIA %
	Feed	Feces	Feed	Feces	Feces	Feces
Experiment 1[a] (Cubed)						
(% straw)						
0	4.1	7.7	2.0	5.6	7.9	5.7
20	8.0	14.3	2.8	6.4	14.5	6.9
45	8.7	15.0	3.2	7.1	15.0	7.4
70	8.7	15.2	3.1	7.1	15.3	7.2
NaOH 90	9.9	16.7	3.2	6.9	17.1	6.9
Plain 90	11.7	19.0	3.4	6.7	19.6	6.9
68	7.0	12.9	2.8	6.7	13.4	6.8
Experiment 2[b] (Pelleted)						
(% straw)						
0	3.1	5.8	1.8	4.9	6.1	4.9
50	5.2	9.3	2.1	5.3	9.5	5.4
68	6.7	12.2	2.6	7.1	12.5	7.2
Random Grab[c] (Pelleted)						
(% straw)						
0	3.2	6.1	1.9	5.2	----	---
50	5.4	10.0	2.2	5.7	----	---
68	6.6	12.4	2.5	6.8	----	---

[a] Each value is the mean concentration in dry matter for 7 periods (feed) or 7 ponies (feces).

[b] Each value is the mean concentration in dry matter for 3 periods (feed) or 3 ponies (feces).

[c] Each value is the mean concentration in dry matter for each diet with 7 ponies per diet.

TABLE 12. RECOVERY OF PERMANGANATE LIGNIN AND ACID INSOLUBLE ASH (EXPERIMENT 1 AND 2)[a,b]

	Lignin %	Acid Insoluble Ash %
Experiment 1 (Cubed)		
0	69.6	100.2
20	65.9	99.2
45	64.6	97.7
70	65.7	98.2
NaOH 90	61.1	96.3
Plain 90	63.5	95.1
68	66.2	97.3
Experiment 2 (Pelleted)		
0	66.7	99.8
50	64.6	96.2
68	65.1	97.0

[a] Recovery equal to the indicator via TFC in feces as a percentage of that in the feed.

[b] All recovery values of PL were different from AIA ($P<.01$).

than computed AIA recovery values.

The data in table 13 show that there was no difference between total fecal collection and AIA indicator determined digestibility of dry matter and energy. The digestibility of dry matter and energy were significantly ($P<.01$) underestimated by using the PL indicator technique. A comparison in table 14 shows that PL indicator technique underestimated digestibility of dry matter by 13.7 percentage units, while underestimating energy by 12.3 percentage units.

The use of random grab samples or subsampling from the total fecal output further substantiated the usefulness of the AIA indicator technique. No differences were found in computing digestibility by AIA indicator ratios when grab or subsampling procedures were incorporated as compared to total fecal collection determined values. Representative samples of feces must be taken to maximize the usefulness of the AIA indicator technique. This work with ponies is in agreement with that of other workers using cattle (Thonney et al., 1979 and Van Keulen and Young, 1977); horses (Schurg, 1981; Schurg et al., 1977; and Sutton et al., 1977); sheep (Block et al., 1981) pigs and chickens (McCarthy et al., 1974).

It is apparent from these studies with ponies that use of the AIA natural indicator technique offers a distinct advantage in saving time and more effeciently using labor when conducting digestibility experiments. Furthermore, caution must be used when considering the use of the PL indicator methods as in these studies that technique underestimated digestibility from that of conventional and AIA significantly. These

TABLE 13. MEAN DRY MATTER (DM) AND ENERGY (E) DIGESTIBILITY COEFFICIENTS (%) OF EXPERIMENTAL DIETS BY THE TOTAL FECAL COLLECTION (TFC), ACID INSOLUBLE ASH (AIA) OR PERMANGANATE LIGNIN (PL) METHODS[a,b]

	TFC		AIA		PL		Subsample AIA		Subsample PL	
	DM	E	DM	E	DM	E	DM	E	DM	E
Experiment 1										
Cubed (7x7)										
(% straw)										
0	63.0$^{c}_{d}$	66.3$^{c,f}_{d}$	64.2$^{c}_{d}$	67.0$^{c,f}_{d}$	47.0$^{c}_{d}$	52.5$^{c,f}_{d}$	65.0$^{c}_{d}$	68.2$^{c,f}_{d}$	48.0$^{c}_{d}$	53.7$^{c,f}_{d}$
20	55.6$_{d}$	59.1$_{d}$	56.4$_{d}$	60.4$_{d}$	44.2$_{d}$	46.4$_{d}$	59.5$_{d}$	61.8$_{d}$	54.0$_{d}$	45.1^{d}
45	53.9$_{d}$	54.7$_{d}$	55.1$_{d}$	56.1$_{d}$	41.9$_{d}$	42.6$_{d}$	57.0$_{d}$	57.2$_{d}$	42.0$_{d}$	44.4^{d}
70	54.6$_{d}$	52.1$_{d,g}$	56.0$_{d}$	53.7$_{d,g}$	42.6$_{d}$	41.1$_{d,g}$	56.8$_{d}$	54.4$_{d,g}$	45.0$_{d}$	42.6^{d}
NaOH 90	52.7$_{d}$	49.1$_{d,g}$	53.3$_{d}$	50.5$_{d,g}$	40.8$_{d}$	39.6$_{d,g}$	53.5$_{d}$	51.0$_{d,g}$	42.0$_{d}$	40.0^{d,g}
Plain 90	47.4$_{d}$	48.3$_{d}$	49.2$_{d}$	49.8$_{d}$	38.5$_{d}$	38.0$_{d}$	50.7$_{d}$	50.3$_{d}$	40.0$_{d}$	39.1^{d,g}
68	56.7	58.3	58.1	60.2	45.9	46.0	58.9	61.5	48.0	47.4^{d}
Experiment 2										
Pellets (3x3)										
(% straw)										
0	62.0	62.1$^{d,f}_{d}$	63.2	64.5$^{d,f}_{d}$	46.4	50.3$^{d,f}_{d}$	63.0	65.0$^{d,f}_{d}$	49.0	51.8^{d,f}
50	59.2	57.8$^{e,g}_{d}$	60.3	59.2$^{e,g}_{d}$	43.8	45.2$^{e,g}_{d}$	61.0	59.9$^{e,g}_{d}$	45.0	46.1^{d}
68	61.4	50.4^{e,g}	63.6	52.1^{e,g}	45.0	41.5^{e,g}	64.0	53.0^{e,g}	47.0	42.0^{e,g}
Experiment 2										
Pellets (Random Grab)										
(% straw)										
0	63.5	64.6$^{c,f}_{d}$	64.2	65.1$^{c,f}_{d}$	47.4	53.1$^{c,f}_{d}$	----	----	----	----
50	61.4	58.4$^{e,g}_{d}$	61.9	60.2$^{e,g}_{d}$	45.9	47.2$^{e,g}_{d}$	----	----	----	----
68	63.0	52.9^{e,g}	63.7	53.4^{e,g}	46.8	40.8^{e,g}	----	----	----	----

[a] All digestibility values calculated via TFC or AIA are similar ($P>.05$).

[b] All digestibility values calculated via PL and compared to both TFC and AIA values are different ($P<.01$).

[c,d,e] Means with different superscripts in the same column comparing straw treatments are different ($P<.05$).

[f,g] Means with different superscripts in the same column comparing straw treatments are different ($P<.01$).

TABLE 14. UNDERESTIMATION OF DIGESTIBILITY COEFFICIENTS USING PERMANGANATE LIGNIN AS A MARKER METHOD

	Total Fecal Collection (TFC)	Acid Insoluble Ash (AIA)	Permanganate Lignin (PL)	Underestination via (PL)
Dry Matter (%)[a]	56.7[c]	57.9[c]	43.6[d]	13.7
Energy (%)[b]	55.8[c]	57.4[c]	44.3[d]	12.3

[a] Means of all dry matter values in the (7x7) and (3x3) trials.

[b] Means of all energy values in the (7x3) and (3x3) trials.

[c,d] Means with different superscripts in the same line are significantly ($P<.01$) different.

findings in ponies are in agreement with the cattle studies of Thonney et al. (1979) which indicates that PL is unreliable as a technique for determining digestibility.

CHAPTER IV

Evaluation of Ryegrass Straw in Rations for Ponies. III. Water Consumption and Excretion in Ponies Fed Various Quantities and Forms of Ryegrass Straw. [1,2]

W.A. Schurg[3] and D.W. Holtan[4]
Oregon State University, Corvallis 97331

Key Words: Water Consumption, Water Excretion, Ryegrass Straw, Ponies.

---

[1] Oregon Agricultural Experiment Station Technical Paper No. _____.

[2] Appreciation for providing the ryegrass straw is expressed to the Willamette Valley Grass Seed Growers Association and to Mr. Tom Miles Jr., Beaverton, OR.

[3] Current Address: Animal Sciences Department, University of Arizona, Tucson 85721.

[4] Department of Animal Science.

SUMMARY

Water consumption and excretion was determined in mature gelding ponies fed various conventional, cubed and pelleted diets containing combinations of concentrates, grass hay, alfalfa hay or ryegrass straw with and without chemical treatment. In the pretrial phase, ponies were allowed a free-choice exercise regime in box stalls compared to the cubed and pelleted phases where ponies were confined to metabolism crates.

Daily water consumption in the pretrial averaged 12000.0 and 13500.0 ml per pony per day for animals consuming all grass hay or alfalfa hay diets, respectively, compared to only 10396.0 ml per pony per day when ponies were receiving a hay-grain diet. Water intakes of 3.0, 4.0 and 2.6 ml per gram of daily feed intake was noted for the grass hay, alfalfa and hay-grain diets, respectively. Animals confined to the digestion crates and fed cubed or pelleted diets consumed less ($P<.01$) water (11965.0, 8190.0 and 7450.0 ml/pony/day) for all diets combined from the pretrial, cubed or pelleted phases, respectively. Likewise, water intake per daily feed intake (ml/g) declined (3.2, 2.8 and 2.0) for the pretrial, cubed or pelleted phases, respectively. In the cubed and pelleted phases drinking water represented about 95% (7560.0 ml) of the total daily water consumption while water from dietary sources made up 5% (380.0 ml) of the water measured in these studies. Urinary excretion accounted for 43.8% (2626.0 ml) of the daily water output, while fecal water contributed the bulk of the output at 56.2% (3220.0 ml) of the water output measured in the study. Urine pH ranged from 8.3 to 9.1 across all cubed and pelleted dietary treatments, which were in the range for normal, healthy ponies.

These observations on water intake and excretion in normal ponies allows an appreciation for the large quantities of water needed by the equine animal, as well as a greater understanding of the conditions which may alter normal consumption and excretion patterns.

INTRODUCTION

Water is the most important nutrient needed by all livestock. In many species of livestock, it is the single most abused and commonly overlooked nutrient. The body in general contains about 70% water on a fatfree basis and this proportion must be maintained within fairly narrow limits if an animal is to survive. The equine animal of today has become extremely dependent upon man for all of his managerial needs. The water requirements for the horse or pony are not well understood, as very little research has been conducted in this area. Many factors are postulated to influence an animal's water requirement. These include; body weight, level of productivity, amount and type of exercise, climatic conditions, kind and type of diet, degree of adaptation and composition and quality of water.

It is apparent in many parts of the country water supplies are relatively constant and among all the various segments of society, water like feedstuffs, are quite competitive items. Therefore, it is safe to presume that livestock, including horses will have a lower priority for high quality water than other groups.

For the equine animal, data from water requirement studies is incomplete (Morrison, 1960). The most current data available is on water intake and excretion in horses fed diets containing all hay or hay-grain combinations (Tasker, 1967a; Fonnesbeck, 1968). Therefore, further understanding of the water needs of mature equine animals is justified. The objective of the study reported herein is to investigate water consumption and excretion in mature ponies that are fed various dietary combina-

tions of hay, grain or ryegrass straw that are in traditional form (long-stem hay), or processed into cubes or pellets.

MATERIALS AND METHODS

In three experiments, 13 diets were fed to mature (170 kg) gelding ponies. The first experiment was a pretrial study involving seven ponies fed conventional long-stem hay and hay-grain diets. These initial studies were carried out over three consecutive 14 day periods with seven day adaptation periods between each change of feed to evaluate daily water and feed intake patterns. Ponies were allotted to individual 3x3 m box stalls and were not restrained in any way to allow for some free choice exercise. Water was offered ad libitum three times daily at 0800, 1500 and 2000 hr. Drinking water was measured daily via calibrated pails. Dietary water was calculated from the dry matter content of the feed. The temperature of the animal environment ranged from 3 to 15C, at which insensible water losses are small. Animals were fed equal portions of their diets twice daily at 0700 and 1900 hr. Dietary ingredients, percentage composition and chemical analysis of all 13 diets used in the water studies are listed in table 15.

In the second experiment, ponies were randomly allotted to a 7 x 7 Latin square design experiment to evaluate water and feed intake as well as urinary excretion. Animals were fed various levels (0-90%) cubed ryegrass straw diets with and without chemical treatment while confined to digestion crates for a 4-day total fecal and urine collection period. Animals were allowed a 7-day adjustment period between dietary treatment changes. Water and feed was handled similarly as described in the pre-

TABLE 15. PERCENTAGES AND CHEMICAL COMPOSITION OF DIETS FED TO PONIES DURING THE WATER STUDIES

	Diets[a]												
	Pretrial[b]			Cubed[c]							Pelleted[d]		
	GH	GH-C	Alfalfa	A	B	C	D	E	F	G	CD	EI	EII
Dry Matter (%)	89.0	91.3	90.7	91.3	91.9	90.4	91.5	90.8	91.3	91.9	91.9	92.4	93.1
Crude Protein (%)	8.3	9.8	16.0	10.0	4.0	4.3	7.6	11.7	15.0	7.4	9.9	9.1	8.9
Acid Detergent Fiber (%)	39.7	22.4	38.0	24.3	41.6	43.0	39.6	41.2	38.5	34.5	21.6	25.8	32.6
Cell Wall Constituents (%)	55.4	44.0	51.0	44.2	65.9	67.9	63.0	60.0	54.8	58.3	43.1	49.3	55.7
Acid Detergent Lignin (%)	8.2	4.3	10.9	4.1	8.0	8.7	8.9	9.9	11.7	7.0	3.1	5.2	6.7
Gross Energy (Kcal/g)	3.7	3.9	3.8	3.9	4.0	3.8	3.8	3.9	3.9	3.6	3.9	3.9	3.9

[a] Dry matter basis.

[b] Pretrial: 100% grass hay, 50% grass hay-50% oats, 100% alfalfa hay.

[c] Cubed: A (50% grass hay-50% concentrates), B (90% ryegrass straw), C (90% ryegrass straw-3% sodium hydroxide), D (70% ryegrass straw-20% alfalfa), E (45% ryegrass straw-45% alfalfa), F (20% grass straw-70% alfalfa), G (68% ryegrass straw-32% concentrates).

[d] Pelleted: CD (50% grass hay-50% concentrates), EI (50% ryegrass straw-50% concentrates) and EII (68% ryegrass straw-32% concentrates).

trial study. Urine volume and pH was measured daily. Feed and fecal analysis for moisture content were done by A.O.A.C. (1970) methods.

In the last experiment, ponies were used to evaluate water and feed intake and urinary excretion patterns when fed 0, 50% or 68% ryegrass in pelleted form. Following 20-day adaptation periods, animals were allotted to a 3 x 3 Latin square design and confined to digestion crates as previously described in the second experiment. Diets were rotated in a manner that attempted to minimize any residual treatment effect. Water, feed, feces and urine were all handled in the same manner as previously described.

All data were tested by the appropriate analysis of variance (Steele and Torrie, 1960).

RESULTS AND DISCUSSION

Body weight, daily water intake (drinking water + dietary water) and daily feed intake for ponies fed grass hay, grass hay-grain or alfalfa hay diets during the pretrial are shown in table 16. Body weight of all subjects was maintained by each of the three diets, which indicates that the diets supplied at least minimum amounts of energy and protein required by 170 kg ponies. Ponies consumed 600 grams/day less alfalfa hay than the other two diets. Daily water consumption (ml/day) was different ($P<.05$) between the grass hay (12000), hay-grain (10396.0) and alfalfa hay (13500) diets. Data is in agreement with the earlier findings of Fonnesbeck (1968) that indicate that mature horses consuming all roughage diets had higher daily water intake than horses receiving hay-grain diets. On a body weight basis, average water consumption (ml/kg) was different

TABLE 16. BODY WEIGHT, WATER CONSUMPTION AND DAILY FEED INTAKE FOR PONIES FED HAY OR HAY-GRAIN DIETS[a] (PRETRIAL)

Item	Grass Hay	Hay-Grain	Alfalfa Hay
Body Weight, kg	172.6	173.0	173.0
Daily Water Consumption			
Total Intake, ml	12000.0[b]	10396.0[c,e]	13500.0[d,f]
Intake, ml/kg Body Weight	69.5[b]	60.1[c,e]	78.0[d,f]
Intake ml/kg Daily Feed Intake	3.0[b]	2.6[b]	4.0[c]
Daily Feed Intake, g	4000.0[b]	4000.0[b]	3400.0[c]

[a] See Table 15 for percentage and chemical composition of diets.

[b,c,d] Means in the same line bearing different superscripts are different ($P<.05$).

[e,f] Means in the same line bearing different superscripts are different ($P<.01$).

($P<.05$) for the grass hay (69.5), hay-grain (60.1) and alfalfa hay (78.0) diets. These data are somewhat higher than values reported by Tasker (1967a). Ponies consumed about 3.0 ml/g of daily feed intake which agrees with data on mature horses (Tasker, 1967a and Fonnesbeck, 1968); cattle (Winchester and Morris, 1956) and sheep (Wallace et al., 1972).

In the second phase of this study, animals were confined to metabolism crates and fed various levels of cubed ryegrass straw. Data on body weight, feed intake, water consumption, urinary excretion and urine pH are listed in table 17. Water consumption patterns for the all roughage combinations were similar ($P>.05$), however ponies eating the diet containing all straw with a NaOH treatment drank significantly ($P<.05$) less water. Ponies tended to eat less feed daily on this ration which may explain the lower water intake, however it is in contradiction to recent studies by Schurg (1981) where horses fed hydroxide treated diets drank 2 to 4 liters/day more water. Ponies eating the control diet of hay-grain drank less ($P<.05$) water than ponies consuming the all roughage diets. One contradiction to this, however, was when the diet contained 68% straw and 32% concentrates the ponies drank more ($P<.01$) water. This may be explained by the higher levels of cell wall constituents comprising the fiber fraction of this diet which would agree with the work of Fonnesbeck (1968).

Urinary excretion patterns were much less variable than their intake patterns. Ponies excreted about 3356.0 ml of urine per day, however the ponies at the higher water intake levels had higher daily urine volumes ($P<.05$). Of this average total urine volume about 268.0 ml was precipitated salts. The urine pH ranged from 8.3 to 8.9 for the cubed diet fed

TABLE 17. BODY WEIGHT, FEED INTAKE, WATER CONSUMPTION, URINARY EXCRETION, AND URINE PH FOR PONIES FED VARIOUS LEVELS OF CUBED RYEGRASS STRAW DIETS[a]

Item	A	B	C	D	E	F	G
Body Weight, kg	177.8	176.5	170.3	170.4	167.4	166.6	171.6
Feed Intake, kg	3.1	2.7	2.7	2.9	2.9	3.0	3.1
Daily Water Consumption							
Total Intake, ml	6407.0^{b,e}	8664.0^{c}	6390.0^{b,e}	8774.0^{c}	8285.0^{c}	8952.0^{c}	9656.0^{d,f}
Intake, ml/kg Body Weight	36.0^{b,e}	49.1^{c}	37.5^{b,e}	51.5^{c}	49.5^{c}	53.7^{c}	57.4^{d,f}
Intake, ml/g Daily Feed Intake	2.1^{b}	3.2^{c}	2.4^{b}	3.0^{c}	2.9^{c}	3.0^{c}	3.2^{c}
Daily Urinary Excretion							
Total Volume, ml	2811.0^{b}	2885.0^{b}	3449.0^{b}	3775.0^{b}	3566.0^{b}	4516.0^{c}	3987.0^{c}
Output, ml/kg Body Weight	15.8^{b,e}	16.3^{b,e}	19.7^{c}	22.2^{c}	21.3^{c}	27.1^{d,f}	23.2^{c}
Urine excreted, ml/g Daily Feed Intake	0.9	1.1	1.2	1.3	1.2	1.5	1.3
Urine pH	8.3	8.5	8.5	8.5	8.8	8.9	8.3

[a] See Table 15 for chemical composition of diets.

[b,c,d] Means in the same line bearing different superscripts are different ($P<.05$).

[e,f] Means in the same line bearing different superscripts are different ($P<.01$).

ponies. The water content in the feces of ponies fed the cubed diets averaged 72 to 78 percent.

In the final phase of this study, ponies were fed pelleted diets containing 0, 50 or 68% straw. Daily water consumption patterns (table 18) were similar for all ponies fed pelleted diets, however ponies eating the straw diets did tend to have somewhat higher water intake. The same patterns are seen in urinary excretion.

A comparative summation of the three studies conducted on water intake and excretion patterns is found in table 19. Ponies fed conventional diets, allowed to free-choice exercise had significantly ($P<.01$) greater water intake than ponies confined to metabolism crates. Furthermore, ponies consuming ryegrass straw diets in the cubed form had greater ($P<.05$) intakes than ponies fed pelleted diets. This may be due to the fact that the pelleted diets moved through the tract faster. Ponies on pelleted diets did have higher feed intakes than ponies fed cubed diets. Urinary excretion patterns followed the trends of the water intake that was previously discussed.

An attempt to partition water intake and output into its component parts (table 20) has been made. As one can see, the dietary water contributed about the same irrespective of dietary treatments. Drinking water was higher ($P<.05$) for the cubed diets. Urine and fecal water excretion followed the same trend as the drinking water intake which would be expected.

A precise water balance study of the ponies was not possible because two measurements were not taken. The water arising from metabolic oxidations in the body represents a significant contribution to the water

TABLE 18. BODY WEIGHT, FEED INTAKE, WATER CONSUMPTION, URINARY EXCRETION, AND URINE PH FOR PONIES FED VARIOUS LEVELS OF PELLETED RYEGRASS STRAW DIETS[a]

Item	Control	50% Straw	68% Straw
Body Weight, kg	169.1	171.1	173.3
Feed Intake, kg	3.7	4.0	3.9
Daily Water Consumption			
Total Intake, ml	7375.0	8246.0	7451.0
Intake, ml/kg Body Weight	43.9	48.2	43.0
Intake, ml/g Daily Feed Intake	2.0	2.1	1.9
Daily Urinary Excretion			
Total Volume, ml	2249.0[b]	2988.0[c]	2826.0[c]
Output, ml/kg Body Weight	13.3[b]	15.1[c]	16.3[c]
Urine Excreted, ml/g Daily Feed Intake	0.6	0.8	0.7
Urine pH	9.1	8.9	8.9

[a] See Table 15 for chemical composition and description of diets.

[b,c] Means in the same line bearing different superscripts are different ($P<.05$).

TABLE 19. COMPARATIVE SUMMATION OF MEAN BODY WEIGHT, FEED INTAKE, WATER CONSUMPTION, URINARY EXCRETION AND URINE PH FOR PONIES FED HAY, HAY-GRAIN, CUBED OR PELLETED RYEGRASS STRAW DIETS

Item	Pretrial	Straw	
		Cubed	Pelleted
Body Weight, kg	172.9	171.5	171.1
Feed Intake, kg	3.8[a]	2.9[b]	3.9[a]
Daily Water Consumption			
Total Intake, ml	11965.0[a,d]	8190.0[b,e]	7691.0[c,e]
Intake, ml/kg Body Weight	69.2[a,d]	47.8[b,e]	45.0[c,e]
Intake, ml/g Daily Feed Intake	3.2[a,d]	2.8[b,e]	2.0[c,e]
Daily Urinary Excretion			
Total Volume, ml	------	3356.0[a]	2355.0[b]
Output, ml/kg Body Weight	------	20.8[a]	13.7[b]
Urine Excretion, ml/g Daily Feed Intake	------	1.2[a]	0.6[b]
Urine pH	------	8.5	9.0

[a,b,c] Means in the same line bearing different superscripts are different (P<.05).

[d,e] Means in the same line bearing different superscripts are different (P<.01).

balance of the animal. It has been indicated by Vohra (1980) that metabolic water may make up to 15 to 19% of the daily water intake. Tasker (1967a) reports that an average of 2.2 liters per day would be a reasonable estimate of daily metabolic water intake of mature horses fed conventional diets.

The other measurement not taken in the studies reported herein was that of loss of water by evaporation from lungs and skin called insensible water loss. Tasker (1967a) indicates that the average healthy adult horse would lose approximately 8.5 liters per day by this route. These values were extrapolated in the current study, with the equivalent amount of metabolic water being 825 ml per day and the insensible losses being about 3100 ml per day (table 20).

The usefulness of understanding normal water intake and excretion rates will assist us in our understanding of sickness and metabolic disorders and diseases that may afflict the pony. Previous work and reviews on water balance and disorders supports the need for such understanding (Tasker, 1967b; Waterman, 1977 and Kienholz, 1978).

TABLE 20. WATER INTAKE AND OUTPUT IN PONIES FED CUBED OR PELLETED RYEGRASS STRAW DIETS

	Water (ml/day)	
	Cubed Diets	Pelleted Diets
Intake[a], ml/day		
Dietary Water	370.0	390.0
Drinking Water	7820.0	7300.0
	8190.0[c]	7690.0[d]
Output[b], ml/day		
Urine Water	3087.0	2166.0
Fecal Water	3410.0	3230.0
	6497.0[c]	5396.0[d]

[a] Total water intake would also include metabolic water (approximately 825.0 ml).

[b] Total water output would also include insensible water (approximately 3100.0 ml).

[c,d] Means in the same line with different superscripts are different ($P<.05$).

CHAPTER V

GENERAL CONCLUSIONS

These studies have produced information regarding the use of ryegrass straw in rations for ponies and furthered knowledge on the techniques for determining digestibility. Also, information on the water requirements of the mature pony were determined when under normal and restricted environments, and when fed various quantities and forms of ryegrass straw, hay or concentrates.

Specific conclusions and recommendations that can be derived from these studies include the following:

1. The studies indicate that straw can be effectively incorporated into pony diets at levels up to 70% when adequately supplemented with protein, mineral and vitamin sources, without adversely affecting intake, body weight, or protein digestibility. Furthermore, as the level of straw increases from 50 to 70% in the diet one must be aware that energy and fiber digestibility will be affected.

2. The use of densification processes like mechanical cubing and pelleting reduce sorting of dietary ingredients by the animal, promote adequate intake of feed and overcome handling and storage problems caused by the bulk of straws.

3. Mechanical and chemical processing of straws increase the feeding value, but at today's energy costs are quite expensive.

4. The use of the acid insoluble ash (AIA) method for determining digestibility proves to be equally acceptable to total fecal collection

(TFC) techniques. In addition the AIA method significantly reduces time and labor involved in carrying out a digestibility experiment. The AIA as well as the TFC method are both superior to the permanganate lignin technique since this method underestimates digestibility. The lignin method should probably not be employed in equine digestibility studies.

5. The mature pony will consume approximately 12000 ml (6% of body weight) of water daily at rest when not confined to a digestion crate. The pony will average about three parts water to each part of dry matter consumed under natural conditions. When introduced to a digestion crate (an unnatural environment) both water and feed intake is less.

6. More specific information on the chemical make-up of the rye-grass straw needs to be conducted to determine specific ultrastructural components of the fibrous fraction which may further explain why some nutrients are less available when high levels of straws are used in rations.

7. Mechanical processing and chemical treatment methods which may improve nutrient availability and acceptability of straws for the equine must be further evaluated.

8. Lower gastrointestinal tract function and fermentation of rye-grass straw both in vitro and in vivo needs to be investigated.

9. Straw usage for incorporation into diets for growth, work, reproduction and lactation of both horses and ponies should be studied.

BIBLIOGRAPHY

Anderson, D. Craig. 1972. *In vitro* and *in vivo* evaluations of chemically treated ryegrass straw. Ph.D. Thesis. Oregon State University, Corvallis, Oregon.

Anderson, D. Craig and A. T. Ralston. 1973. Ryegrass straw utilization by sheep. Proc., West. Sec. Amer. Soc. Anim. Sci. 24:365.

A. O. A. C. 1970. Official Methods of Analysis (11th Ed.) Association of Official Agric. Chem., Wash. D. C.

Berger, I. L., T. J. Klopfenstein and R. A. Britton. 1980. Effect of sodium hydroxide treatment on rate of passage and rate of ruminal fiber digestion. J. Anim. Sci. 50:745.

Block, Elliot, L. H. Kilmer and L. D. Muller. 1981. Acid insoluble ash as a marker of digestibility for sheep fed corn plant or hay and for lactating dairy cattle fed hay *ad libitum*. J. Anim. Sci. 52:1164.

Church, D. C. and K. A. Champe. 1980. Digestibility of untreated and hydroxide treated annual ryegrass straw. J. Anim. Sci. 51:20.

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

Fonnesbeck, P. V. 1968. Consumption and excretion of water by horses receiving all hay and hay-grain diets. J. Anim. Sci. 27:1350.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses, Agric. Handbook No. 379. ARS, USDA.

Haenlein, G. F. W., R. C. Smith and Y. M. Yoon. 1966. Determination of the fecal excretion rate of horses with chromic oxide. J. Anim. Sci. 25:1091.

Hart, M. R., H. G. Walker, Jr., R. P. Graham, P. J. Harris, A. H. Brown and G. O. Kohler. 1981. Steam treatment of crop residues for increased ruminant digestibility. I. Effects of process parameters. J. Anim. Sci. 51:402.

Hintz, H. F., D. E. Hogue, E. F. Walker, Jr., L. E. Lowe and H. F. Schryver. 1971. Apparent digestion in various segments of the digestive tract of ponies fed diets with varying roughage-grain ratios. J. Anim. Sci. 32:245.

Jones, S. R. 1978. The effects of aerobic and anerobic fermentation on the nutritive value of ryegrass straw. Ph.D. Thesis. Oregon State University, Corvallis, Oregon.

Kane, E. A., W. C. Jacabson and L. A. Moore. 1949. Digestibility studies on dairy cattle: a comparison of the total fecal collection methods; conventional versus chromium oxide and lignin techniques. J. Anim. Sci. 8:623.

Kiemholz, E. W. 1978. Why water is so important to animals. Feedstuffs 50:17.

Knapka, J. J., K. M. Barth, D. G. Brown and R. G. Crable. 1967. Evaluation of polyethylene, chromic oxide, and cerium^{144} as digestibility indicators in burros. J. Nutr. 92:79.

Kotb, A. R. and T. D. Luckey. 1972. Markers in nutrition. Nutr. Abstr. and Rev. 42:813.

Lesoing, Gary, Terry Klopfenstein, Ivan Rush and John Ward. 1980. Chemical treatment of wheat straw. J. Anim. Sci. 51:263.

Mc Carthy, J. F., F. X. Aherne and D. B. Okai. 1974. Use of HCl insoluble ash as an index material for determining apparent digestibility with pigs. Can. J. Anim. Sci. 54:107.

Morrison, F. B. 1960. Feeds and Feeding. (22nd Ed.) Morrison Publ. Co. Ithaca, New York.

Pigden, W. J. and D. P. Heaney. 1969. Lignocellulose in ruminant nutrition. Amer. Chem. Soc. Adv. in Chem. Ser., No. 95:245.

Pulse, R. E., J. P. Baker and G. D. Potter. 1973. Effects of cecal fistulation upon nutrient digestion and indicator retention in horses. J. Anim. Sci. 37:488.

Schurg, W. A. and D. W. Holtan. 1981. Evaluation of ryegrass straw in rations for ponies I. Completely cubed or pelleted ryegrass straw diets fed to ponies. In preparation for J. Anim. Sci.

Schurg, W. A. 1981. Compilation of data evaluating various techniques for determining digestion of equine rations. Proc. of the 7th Equine Nutr. and Physiol. Soc. Sym., Warrenton, VA., p. 1.

Schurg, W. A. 1981. Alternative roughage utilization by horses. I. Evaluation of untreated and sodium hydroxide treated wheat straw in horse diets. Proc. of the 7th Equine Nutr. and Physiol. Soc. Sym., Warrenton, VA. p. 8.

Schurg, W. A., R. E. Pulse, D. W. Holtan and J. E. Oldfield. 1978. Use of various quantities and forms of ryegrass straw in horse diets. J. Anim. Sci. 47:1287.

Schurg, W. A., D. L. Frei, P. R. Cheeke and D. W. Holtan. 1977. Utilization of whole corn plant pellets by horses and rabbits. J. Anim. Sci. 45:1317.

Schurg, W. A. 1976. Ryegrass straw and whole corn plant pellets as alternative roughages for horses. M. S. Thesis. Oregon State University, Corvallis, Oregon.

Slagsvold, P., H. F. Hintz and H. F. Schryver. 1979. Digestibility by ponies of oat straw treated with anhydrous ammonia. Animal Prod. 28:347.

Solaiman, S. G., G. W Horn and F. N. Owens. 1979. Ammonium hydroxide treatment of wheat straw. J. Anim. Sci. 49:802.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. Mc Graw-Hill Book Co., New York.

Stillions, M. C. and W. E. Nelson. 1968. Metabolism stall for male equine. J. Anim. Sci. 27:68.

Sutton, E. I., J. P. Bowland and J. F. Mc Carthy. 1977. Studies with horses comparing 4H-HCl insoluble ash as an index material with total fecal collection in the determination of apparent digestibilities. Can. J. Anim. Sci. 57:543.

Tasker, J. B. 1967a. Fluid and electrolyte studies in the horse III. Intake and output of water, sodium and potassium in normal horses. Cornell Vet. 57:649.

Tasker, J. B. 1967b. Fluid and electrolyte studies in the horse. IV. The effects of fasting and thirsting. Cornell Vet. 57:658.

Thonney, M. L., D. J. Duhaime, P. W. Moe and J. T. Reid. 1979. Acid insoluble ash and permanganate lignin as indicators to determine digestibility of cattle rations. J. Anim. Sci. 49:1112.

VanderNoot, G. W., P. V. Fonnesbeck and R. K. Lydman. 1965. Equine metabolism stall and collection harness. J. Anim. Sci. 31:351.

Van Keulen, J. and B. A. Young. 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestion studies. J. Anim. Sci. 44:282.

Van Soest, P. J. and L. H. Jones. 1968. Effect of silica in forage upon digestibility. J. Dairy Sci. 51:1644.

Vohra, P. N. 1980. Water quality for poultry use. Feedstuffs 52:24.

Waldern, D. E. 1971. A rapid micro-digestion procedure for neutral acid detergent fiber. Can. J. Anim. Sci. 51:67.

Wallace, J. D., D. N. Hyder and K. L. Knox. 1972. Water metabolism in sheep fed forage rations differing in digestibility. Am. J. Vet. Res. 33:921.

Waterman, A. 1977. A review of the diagnosis and treatment of fluid and electrolyte disorders in the horse. Equine Vet. J. 9:43.

Williamson, Grahame. 1941. The effect of Beckmann's treatment by sodium hydroxide on the digestibility and feeding value of barley straw for horses. J. Agric. Sci. 31:488.

Winchester, C. F. and M. J. Morris. 1956. Water intake rates of cattle. J. Anim. Sci. 15:722.

APPENDIX

APPENDIX TABLE I. Perennial Ryegrass Straw Used in Metabolism and Digestibility Trials.

	Percentage
Dry Matter	91.5
Crude Protein	4.4
Cell Wall Constituents	70.8
Acid Detergent Fiber	42.3
Acid Detergent Lignin	6.9
Cellulose	34.6
Hemicellulose	28.6

APPENDIX TABLE 2. Experimental Design -- Experiment I Digestibility (7 x 7).

Pony	Period						
	1	2	3	4	5	6	7
2	D	C	F	B	G	E	A
21	A	G	C	F	E	B	D
4	C	B	E	A	F	D	G
11	F	E	A	D	B	G	C
17	E	F	G	C	D	A	B
10	B	A	D	G	C	F	E
8	G	D	B	E	A	C	F

Treatments: Control 50% grass hay-50% concentrates (A); 90% straw-10% molasses (B); 90% straw-10% molasses-3% NaOH (C); 70% straw-20% alfalfa-10% molasses (D); 45% straw-45% alfalfa-10% molasses (E); 20% straw-70% alfalfa-10% molasses (F); and 60% straw-12% soybean meal-10% barley-10% molasses (G).

APPENDIX TABLE 3. Experimental Design -- Experiment 3 Digestibility (3 x 3).

Pony	Period		
	1	2	3
2	CD	EI	EII
4	EI	EII	CD
17	EII	CD	EI

Treatments: Control (50% grass hay-50% concentrates), Experimental I (50% straw-50% concentrates), Experimental II (68% straw-32% concentrates).