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Introduction

Large hay packaging systems are becoming increasingly popular as a means of storing hay conveniently with a minimum amount of labor. It has been noted that as much as 28% of the hay crop may be lost during the number of sequential operations involved in traditional hay making. The "one-man operation" packaging systems may allow harvesting at higher than normal moisture levels (approximately 30%) which reduces the chances of leaf loss and weathering during drying in a field. It follows, however, that quality loss during storage might be a greater problem with forage stacked at higher moisture levels. Such loss of quality may be difficult to determine by visual observation only, except for mold and/or color changes.

The purpose of this study was to determine to what extent large hay package storage retained the initial forage quality by measurement of seven quality parameters over an extended period. The Hesston 60 and Haybuster 1800 were used as examples of hay packing systems for study.

Materials and Methods

Seventy-three samples of alfalfa forage were taken in different locations from three Hesston stacks located on the Richards Farm near Ipswich during three collection periods (June 6, 1972; Oct. 10, 1972 and May 5, 1973). A similar sampling (207 samples) was made from three Hesston stacks at the Richards Farm and three Haybuster stacks at the Pasture Research Center at Norbeck on June 13, 1973; July 12, 1973 and October 19, 1973.

The quality measurements--moisture, crude protein (CP), ash, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), acid-detergent lignin (ADL), Crampton and Maynard cellulose (CMC) and *in vitro* dry matter digestibility (IVDMD)--were made on all samples collected over this 2 year period. Using a multiple regression equation, quality components were compared as independent variables to *in vitro* dry matter digestibility as a dependent variable to determine which single or combination of quality components exerts the greatest influence on digestibility. Previous research has shown laboratory digestibility to be highly related to actual digestibility trials.

Results and Discussion

It was shown that nearly 40% of the variation in digestibility could be accounted for by the two quality components, acid-detergent lignin and neutral-detergent fiber (table 1). This would suggest that of the quality components measured these two appear

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to have the most influence on animal utilization of forage material. Neutral-detergent fiber can be an indirect measure of plant cell contents, whereas lignin is a measure of plant encrustation. It has long been known that as the lignin content of a plant increases digestibility decreases, since lignin encrustation inhibits digestibility by rumen microorganisms.

Using only three quality components, neutral-detergent fiber, acid-detergent fiber and *in vitro* digestibility in equation form, a single value or quality index was developed. The values for all samples taken from the stacks are represented in the index and compared to a hay "standard" of known quality. A regression equation was obtained using all values which contributed significantly to the regression.

A summary of hay quality parameter measurements of each stack is shown in table 2. The data were used in the Stepwise-Forward Multiple Regression method of selection of quality parameters for an index equation. This procedure involved the use of the dependent variable (IVDMD) and seven independent variables (ADF, NDF, ADL, CP, CMC, ash and moisture). The proportion of the variability contributed by each independent variable is explained in table 1. The regression equation obtained using all values which contribute significantly to the regression was $Y = 86.4 - 0.75$ (ADL,%) - 0.34 (NDF,%) + 1.37 (moisture,%) + 0.31 (crude protein,%) - 0.54 (ash,%).

A more simplified equation, $Y = 87.8 - 1.33\ (ADL) - 0.258\ (NDF)$, is more practical and would be justified since ADL and NDF explained 39.3% of the total variability accounted for by all quality parameters measured (49.0%).

If the simpler equation was used, an example would be as follows:

1. Substitute values into equation of a known standard of choice to obtain a comparison for quality index--for example, immature alfalfa having values of 3.0 and 37.0% ADL and NDF, respectively

$$Y = 87.8 - 1.33\ (3.0) - 0.258\ (37.0)$$

$$Y = 87.8 - 13.54$$

$$Y = 74.26$$

$$\frac{74.26}{74.26} \times 100 = 100$$

2. Substituting mean values of ADL and NDF obtained from stack 1 on the first (a) and third (b) collection dates, we obtain

   a. Stack 1, collection 1

$$Y = 87.8 - 1.33\ (7.0) - 0.258\ (55.7)$$

$$Y = 87.8 - 23.7$$

$$Y = 64.1$$

b. Stack 1, collection 3

$$Y = 87.8 - 1.33\ (10.0) - 0.258\ (70.0)$$

$$Y = 87.8 - 31.36$$

$$Y = 56.44$$

3. Nutritive value index (NVI) values relative to the standard forage were then calculated

a. $NVI = \frac{64.1}{74.26} \times 100 = 86.3$

b. $NVI = \frac{56.44}{74.26} \times 100 = 76.0$

IVDMD values decreased approximately 22.5, 13.5, and 10.1 percentage units during a period of 1 year storage in stacks 1, 2, and 3, respectively. NVI values for collections 1, 2, and 3 in stacks 1, 2, and 3 decreased approximately 10.3, 13.0, and 10.5 nutritive value units, respectively.

The results of the NVI calculations above indicate a reduction of 10.3 nutritive value units in the first year of storage in stack 1. IVDMD during this same period indicated a reduction of 22.5 percentage units in the same stack.

Table 1. Stepwise-Forward Multiple Regression of Seven Chemical Components on *In Vitro* Dry Matter Digestibility

Independent variable[a]	Proportion explained	Total explained
	%	%
ADL[b]	30.1	30.1
NDF[b]	9.2	39.3
Moisture	6.4	45.7
Crude protein	1.4	47.1
Ash	1.6	48.7
CMC[b]	0.3	49.0
ADF[b]	0.0	49.0
Total for all seven variables		49.0

[a]Each independent variable was regressed on IVDMD.
[b]ADL = acid-detergent lignin, NDF = neutral-detergent fiber, CMC = Crampton and Maynard cellulose and ADF = acid-detergent fiber.

Table 2. Average Composition of Nine Stacks and Three Collection Dates

Stk.	Date	ADF[a]	NDF	ADL	CMC	CP	IVDMD	Moisture	Ash
1	6-15-72	40.27	55.65	7.04	33.43	12.87	72.66	35.80	11.90
1	10-10-72	44.22	62.08	8.28	33.91	13.31	63.94	11.70	12.28
1	5- 2-73	46.11	70.38	10.02	45.06	13.09	50.13	7.90	9.94
2	6-15-72	36.98	49.93	6.86	31.14	22.10	67.69	31.80	13.38
2	10-10-72	43.91	59.90	7.88	34.08	21.35	68.47	11.40	13.11
2	5- 2-73	44.57	70.13	10.30	39.15	13.37	54.23	7.60	9.58
3	6-15-72	39.93	56.22	6.42	34.13	12.16	65.67	29.00	12.37
3	10-10-72	43.23	62.08	7.76	36.11	12.77	57.56	11.33	12.41
3	5- 2-73	44.50	70.55	9.51	43.60	12.48	55.56	8.02	9.61
4	6-13-73	27.96	49.94	8.29	23.31	17.97	66.28	34.20	11.15
4	7-12-73	33.76	50.88	10.65	23.37	18.52	61.47	18.83	11.61
4	10-19-73	31.29	53.94	8.07	23.70	18.22	63.99	9.90	11.91
5	6-13-73	29.16	53.03	7.22	23.73	17.92	64.24	29.50	10.89
5	7-12-73	33.86	52.19	12.29	24.09	18.76	61.30	16.00	11.10
5	10-19-72	31.30	53.75	7.55	23.64	17.85	63.19	9.80	11.36
6	6-13-73	30.53	55.24	7.79	25.34	17.76	64.14	32.30	10.81
6	7-12-73	35.32	53.95	9.90	25.67	18.01	61.00	12.17	11.46
6	10-19-73	33.00	52.03	8.09	26.52	17.66	62.88	9.10	11.25
7	6-13-73	32.48	52.81	7.77	27.18	17.42	62.41	39.90	12.05
7	7-12-73	37.42	54.39	9.17	26.25	16.68	58.12	12.83	13.88
7	10-19-73	36.44	52.59	7.89	27.92	16.47	57.97	9.70	13.10
8	6-13-73	32.32	53.28	7.95	28.38	16.19	62.82	40.10	11.98
8	7-12-73	37.35	55.11	9.05	26.57	16.58	56.87	13.42	16.82
8	10-19-73	36.38	55.54	8.00	28.44	16.64	59.59	9.67	12.44
9	6-13-73	33.52	54.72	7.64	28.11	17.13	63.40	39.80	11.29
9	7-12-73	36.52	56.69	8.74	26.36	17.08	57.77	11.30	15.43
9	10-19-73	34.89	55.21	7.40	27.49	16.95	61.60	8.90	11.67

[a]ADF = acid-detergent fiber, NDF = neutral-detergent fiber, CMC = Crampton and Maynard cellulose, ADL = acid-detergent lignin, CP = crude protein and IVDMD = *in vitro* dry matter gestibility.

Summary and Conclusions

A Nutritive Value Index System has been proposed for alfalfa hay stored by large hay packaging systems which uses three quality component measurements. It was formulated by determination of the contribution of various quality components to the variability of *in vitro* digestibility of forage stored by the Hesston and Haybuster packaging systems. The index system is only in its formative stages and will require usage with forage stored for longer periods than 1 year and with other forage species. Mixed prairie hay stacks are presently being sampled for analysis.