Digesting Ability of Dairy Calves to Milk and Hay during Early Growth Stage

Tatsuo HAMADA, Kenichi KAMEOKA, Shoichiro OMORI
and Hiroshi MORIMOTO

(National Institute of Animal Industry, Chiba-shi, Japan)
(Received for publication on April 27, 1965)

Milk and hay are the most conventional feeds for calves. The former is a liquid feed, a large part of which passes via the esophageal groove into the abomasum. The latter is a solid feed, which enters directly into the reticulorumen and undergoes complex microbiological changes. The development of the reticulorumen is found to be influenced by physical and chemical stimuli and other physiological factors concerned with the reticulorumen functions as shown by the reviews^{1,2}). An examination of the literature revealed that calves could attain sufficient adult-type rumen functions to digest pasture grass before 3 mo. of age³⁻⁶). It has still remained a question, however, as to the specific growth stage at which calves can digest hay, especially the crude fiber of hay, at the adult level. According to BARTLEY et al.⁷), the digestion coefficients of the crude fiber of alfalfa hay were 41.6 and 44.3% at 10 and 14 wk. of age, respectively. But MÄKELÄ⁸) obtained the difference in digestibility of hay between calves of less than 3 mo. of age and those of 5 to 6 mo. of age. The following experiments were designed to obtain the information concerning the digestibility of Italian ryegrass hay by Holstein male calves of up to 15 wk. of age.

Experimental procedure

Three calves for Exp. I and three for Exp. II were purchased from the farmers near the Institute at about 1 wk. of age and were reared on the special vinyl mats to prevent bedding consumption. Three (No. 1, 2 and 3) and two (No. 11 and 12) Holstein male calves were selected for the digestion experiments in Exp. I and II, respectively.

The total amount of milk fed per day was equal to about 10% of liveweight. The milk was fed in open pails twice per day at 8:30 am and 4:30 pm throughout the experimental period. Italian ryegrass hay produced in the Tcchigi district was fed ad libitum from 5 and 2 wk. of age in Exp. I and II, respectively. The calves were weighed weekly and records of feed consumption were kept.

The digestion experiments were carried out according to the schedule shown in Table 1. The digestibility was measured using Cr_2O_3 as an index and in order to check the recovery of Cr_2O_3 , feces during some of the collection periods were collected quantitatively by means of feces bags. A 6-day preliminary period and a 3-day collection period were used. Throughout the both periods glucose containing approximately 5% of Cr_2O_3 was completely dispersed into milk immediately before feeding at the rate of 0.5 to 1.0 g of the glucose per kg of milk.

Milk and Hay Digestion by Dairy Calves

Table 1. Schedule of digestion experiments

Exp. No.	Age	Feed intake		Calf No.	Average body wt.
		Milk	Hay		
I — 1	3 ~ 4 wk.	5.0 kg	— g	No. 1, 2, 3	50 kg
I — 2	8 ~ 9	6.5 ~ 7.5	300 ~ 450	No. 1*, 2*, 3*	70
I — 3	13 ~ 14	9.5 ~ 10.5	700 ~ 900	No. 1, 2*, 3*	100
II — 1	5 ~ 6	5.5	300	No. 11*, 12*	56
II — 2	9 ~ 10	6.0	800	No. 11, 12	76

* The recovery of Cr_2O_3 was examined by the total collection of feces

The feeding level of milk and hay was kept constant. There were only a few small hay refusals throughout the digestion periods.

Hay was carefully mixed at the start of each digestion experiment and the sample was saved for chemical analysis. "Grab" samples of feces were taken four times daily and stored in a refrigerator. At the end of each collection period, the daily aliquots of feces were mixed, dried in a circulating dryer at about 60°C and allowed to equilibrate with atmospheric moisture. A subsample was then taken for chemical analysis.

Moisture, crude protein, ether-extract, crude fiber, NFE and crude ash were determined by the AOAC method⁹. Milk was analyzed for fat by the BABCOCK method and the other components by the AOAC method. The soap content of feces from calves fed only milk and Cr_2O_3 was determined according to the procedure described by HARTFIEL¹⁰. The amount of Cr_2O_3 was determined according to the procedure described by KAMEOKA *et al.*¹¹.

The chemical composition of feeds used is shown in Table 2. The digestion experiments of Exp. I and II were carried out from July to Sept. and from Nov. to Dec. of 1963, respectively.

Table 2. Chemical composition of feeds used in the calf digestion trials

Feed	Exp. No.	Moisture	Crude protein	Ether extract	Crude fiber	NFE	Crude ash
		%	%	%	%	%	%
Milk	I — 1	88.1	3.2	3.3	—	4.7	0.7
Hay*	I — 2	14.8	13.3	2.2	26.1	34.3	9.3
Hay*	I — 3	15.3	7.6	1.9	25.2	44.4	5.6
Hay*	II — 1	11.8	8.1	1.9	31.0	40.3	6.9
Hay*	II — 2	8.9	9.0	1.9	32.3	41.2	6.7

* Chemical composition of the milk fed with Italian ryegrass hay is not presented in the table

Results and Discussion

The hay consumption rates increased with advancing age, as shown in Fig. 1. During the whole experiment, the average daily increase in hay intake was estimated to be about 12g from Fig. 1 and the average daily gains of the experimental period were 0.70 and 0.67 kg in Exp. I and II, respectively. For the whole experiment, the hay intakes were not strictly ad libitum. Since, during digestion experiment, the feeding level of hay was maintained constant at just below an ad libitum feeding level.

←→ shows digestion period
Fig. 1. Hay consumption rates

The apparent digestion coefficients of milk by the calves at 3 to 4 wk. of age are shown in Table 3. The digestion coefficients of the ether-extract were calculated by considering the fecal soaps which were 3.2 to 3.7% of the air-dry feces. If the fecal soaps were not accounted for, the digestion coefficient of the ether-extract would have been 0.5% higher than the present value. Many data concerning the digestibility of milk¹²⁻¹⁹ have been published, which coincide well with the digestion coefficients shown in Table 3. The metabolic fecal nitrogen was reported to be 0.27, 0.334 or 0.43 g per 100 g dry matter intake by different authors, respectively¹⁷⁻¹⁹, and the metabolic fecal fat was reported to be 19 to 29 mg per kg body weight per day at 7 to 8 wk. of age²⁰. If these factors were applied to the above data, the digestion coefficients of crude protein and ether-extract would approach 100 and 99%, respectively.

Table 3. Digestibility of Milk at 3 to 4 wk. of age (Av.±S.D.)

Organic matter	Crude protein	Ether extract	NFE	Crude ash
97.4 ± 0.3 %	93.9 ± 0.8 %	97.7 ± 0.2 %	99.7 ± 0.2 %	94.7 ± 0.9 %

Table 4. Comparison of digestion coefficients of organic matter derived from milk and hay, determined by total collection method and indicator method

Exp. No.	Calf No.	Total collection method %	Indicator method %	Recovery of Cr ₂ O ₃ %
I — 2	No. 1	85.5	85.9	102.5
I — 2	No. 2	89.0	89.5	102.4
I — 2	No. 3	89.5	88.8	93.1
I — 3	No. 2	83.5	84.3	105.0
I — 3	No. 3	85.5	84.2	92.7
II — 1	No. 11	83.6	86.9	107.8
II — 1	No. 12	86.9	85.8	91.6
Av. ± S.D.				99.3 ± 6.8

Milk and Hay Digestion by Dairy Calves

The digestion coefficients of organic matter derived from milk and hay, determined by the total collection method and by the indicator method, and the recovery of Cr_2O_3 are shown in Table 4. The average Cr_2O_3 recovery was 99.3% and the standard deviation was 6.8%. In this case, a large part of Cr_2O_3 was considered to enter into abomasum with milk, where Cr_2O_3 was mixed with the digestion residues of hay which had passed through reticulorumen and omasum. There was found no significant difference between the digestion coefficients obtained by the total collection method and those obtained by the indicator method.

In calculating the digestibility of the hay by growing calves, there is a possibility of weight reducing error due to the increasing size of the reticulorumen. The increasing residue retained by this organ is assumed to be digested, thus causing the result to be a little too high. In these digestion periods, however, feed intakes were restricted to a constant, which probably minimized this phenomenon. If the maximum rate of increase in the capacity of the reticulorumen was in fact equal to the increased amounts of hay consumed, it would correspond to about 12 g per day. This fact enables one to estimate the maximum amounts of error involved.

Digestion coefficients and TDN content of the hays determined by the indicator method are presented in Table 5. The digestion coefficients of hay were calculated by difference using the above values for milk (Table 3). According to THOMKE¹⁶⁾, the digestibility of milk changes little from 4 to 11 wk. of age. From the time the calves began to consume hay to the first collection period, 5 and 4 wk. had elapsed in Exp. I and II, respectively.

Table 5. Digestion coefficients and TDN content of hay fed to young dairy calves*

Exp. No.	Age	Organic matter	Crude protein	Ether extract	NFE	Crude fiber	TDN
	wk.	%	%	%	%	%	%
I — 2	8 ~ 9	61.3 (2.2)	62.8 (8.7)	84.9 (9.4)	58.6 (0.7)	62.1 (1.9)	48.9 (1.9)
I — 3	13 ~ 14	62.0 (1.3)	44.2 (5.1)	64.0 (5.7)	64.4 (3.0)	64.2 (1.6)	50.9 (1.6)
II — 1	5 ~ 6	53.8 (3.3)	23.7 (15.7)	66.7 (47.1)	48.9 (5.6)	68.2 (7.7)	46.1 (2.3)
II — 2	9 ~ 10	58.6 (0.6)	34.5 (11.3)	82.2 (4.8)	55.1 (1.7)	68.7 (3.0)	52.0 (0.6)

* The above figures are the averages and the figures in parenthesis are the standard deviations

The standard deviations for crude protein and ether-extract were much greater than those of the other fractions, which might be expected since the amounts of digestible protein and ether-extract derived from the hay were small compared to those derived from the milk. The digestion coefficients of all fractions, except crude protein and ether-extract in Exp. I, increased to a small degree with advancing age, and only with NFE in Exp. I was there a statistically significant increase ($P < 0.10$). No doubt one of the reasons why the digestion coefficient for crude protein showed a downward trend was due to the unusually high protein content of the hay during the 8~9 wk. trial (Table 2).

According to MORRISON²¹⁾, the digestion coefficients of NFE and crude fiber and the TDN content of Italian ryegrass hay are 67, 65 and 52%, respectively. The digestibility of this hay by mature goats gave values of the same order in the unpublished data from our laboratory. The values in Table 5 are a little lower than these "adult" data, except for crude fiber in Exp. II. If the above correction for increased rumen fill is taken into account, the digestion

coefficients of crude fiber would be about 5 and 2 percentage units lower than shown in Table 5 in the first and second digestion experiment period of both Exp. I and II, respectively.

From these results, it was concluded that the digestive ability of calves for hay, especially the crude fiber of hay, increased rapidly almost to the adult level within 4 to 5 wk. after they began to consume hay. From then on the digestibility increased gradually to the adult level. Many digestion experiments using grass³⁻⁶⁾ have shown the same trend. According to the data of HEMKEN *et al.*²²⁾, the TDN content of mixed hay by the calves of 14 wk. of age were from 4 to 10% lower than those of 3-year old cows, and the digestion coefficients of crude fiber were the same in early-cut hay but different in late-cut hay between the calves and the cows. MÄKELÄ⁸⁾ obtained the results showing the difference in the digestibility of hay between calves and cows. According to HOGUE *et al.*²³⁾, the digestion coefficients of crude fiber derived from hay and calf starter changed little from the calves of about 8 wk. of age to those of 11 wk. of age.

It is difficult to specify precisely when calves will attain the adult-type rumen function sufficient to digest roughage, since it is influenced by many factors such as types of ration and quality of roughage. A lot of evidences has suggested that, even in uninoculated calves, the adaptation period of rumen function to digest roughage satisfactorily may be within 4 or 5 wk. after they begin to consume it.

Summary

The influence of age upon the digestibility of Italian ryegrass hay was examined by the total collection method and the indicator method of Cr_2O_3 , using a total of 5 Holstein male calves. The digestibility of milk was determined at 3 to 4 wk. of age and the digestion experiments fed milk and hay were carried out at two growth stages in two experiments.

The average recovery of Cr_2O_3 in seven collection periods fed milk and hay and its standard deviation were 99.3 and 6.8%, respectively. Within 4 or 5 wk. after the calves had begun to consume hay, the digestibility of hay increased rapidly to near the adult level and from then on increased to a small degree with advancing age.

Acknowledgement

The authors express their sincere appreciation to Dr. R.G. WARNER of the Department of Animal Husbandry, Cornell University for his revision of this paper.

References

- 1) KAY, R.N.B. (1963) J. Dairy Res., **30** : 261.
- 2) PRESTON, T.R. (1963) World Rev. of Nutrition and Dietetics., **4** : 117.
- 3) ARMSTRONG, D.G., T.R. PRESTON, and R.H. ARMSTRONG (1954) Nature, **174** : 1182.
- 4) GODFREY, N.W. (1961) J. Agric. Sci., **57** : 177.
- 5) McARTHUR, A.T.G. (1957) N.Z.J. Sci. Tech., **A 38** : 696.
- 6) PRESTON, T.R., J.D.H. ARCHIBALD, and W. TINKLER (1957) J. Agric. Sci., **48** : 259.
- 7) BARTLEY, E.E., D.B. PARRISH and K.L. WHEATCROFT (1956) J. Dairy Sci., **39** : 319.

Milk and Hay Digestion by Dairy Calves

- 8) MÄKELÄ, A. (1960) J. Scientific Agric. Soc. Finland, **32**: 161.
- 9) Assoc. of Official Agr. Chemists. (1960) Official Methods of Analysis, 19th Ed.
- 10) HARTFIEL, W. (1960) Arch. f. Tierernährung, **10**: 264.
- 11) KAMEOKA, K., M. YOSHIDA, T. KUBOTA and S. TAKAHASHI (1957) Bull. Nat. Inst. Agric. Soc., Japan, **G13**: 67.
- 12) BLAXTER, K.L. and W.A. WOOD (1952) Brit. J. Nutr., **6**: 1.
- 13) BRISSON, G.J., H.M. GUNNINGHAM and S.R. HASKEL (1957) Can. J. Anim. Sci., **37**: 157.
- 14) HUGHES, J.S. and H.W. CARE (1931) J. Nutr., **4**: 163.
- 15) NOLLER, C.H., G.M. WARD, A.D. MCGILLARD, C.F. HUFFMAN and C.W. DUNCAN (1956) J. Dairy Sci., **39**: 1288.
- 16) THOMKE, S. (1963) Züchtungskunde, **35**: 214.
- 17) LOFGREEN, G.P. and M. KLEIBER (1953) J. Nutr., **49**: 183.
- 18) CUNNINGHAM, H.M. and G.J. BRISSON (1957) Can. J. Anim. Sci., **37**: 152.
- 19) BLAXTER, K.L. and W.A. WOOD (1951) Brit. J. Nutr., **5**: 11.
- 20) CUNNINGHAM, H.M. and J.K. LOOSLI (1954) J. Dairy Sci., **37**: 453.
- 21) MORRISON, F.B. (1959) Feeds and Feeding. 22nd Ed. The Morrison Publishing Company, Ithaca, N.Y.
- 22) HEMKEN, R.W., G.W. TRIMBERGER and K.L. TURK (1958) Cornell Univ. Agr. Exp. Sta. Bull., **933**:
- 23) HOGUE, D.E., R.G. WARNER, C.H. GRIFFIN and J.K. LOOSLI (1956) J. Animal Sci., **15**: 788.

乳用子牛の牛乳と乾草の消化能力について

浜田 龍夫・龜岡 暄一・大森昭一郎・森本 宏

(農林省畜産試験場)

5頭のホルスタイン種雄子牛を供試して、イタリアンライグラス乾草の消化率におよぼす子牛の年令の影響について、全糞採取法と酸化クロムの index 法とにより検討した。牛乳の消化率を 3~4 週令で測定し、牛乳と乾草を給与した場合の消化試験を異なる成長段階でそれぞれ 2 回ずつ反復実施した。

牛乳と乾草を給与した場合の 7 回の糞採集期における酸化クロムの平均回収率とその標準偏差は、それぞれ 99.3% と 6.8% とに相当した。子牛が乾草を摂取し始めてから 4~5 週間以内に、乾草の消化率はほとんど成牛により求めた消化率に近い値まで急速に高まり、それ以後は年令がすすむにつれて、わずかに増加した。