

# Effect of Feeding a Large Amount of High Starch Ration on the Rumen Fermentation and the Starch Appearance in the Abomasum

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**Summary.** Two wethers fitted with the ruminal and the abomasal fistulas were used to evaluate the relationship between rumen fermentation and amount of starch escaping into the abomasum when the animals were fed with high starch ration in maximum intake (3% of B. W./head/day).

Total VFA and pH in the rumen were lower and  $C_2/C_3$  was higher in high starch ration (Barley : Hay=80 : 20) than in low starch ration (50 : 50). One of the animals on high starch ration produced a large amount of lactic acid in the rumen. The average percentages of the dietary starch escaping into the abomasum were 9.7 and 14.7% in low starch ration, 4.7 and 2.8% in high starch ration, respectively.

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## Introduction

In recent years, beef cattle fattening uses a large amount of cereal grain aiming the short period fattening by high energy rations. These high energy rations contain cereal grain which are rich in readily available carbohydrates. Consequently, efficient utilization of readily available carbohydrates in high energy ration are very important problem in beef cattle fattening.

A large part of the readily available carbohydrate in cereals is generally a starch, and the readily available carbohydrates like simple sugars and starch are almost completely digested in the digestive tract. In the ruminants, it is well known that the most of these carbohydrates are degraded into volatile fatty acids (VFA) by microorganisms and absorbed as energy source in the forestomachs. However, it is also well known that a part of the carbohydrates escaped the degradation in fore-stomachs and flow into the abomasum. Some reports on the quantity of starch passing into the abomasum are available, though they have not been satisfactorily explained in those reports the relation between the amount of the readily available carbohydrates which escape the rumen fermentation especially starch, and the amount of starch in the ration.

It could be assumed that the state of fermentation in the rumen affected the amount of starch which escaped the rumen fermentation in the previous experiment. In the present

study, a large amount of steam rolled barley was fed to the sheep to obtain more informations concerning the effect of the amount of starch in ration on starch digestion of ruminant.

### Experimental

Two adult Japanese Corriedale wethers weighing about 37kg (sheep No. 1) and 40kg (sheep No. 2) which were fitted with ruminal and abomasal fistulas according to the DOUGHERTY's method<sup>1)</sup>. After two months' healing period they were kept singly in pens and fed two kinds of experimental rations consisting of steam-rolled barley and alfalfa hay cube at different ratios as shown in Table 1. The amount of ration given to each animal was 3% of body weight (nearly the maximum intake) per day, which were divided into two equal portions and was given at 9:00 a.m. and 6:00 p.m. respectively. Water and mineral block were available at all time.

In the first period, the ration consisting of stem-rolled barley and alfalfa hay cube, 50:50 in weight ratio was given to the animals for 7 days. Then, about 10 ml of ruminal digesta was collected from the rumen via rumen fistula three hours after every morning feeding for three days. The pH value of fresh ruminal digesta was measured by the pH meter immediately. About 70 ml of abomasal digesta was collected for consecutive three days from the abomasum via abomasal fistula two, four and six hours after morning feeding. The ruminal and the abomasal digesta were stored in a freezer at  $-20^{\circ}\text{C}$  until analysis. Thereafter, each animal was removed from pen to individual metabolic stall to collect feces for determination of the total digestibility of starch in the ration.

Similar experimental procedure was followed in the second period, except the different ration which consisted of 80% steam-rolled barley and 20% alfalfa hay cube were given to the animals. Composition of high or low starch experimental diet is shown in Table 1.

Total VFA concentration and molar proportion of VFA of ruminal digesta were determined by Packett and MACUNE's method<sup>2)</sup>. Abomasal digesta were homogenized in the glass homogenizer jacketed with ice water and the amount of starch and simple sugars (80% ethanol soluble carbohydrate) were determined by the CLEGG's method<sup>3)</sup>. The lignin ratio technique<sup>4)</sup> was used to determine the amount of starch escaping into the abomasum which was expressed as percentage of starch intake and whole digestibility. The lignin as an indicator in the abomasal digesta, feces and ration was determined by using 72%  $\text{H}_2\text{SO}_4$ <sup>5)</sup>. To determine the dry matter of abomasal digesta 3 ml of digesta was

Table 1. Composition of diets (% of dry matter)

Diet	Starch	Ethanol soluble carbohydrate
Steam rolled barley	63.3	4.1
Alfalfa hay cube	2.2	5.5
Barley : Alfalfa		
50 : 50	32.6	5.0
80 : 20	51.0	4.5

poured into aluminium dish and dried for 24 hours at 80°C in a drying oven and weighed.

**Results**

Changes of dry matter percent of starch in the abomasum are shown in Figure 1. The amount of starch escaped into the abomasum expressed as percentage of dry matter 4 hours after feeding was the highest among the three times of sampling either in the animal fed low starch ration (50 : 50=barley : hay) or in the high starch ration (80 : 20=barley :

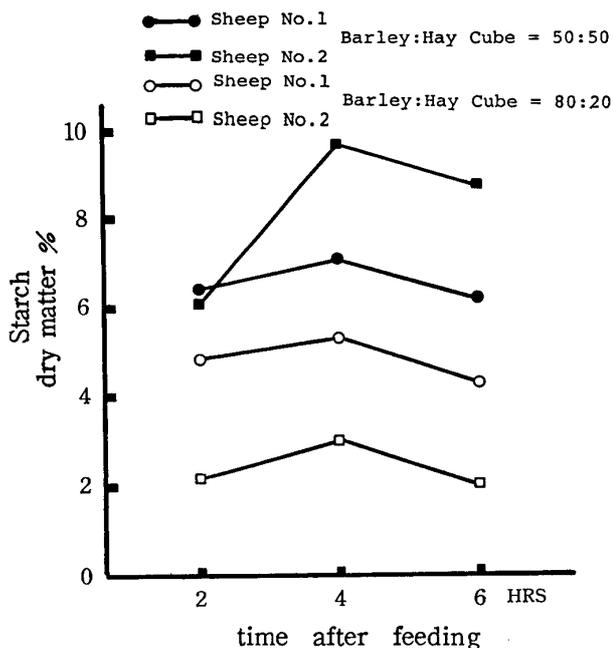


Figure 1. Starch reaching the abomasum expressed as percentage of dry matter

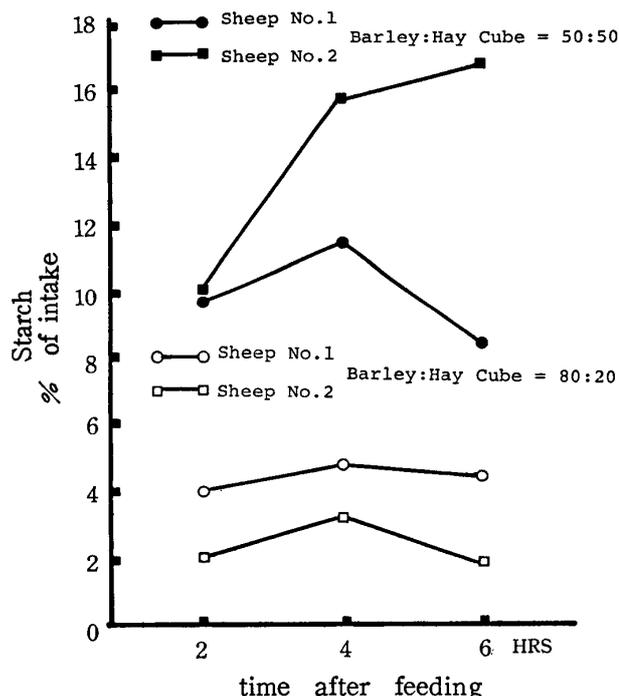


Figure 2. Starch reaching the abomasum expressed as percentage of intake of wethers

hay). The amount of starch escaping into the abomasum showed higher levels when the animal was fed the low starch ration than the high starch ration in each animal especially in the sheep No. 2.

Average dietary starch passing into the abomasum are shown in percentage in Figure 2. When the animals were fed low starch rations about 8% or more of dietary starch escaped into the abomasum. Especially in the sheep No. 2, the amount of dietary starch escaped into the abomasum reached approximately 17% 6 hours after feeding. When the animals were fed with high barley ration, the amount of dietary starch escaped into the abomasum were 5% or less at every sampling time.

Average amount of simple sugars (80% ethanol soluble carbohydrate) in the abomasum are shown in Figure 3. The amount of simple sugars appearing in the abomasum expressed as percentage of dry matter was somewhat higher in the animals fed high barley ration than low barley ration. The amount of simple sugars in the abomasum was, however, extremely low comparing with the starch in the abomasum.

The state of fermentation in the rumen three hours after feeding is shown in Table 2. When the animals were fed with high starch ration, total VFA and pH decreased, the molar proportion of butyric acid was increased as compared with low starch ration. The molar proportions of acetic acid, and acetate to propionate ratio were also affected by the change from low starch ration to high starch ration. There were differences, however, between

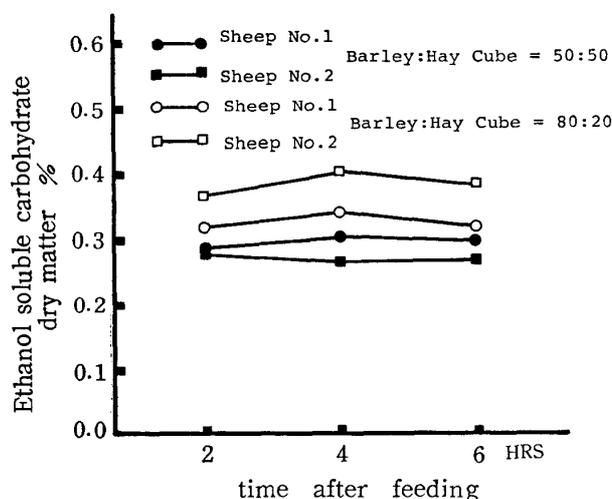


Figure 3. Ethanol soluble carbohydrate reaching the abomasum expressed as percentage of dry matter

Table 2. VFA production, proportion of VFA, pH and lactic acid in rumen of wethers

Barley : Alfalfa	Sheep No.	Total VFA mmol/l	VFA proportion mol %					pH	Lactic acid mg/dl
			C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>2</sub> /C <sub>3</sub>		
50 : 50	No. 1	65.5	61.9	28.8	7.8	1.5	2.2	6.0	trace
	No. 2	59.6	64.1	27.0	7.5	1.4	2.4	5.9	trace
80 : 20	No. 1	54.0	58.7	20.1	19.6	1.6	2.9	5.4	trace
	No. 2	44.3	61.8	19.0	18.0	1.2	3.3	5.2	93-539

Table 3. Effect of high barley feeding on starch digestion of ruminant

Barley : Alfalfa			Abomasal digesta				Total Starch
			Dry matter g/dl	Starch % of intake	Starch % of D. M.	Simple sugar % of D. M.	Diges. %
50 : 50	No. 1		4.4 ± 0.4	9.7 ± 2.2	6.1 ± 1.6	0.29 ± 0.10	99.1
	No. 2		4.1 ± 0.4	14.7 ± 8.1	8.1 ± 3.8	0.27 ± 0.07	97.0
80 : 20	No. 1		4.8 ± 0.4	4.7 ± 0.1	5.1 ± 1.4	0.32 ± 0.08	99.3
	No. 2		4.3 ± 0.4	2.8 ± 1.2	2.7 ± 1.3	0.38 ± 0.07	99.3

sheep No. 1 and sheep No. 2 in the degree of variance. The amount of the lactic acid in the rumen was increased extremely according to the shift from low starch ration to high starch ration only in the case of sheep No. 2. The amount of lactic acid in the rumen of the sheep No. 2 on high starch ration varied from day to day during the sampling period, e. g. 93, 108 and 539 mg/dl respectively.

The amount of dry matter, the amount of starch and simple sugar in the abomasum, the appearance of dietary starch in the abomasum and the total digestibility of starch are shown collectively in Table 3. These values are the averages of 3 days, each with three samplings except the values of the total digestibilities of starch. The latter was remarkably high regardless of the difference of ration or animal.

### Discussion

It was assumed that rumen fermentation was related to the amount of starch escaping into the abomasum in the previous experiment<sup>6)</sup> using two wether sheep. This estimation was obtained from the experiment using two kind of rations, namely low starch ration and high starch ration. In that case, low or high means the ratio of the concentrate to the roughage, and the amount of ration consumed by animals was only 2% of body weight per head per day. It was not that maximum intake nor a high consumption (approximately 70% of the maximum intake). Daily consumption of starch was only about 280g in dry matter per head per day when the animals were on low concentrate ration, only about 430g on the high concentrate ration.

The question then arose as to what was occurring in the relation between ruminal fermentation and the amount of starch escaping into the abomasum in the animal on a high concentrate or low concentrate ration in the maximum intake.

The daily consumption of starch by sheep No. 1 and sheep No. 2 in the present experiment were 330 and 356 g on low starch ration, and 516 and 556 g on high starch ration, respectively. The amount of starch escaped into the abomasum expressed as percentage of dry matter had a tendency to be higher on low starch ration than on high starch ration. This tendency was remarkable in sheep No. 2. A three to four fold greater amount of starch appeared in the abomasum in sheep No. 2 on low starch ration than on high starch ration. These results did not agree with the findings of the previous report. The amount of starch escaped into the abomasum expressed as percentage of dry matter was somewhat

higher in the sheep on high starch ration in the previous report.

WRIGHT et al. (1966)<sup>7)</sup> reported when the sheep were fed with ration containing 64% cracked corn, averaged concentration of amylase hydriized carbohydrate in the abomasum reached 29.4% of dry matter 3 hours after feeding, and it became 15.6% and 6.6%, 6 and 24 hours after feeding respectively. TOPPS et al. (1968)<sup>8)</sup> reported that the anthrone method and enzymic method for determining starch in feed and digesta usually gave similar result, the values obtained by the anthrone method being often a little higher than those by the enzymic method. Giving consideration to the amount of consumed concentrate, the dry matter percentages of starch in the abomasum in the present experiment were not so high.

The amount of starch escaped into the abomasum expressed as percentage of dietary starch varied considerably with the time of sampling. Especially, in sheep No. 2 on low concentrate ration, the values of the amount of starch escaped into the abomasum expressed as percentage of dry matter and dietary starch varied greatly with the sampling time. The results similar to that in the present study are found in the author's previous report and other investigators<sup>9)</sup>. These indicate that starch flow from the fore-stomachs to the abomasum is not constant. The estimates were higher on low starch ration than on high starch ration in the present experiment. This tendency was similar to the amount of starch escaping into the abomasum expressed as dry matter basis. It is hence concluded a simple relation, such as, the higher the amount of starch in the ration the higher the amount of starch escaped into abomasum was not found.

DRENNAN et al. (1970)<sup>10)</sup> reported that the abomasal samples 2 or 4 hours after feeding could have been representative of the major part of the daily flow. Abomasal samples were collected 2, 4 and 6 hours after feeding, of which the average values of estimates are shown in Table 3. It was of interest that the dry matter (g/dl) in the abomasum were almost same in two animals on different rations. There were, on the other hand, appreciable differences in the starch digestion in the fore-stomachs between the animals or the rations.

The quantity of starch digested in the fore-stomachs in the animals on low starch ration calculated from average estimates in Table 3 were 298.8g per head per day for sheep No. 1 and 304.1g for sheep No. 2, and those on high starch ration were 491.7g and 540.4g, respectively. It was obvious that a large amount of starch was digested in the fore-stomachs in the animals on high starch ration. Though the amount of starch escaped into the lower digestive tract per head per day were 32.1g for sheep No. 1 and 52.4g for sheep No.2 on low starch ration, those on high starch ration were 24.3g for sheep No. 1 and 15.6 for sheep No. 2. This indicates that the larger amount of starch flowed into the lower digestive tract in the animal on low starch ration than in those on high starch ration. Thus, it suggests that the amount of starch ingested by the animals are not parallel to the amount of starch flowing to the post abomasal digestive tract.

KARR et al. (1966)<sup>11)</sup> demonstrated when steers fed with the rations containing 20, 40, 60 and 80% corn, the passage of undigested starch from the fore-stomachs were 25.9% (357g), 36.5% (511g), 44.2% (1062g) and 31.8% (841g), respectively. In their experiment there was not a consistent trend for the percentage of escaping starch to be higher or

lower as the proportion of corn in the ration increased. As to the percentage of starch in the ration, 40 % corn ration (36.0 % starch) and 60 % corn ration (50.7 % starch) in the experiment of Karr et al. are nearly equal to the low (32.6% starch) and high starch (51.0 % starch) ration in the present experiment. The percentage of escaped starch were 25.9 % and 36.5% for 40% and 60% corn ration respectively. These results do not agree with the trend in the present experiment. They were 12.2 % and 3.8 % in averaged value for low and high starch rations in this experiment.

HOLMES et al. (1967)<sup>12)</sup> reported that starch digestion in the fore-stomachs was about 90% in the sheep on ration containing 80% steamed milo, and about 95% on ration containing 80% steam-rolled milo. They also reported that these results were similar to the experiments by sheep and cattle. These results were different with the results Karr et al. This might be owing to the increased susceptibility of grain by the heat treatment and/or pressure. So, it would be expected that the higher estimates of the degree of digestibility in the fore-stomachs might depend on ration which contained steam-rolled barley. However, McCULLOUGH and MATSUSHIMA (1973)<sup>13)</sup> reported that starch digestibility in the rumen were higher in steers fed with whole corn than steam flaked corn in all concentrate ration.

COLE et al. (1976)<sup>14)</sup> reported that 20 to 32% of dietary starch escaped the digestion in fore-stomachs when steers were fed with the ration containing 0 to 20% roughage and whole shelled corn. However, the amount of escaped starch did not increase as the amount of starch in the ration increased in their experiment.

On the other hand, Topps et al. reported when the sheep were fed daily with the ration containing 298g starch, the amount of starch passed to abomasum were only 6 to 35g. ØRSKOV et al. (1969)<sup>15)</sup> reported that the amount of dietary starch escaping fermentation in the rumen was 6.8 % on a barley diet and 12.8 % on a diet consisting of 40% dried grass and 60% barley in ad libitum feeding. NICHOLSON and SURTON (1969)<sup>16)</sup> reported that the most of dietary starch was fermented in the rumen and 5 to 11% of starch in the diet passed into the duodenum. BEEVER et al. (1970)<sup>17)</sup> reported that the amount of starch escaped into the intestine was about 4% when the sheep were fed with the ration containing 80% flaked corn as concentrate, but it increased to 22% with 80% ground corn ration. These difference may depend on the reduction in the breakdown of raw maize in the reticulo-rumen. Very similar results were reported by OTCHENE et al. (1974)<sup>18)</sup> that when the steers were fed with high grain diets, only 3.6 and 5.2% of  $\alpha$ -linked glucose polymers entered the duodenum.

The results of these investigators mentioned above can fall into two categories, namely, the case that a fairly large amount of starch escaped digestion in the fore-stomachs, and another case that a small amount of starch escaped it. The result in the present experiment may fall into latter case.

As to the state of fermentation in the rumen in the present experiment, there was little difference between sheep on low starch ration in total VFA, VFA proportion and acetate to propionate ratio. And a trace amount of lactic acid was found in rumen of the sheep on low starch ration. Total VFA, proportion of propionic acid and pH were decreased, and the proportion of acetic acid, butyric acid, and acetate to propionate ratio were increased in

the sheep on high starch ration, when ration was shifted from low starch ration to high starch ration. Fairly large amount of lactic acid, however, were found in sheep No. 2 as compared with the sheep No. 1. It indicated that the fermentation in the rumen became unstable when a large amount of readily available carbohydrate was induced to the rumen.

In the previous experiment, the highest amount of starch escaped into the abomasum in the one of the animals which were fed with diet containing 80% cooked barley, and the lowest value of pH and acetate to propionate ratio were found simultaneously. It was assumed that the rumen fermentation was not the same between the animals fed 80% barley, in the previous and the present experiments. The low pH, higher ratio of acetate to propionate and considerable amount of lactic acid indicated that the abnormal fermentation was occurred in the sheep No. 2 on 80% barley diet in the present experiment. Though the sheep No. 1 fed high starch ration produced trace amount of lactic acid in the rumen, the other values on the rumen fermentation remained substantially the same to the sheep No. 2 on same ration in the present experiment. It might be expected that the rumen fermentation of the sheep No. 1 on high starch ration was close to abnormal.

As to the relationship between the state of fermentation in the rumen and the amount of starch escaping into the abomasum, it is assumed as follows. When the state of fermentation in the rumen was relatively stable like in the case of low concentrate ration in present experiment, more amount of starch escaped into the abomasum than in the case of high concentrate diet which induced the abnormal fermentation. It may be explained that the feeding of large amount of grain brought about the abnormal fermentation in the rumen and the stagnation of feed in the reticulo-rumen, which in turn caused these slight flow of starch into the abomasum. BRUCE and HUBER (1973)<sup>19)</sup> reported that the infusion of lactic acid into the duodenum restrained the contraction of the reticulo-rumen. Kojima and SAKURAI (1978)<sup>20)</sup> and KOJIMA et al. (1979)<sup>21)</sup> reported that the lactic acid accumulated in the reticulo-rumen passed into the post ruminal digestive tract in large quantities.

Total starch digestibility was not affected by the amount of starch in ration and most of starch in ration was digested. It is expected that the efficiency of utilization of starch in ruminant was affected mainly by the site of degradation in the digestive tract.

The amount of simple sugar which appeared in the abomasum was very low and compared with the case of the starch. Similar result was also obtained in the previous experiment. It was believed that the flow of the simple sugar into the post-ruminal tract as useful energy source was little as compared to the starch.

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## 穀類の多給が、反すう動物のでんぷん消化に及ぼす影響

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**要旨** 穀類飼料を多給すると、かなりのでんぷんが反すう胃での微生物による発酵分解をのがれて第4胃へ移行してくることが報告されている。また著者らは与えた飼料の反すう胃内における発酵状況が、第4胃へのでんぷん移行量に影響すると推察し得る結果をさきに報告している。本試験においては、濃厚飼料：粗飼料比の異なる飼料を多給し、前回の結果をさらに検討した。

第1胃および第4胃にフイステルを装着した去勢成めん羊2頭(1号, 2号)に圧片大麦：アルファルファヘイキューブ=50：50および80：20の飼料を1日1頭当り、体重の3%を朝夕等分して与えた。7日間の予備期の後、飼料給与3時間後に第1胃液を、2, 4および6時間後に第4胃液をそれぞれ3日間採取し、また消化率測定のため糞を採取した。採取したサンプルより、第1胃内VFA産生状況、第4胃へのでんぷん移行率、第4胃内エタール可溶性糖量およびでんぷん消化率を測定した。また採取したサンプル中のリグリン含量を測定し、第4胃移行率および消化率を求めるための指標とした。

50：50に比して80：20では、VFA総量およびpHは低下し、 $C_2/C_3$ は上昇した。とくに2号羊で著しかった。2号羊では乳酸の含量が顕著に高かった。でんぷんの第4胃内乾物中パーセントおよび第4胃への移行率は50：50で高く、また80：20においては2号羊において低い傾向がみられた。第4胃エタノール可溶性糖は量的にデンプンに比してわずかなものであった。でんぷんの消化率は50：50および80：20の間に差はみられずほとんど完全に消化されていた。