The Fasting Metabolism of Adult Goats.

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ヤギの絶食時代謝について

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INTRODUCTION

It has been realized that if an animal is not given a food and certain other conditions are met, the heat production measured represents minimal demand of that animal. The measurements of this type are called basal metabolism determinations, and for this measurement, the conditions are that the animal should be in a post-absorptive state, and it should be in a state of muscular repose though not asleep. In normal and healthy animals, the condition of muscular repose cannot be ensured unless the measurement is very short period. Therefore, it is usual to measure the metabolism for a fairly long period of time in the confines of the apparatus. This measurement is called the fasting metabolism. With ruminants, the difference between the basal metabolism and the fasting metabolism is not great, because muscular activity is minimal under these conditions.[1] In view of this consideration the heat produced when a ruminant is fasted in a certain condition is a measure of the energy needed to maintain that ruminant animal.

There are many investigations on energy metabolism of ruminants in the fasting condition.[2)3)4)] From the estimation of heat production of goats in a fasting condition, TASAKI[2] reported that the net energy for maintenance of 50 kg body weight was 1018 Cal. per day. HIROSE and ASAHIDA[5] also has shown with two castrated male goats that the energy requirement for maintenance of 50 kg body weight was 936 Cal. per day.

Recently, FUJIHARA et al.[6] reported of a simple technique for tracheal cannulation with goats, and using this method they described that the average heat production was 3.55 Cal./kg body weight$^{3/4}$ per hour on 5th, 6th and 7th days of fasting.[7] The objective of the present experiment was to obtain the detailed data of fasting metabolism in goats using the method of the tracheal cannulation.

EXPERIMENTAL PROCEDURE

Animals : One male and two female Japanese Saanen goats named A, B and C,

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weighing 32, 26 and 35 kg respectively, were used. Two goats (B and C) were fitted with a tracheal cannula by the method of FUJIHARA et al.[6] After recovered from the suffer by the surgical operation of the tracheal cannulation, the animals were placed into the metabolism cages to collect feces and urine separately.

Measurement of heat production : The goats were given a ration of hay, calculated to be sufficient to prevent its losing or gaining weight, for at least 10 days before the determination of fasting heat production began. This procedure was adopted because MARSTON[8] showed that the level of feeding of sheep before a fast had a marked effect on the length of time it took to reach a minimal metabolism. The total length of fast was consecutive 7 days. On the 5th, 6th and 7th days of fasting, expired gas was collected in a Douglas bag through the respiration mask[9] in goat A or the tracheal cannula in goats B and C for 10 minutes in each time. The collection of expired gas was performed at 9, 11, 13, 15 and 17 hours, and the collected gas was used for oxygen and carbon dioxide analysis. The heat production was calculated with reference to the report of TASAKI and SAKURAI.[10] Feces and urine were collected at 9 hour in each day of fasting to determine the nitrogen excretion. In goats B and C, about 5 ml of jugular blood was sampled at just before the gas collection at 9 hour on the final day of fasting, and plasma amino acid concentration was determined.

Analytical method : The Kjeldahl method was employed to determine the nitrogen content of feces and urine. The concentration of plasma amino acid was analyzed by ion exchange chromatography[11] on automatic amino acid analyzer (KLA-5 Model, HITACHI Co. Ltd.).

RESULTS and DISCUSSION

Figure I shows the daily changes of body weight. The body weight rapidly decreased during the first few days of the trial, and then the decrease became slow and the rate of decrease in body weight seemed to be almost constant in three goats. This rapid decrease of body weight during the first stage of the trial might be mainly due to the feces excretion. The slow decrease of body weight during the second stage may

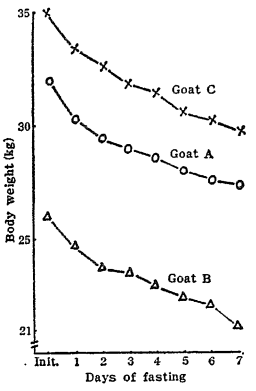

Fig. 1. Cahnges of body weight

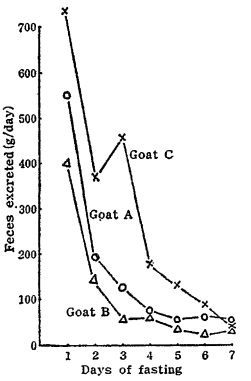

Fig. 2. Changes of feces excretion.

be considered to be due to the losses of the body constituents caused by fasting. This problem will be discussed later from the result in measurement of the heat production of goats in fasting condition.

As shown in Figure 2, the excretion of feces decreased rapidly during the first few days as in the case of the diminution in the body weight. According to TASAKI,[9] even on the 15th day of fasting a small amount of feces was excreted ; however, the residual part of the ingested feeds was not found in the feces, and he described that the condition of fasting also may be predicted by determining the state in which the animal's very large feces excretion ceases. Using barium sulfate as an unigestible marker in the gastro-intestinal tract, TASAKI[12] also described that when goats were given barium sulfate no trace of it could be found in the feces on the 4th day after fed, and therefore, goats were in a condition of fasting on the 4th day of starvation. BALCH[13] showed with cattle using the stained particle technique that the major part (80-90%) of a meal is usually excreted within 24-96 hours of its ingestion. The result obtained in the present experiment was in good agreement with the result of TASAKI.[9]

Fecal nitrogen excretion are shown in Figure 3. On the 7th day of trial fecal nitrogen excretion was 0.4-0.8 g per day in three goats. This fecal nitrogen may not largely originate from the previous diet, since the goats were fed no nitrogenous materials. This may be explained by the result of TASAKI[9] and BALCH[13] in which the fasted animals were in a post-absorptive condition on the 4th or more days of fasting. According to UKAI,[14] the metabolic fecal nitrogen was calculated as 1.34 g per day in goats infused the non-protein purified diet into the abomasum. From these results, it is suggested that the fecal nitrogen may be considered to be metabolic nitrogen at least on the 7th day of fasting.

The daily changes of urinary nitrogen excretion during the fasting 7 days are shown in Figure 4. The urinary nitrogen excretion in goat C was higher than those of goats A and B. This may be due to difference of body weight in the experimental animal. The similar pattern in urinary nitrogen excretion was not observed in three goats during the 7-day experimental period ; however, at least after 4 days of fasting urinary

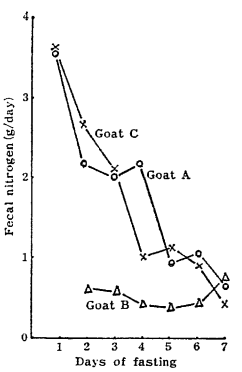

Fig. 3. Fecal nitrogen excretion.

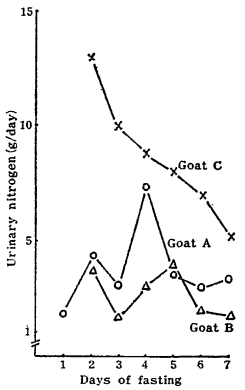

Fig. 4. Urinay nitrogen excretion

Table 1. Heat production of goats calculated by BENEDICT's method

Goat	O_2 Consumption (l/day)	CO_2 Elimination (l/day)	R. Q.	Heat production (Cal./day)
A	165.45	118.60	0.717	755.15
B	114.27	81.23	0.711	536.00
C	162.30	117.90	0.736	765.02

nitrogen may be considered to originate from the decomposed body protein, because the goats were given no materials containing nitrogen.

Heat production calculated by BENEDICT's method is shown in Table 1. In goat B, heat production was slightly lower than those of goats A and C. It is generally recognized that a large animal produces more heat than a small animal. As shown in Table 1, the heat production in each goat varies with each other to such a degree because of the difference in the body weights of the experimental goats. Table 2 shows the heat production calculated by LUSK's method. The heat production from protein decomposition was about two times higher in goat C than those of goats A and B, and consequently the ratio of the heat production from protein decomposition to the total heat production was 20.4% in goat C, while it was 12.6 and 10.7% in goats A and B, respectively. BLAXTER[3] reported with adult wether sheep that about 20% of the heat produced was derived from protein on the 3rd and on 4th day of fasting. In comparison with the two method in energy calculation, the difference of heat production was 1-2%, and this result is in agreement with that reported by TASAKI and SAKURAI[10] using the cockerels in fasting condition.

In order to compare the individual heat production of each animal, the values shown in the Tables 1 and 2 must be converted to a common denominator. The standard body weight for goats is generally designated at 50 kg. Using the method stated in the report of TASAKI[9], the converted values from the results in the Tables 1 and 2 are shown in the Table 3. The heat production per day per 50 kg body weight of goat in fasting condition was 1108.36, 941.85 and 1059.80 Cal. in goats A, B and C, respectively ; when calculated as the heat production is proportional to the body surface area. The average value of heat production for three goats was 1036.67 Cal. per day. This result was very comparable with that of TASAKI[2] in which the heat production of

Table 2. Heat production of goats calculated by LUSK's method

Goat	O_2-Consumption (l/day)	CO_2-Elimination (l/day)	Nitrogen excretion (g/day)	Non-protein R. Q.	Heat production: From protein (A) (Cal./day)	Heat production: From N.P.S* (Cal./day)	Heat production: Total (B) (Cal./day)	(A)/(B) (%)
A	165.45	118.60	3.34	0.712	79.40	660.08	739.32	10.7
B	114.27	81.23	2.81	0.709	65.98	474.90	540.66	12.6
C	162.30	117.90	6.57	0.724	154.25	599.70	753.95	20.4

* Non-protein substances.

Table 3. The heat production per 50 kg body weight of goats (Cal./day)

Goat	Based on body surface area (B. W. $kg^{2/3}$)		Based on metabolic body size (B. W. $kg^{3/4}$)	
	B* method	L* method	B* method	L* method
A	1124.59	1108.36	1169.21	1140.34
B	933.78	941.85	1000.98	1009.66
C	1075.32	1059.80	1160.05	1120.27

* B ; BENEDICT's, L ; LUCK's

goats fasted was 1017.53 Cal. per day per 50 kg body weight, when it was calculated based on the body surface area. On the other hand, when calculated on the assumption that the heat production is proportional to the metabolic body size, the heat production per 50 kg of goat in the fasting condition was 1140.34, 1009.66 and 1120.27 Cal. per day in goats A, B and C, respectively. These figures are averaged to be 1090.09 Cal. per day in three goats. TASAKI[9] reported that the heat production of fasted goats was 1063.9 Cal. per day per 50 kg body weight, when, it was calculated based on the metabolic body size, and also he stated that in goats the values of heat production calculated by using the power 0.75 was larger than those calculated by using the power two thirds if the animals were lighter than the standard weight, when 50 kg was taken as the standard body weight for goats. In the present experiment it was impossible to clarify which method of conversion was the most suitable ; however, the difference of the heat production between the two methods may be explained by TASAKI's suggestion[9], because the body weights of the experimental animals used in the present study were smaller than the standard body weight (50 kg) of goat adopted in calculation of the heat production. From the result in the present study, it is concluded that the daily heat production of goats weighing 50 kg was 1040-1090 Cal. in the fasting condition. KLEIBER[15] presented the following formula : *Basal Metabolism*= $70W^{0.75}$, and calculated with this formula, the heat production of goat per 50 kg body weight is 1316 Cal. per day. BLAXTER[3] also reported with adult wether sheep that the heat production per 50 kg body weight per day was 1016 Cal. in a fasting condition. The heat production in the present experiment was slightly high compared with those of TASAKI[9] and of BLAXTER[3], and was fairly lower than that of KLEIBER[15]. According to MARSTON[8], the level of feeding of sheep before fasting had a marked effect on the length of time it took to reach a minimal metabolism. The difference between the value in the present study and that described by other workers[3)9)15)] may be explained by the result of MARSTON[8], because the condition before fasting was not always similar in those experiments mentioned above.

It may be considered that the heat production of animals in a fasting condition is equal to the net energy requirement for maintenance, and therefore, 1040-1090 Cal. correspond to the net energy necessary for the maintenance of a goat weighing 50 kg. According to HIROSE and ASAHIDA[5], the goats required 936 Cal. per day per 50 kg

body weight when the net energy for maintenance was measured by an indirect method. This value is about 150 Cal. lower than that obtained in the present study, the difference between these two values may be due to the difference of the methods in measuring the heat production. Recently, FUJIHARA et al.[7] reported that the average heat production was 1605 Cal. per 50 kg body weight per day on the 5th, 6th and 7th days of fasting. The discrepancy between the result in the present study and that obtained previously[7] was occurred despite the experimental procedure being almost similar in both experiments ; however, the age of experimental animal was not always the same in both experiments. BLAXTER[3] described with sheep that the basal metabolism was tended to fall with age ; therefore, in goats it seems that the relationship between the age and the basal metabolism is similar to that in sheep.

The concentration of plasma total amino acid was 121.2 and 145.4 μm/100 ml in goats B and C, respectively. The ratio of essential to non-essential plasma amino acid concentrations was 0.85 and 0.72 in goats B and C, respectively. There are few information of the plasma amino acid concentration of goats fasted for a long time. With sheep, CROSS et al.[16] recently reported that the concentration of plasma amino acid was 257.9 μm/100 ml, and the ratio of essential to non-essential plasma amino acid concentrations was 0.66 in 24 hour postprandially. The concentration of plasma total amino acid obtained in the present study was extremely low compared with that of C et al.[16] and the ratio of essential to non-essential plasma amino acid concentrations in the present experiment was higher than that of CROSS et al.[16] The low level of plasma amino acid in the present study may be considered to be due to the long period of fasting ; however, to obtain a clear evidence, further experiment should be carried out somewhere else.

SUMMARY

In order to investigate the fasting metabolism of goats, the present experiment was carried out using a castrated male and two tracheostomized female Japanese Saanen goats, weighing 26-35 kg. The total length of fast was consecutive seven days, and feces and urine were daily collected for the determination of nitrogen excretion. On the 5th, 6th and 7th days of fasting, expired gas was collected for oxygen and carbon dioxide analysis. In two goats, the jugular blood was sampled for measurement of plasma total amino acid concentration on the final day of fasting. From the data of oxygen consumption and nitrogen excretion in the urine, the amount of body protein decomposed and heat production were calculated. The following results are obtained.

1. The body weight rapidly decreased during the first few days of fasting, and then the decrease became slow and the rate of decrease in body weight seemed to be almost constant. The degree of decrease in body weight was almost parallel to the excretion of feces and body materials.
2. The fecal nitrogen excretion was 0.4-0.8 g per day on the 7th day of fasting, and this amount might be considered to be metabolic fecal nitrogen.
3. In calculating the heat production of goats, LUSK's and BENEDICT's methods

coincided comparatively well in results. The difference in value between these methods was 1 to 2 per cent.

4. The heat production from protein decomposition was 12.6-20.4% of the total heat production on the 5th to 7th day of fasting.

5. The heat production per 50 kg body weight of a goat was 1036.67 Cal. per day in fasting condition when it was calculated based on the body surface area. When it was calculated based on the metabolic body size, the heat production was 1090.09 Cal. per day per 50 kg body weight of a goat.

6. The concentration of plasma total amino acid was 121.2 and 145.4 μm/100 ml, and the ratio of essential to non-essential plasma amino acid concentrations was 0.85 and 0.72 in goats B and C, respectively, on the 7th day of fasting.

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摘　　要

ヤギの基礎代謝に関する詳細な資料を得る目的で，成ヤギ3頭（2頭は気管カニューレ装着）を用い，絶食7日間における糞尿中への窒素排泄量および最後3日間にガス代謝の測定を行い，次の様な結果を得た．1：体重は絶食開始後2日間は急激に減少するが，それ以後減少速度はゆるやかで大体一定していた．2：糞中への窒素排泄量は絶食7日目で 0.4～0.8g/日であり，この量は食餌由来のものではなく，代謝性のものであると考えられた．3：BENEDICT の方法および LUCK の方法によって算出した全発生熱量は，比較的よく一致し，その差は1%前後であった．4：全発生熱量中にしめる体蛋白質分解による発生熱量は，絶食5日～7日目で10.7～20.4%であった．5：体重 50kg 当りのヤギの発生熱量は，体表面積を算出の基礎にすると 1040Cal./日であり，体量を基礎にして計算すると 1090Cal./日であった．6：絶食7日目の血中全遊離アミノ酸濃度は 121.2～145.4μm/100ml であり，可欠アミノ酸に対する不可欠アミノ酸の比は 0.85～0.72 であった．