STUDIES ON THE DIGESTION IN THE DOMESTIC FOWL I. "ARTIFICIAL ANUS OPERATION" FOR THE DOMESTIC FOWL AND THE PASSAGE OF THE INDICATOR THROUGHOUT THE DIGESTIVE TRACT

STUDIES ON THE DIGESTION IN THE DOMESTIC FOWL

I. "ARTIFICIAL ANUS OPERATION" FOR THE DOMESTIC FOWL AND THE PASSAGE OF THE INDICATOR THROUGHOUT THE DIGESTIVE TRACT

By

Ken-ichi IMABAYASHI, Masao KAMETAKA* and Tadashi HATANO

Department of Animal Hasbundry, Faculty of Agriculture, Tohcku University, Sendai, Japan

**Department of Agricultural Chemistry, Faculty of Agriculture, University of Tokyo, Tokyo, Japan*

(*Received August 11, 1955*)

Introduction

It is well known that the domestic fowl have a special digestive system comparing with the domestic mammalian animals. The most peculiar point of that system is the cloaca, which is the "only-one" opening for excretion of feces and urine together (so-called "excreta"), while the crop, preventricule and gizzard, instead of the stomach of the mammalian are the other characteristics of it. On the other hand, the domestic fowl, because of their nature to fly, have a comparatively short digestive tract.

The digestibility of the feeds with the domestic fowl have been first studied in 1878 by Mehlis (1) on the crude fiber, and many evidences were made thereafter. However, because of the peculiarity of the digestive systems as described above, measurement could not be made as to the composition of true feces which differ from the excreta of the domestic fowl. Since 1902, when Paraschtschuk (2) first tried to collect the feces separated from the urine by applying the "*artificial anus operation*" for the domestic fowl, many investigators have tried this procedure and studied on the digestibility of feeds with domestic fowl. Katayama (3) reported on the conversion formula to calculate the digestibility of feeds depending upon the analytical values measured on the excreta. However, he and other investigators who tried to make this operation reported that the fowl which was operated upon died, except for a few instances, in a comparatively short time due to the some kind of constipation of unknown reason.

We attempted to exclude this obstruction on the measurement of digestibility of feeds with domestic fowl by improving the technique of artificial anus

operation, and then to know whethere there is any difference between the normal fowl and operated one according to the time of passing of the indicator through the digestive tract.

Experimentals

Part I. Artificial Anus Operation

Seven domestic fowls of 6 to 18 months old were used in this experiment. One of them was Plymouth-Rock and the others were White Leghorn. They were kept in the metabolic cage and 90 g of the commercial fowl diet was divided into three equal parts, which was fed three times at 9:00 A.M., 1:00 P.M., and 5:00 P.M., respectively. Fresh water was supplied freely. The cage and feeding vessels are shown in Fig. 9.

The method of operation is as follows:

Purpose: To collect the feces of the domestic fowl separated from the urine.
Instruments: Common surgery instrument, and fowl holder.
Anesthesia: Not needed, especially.

(1) Hold up the fowl in supine position on the holder by means of the rubber cord, as shown in Fig. 1.

(2) Feathers around the cloaca were removed, and the operating portion is disinfected.

(3) The longitudinal incision is made on the abdominal wall on the left side along the median line between about 1 cm below the zyphoid process of sterum and above the os pubis (Fig. 2.).

(4) The peritoneal approach is made to the abdominal cavity, and the wound is opened to detect the rectum (Fig. 3).

(5) The rectum is drawn up slowly by means of the bending stick made from glass.

(6) The rectum is ligated just before the cloaca. Attention should be made to ligate the rectum not with the blood vessels which supply the blood to it (Fig. 4).

(7) The rectum is cut off and tied to the cannula with its tail end (Fig. 5).

(8) The abdominal muscle is cut around to suit the cannula, and is sutured to the cannula.

(9) The abdominal skin is treated just as the muscle (Fig. 6).

(10) The fowl should be starved for 24 hours before and after the operation.

c. f. (7) and (8) were abridged when the cannula was not used. In this case, the rectum was sutured directly to the abdominal wall (Fig. 7).

No. 1 fowl was operated upon with only suturing the rectum to the abdominal wall directly, and No. 2 was with suturing the rectum to the abdominal wall which was cut around to suit the section of the rectum. No. 3 fowl was operated upon with glass cannula to which the rectum was bound and the

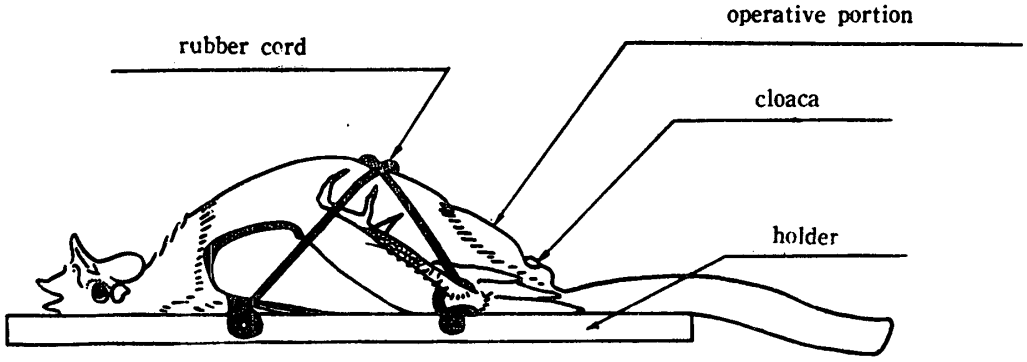


Fig. 1. Holding of fowl on the holder.

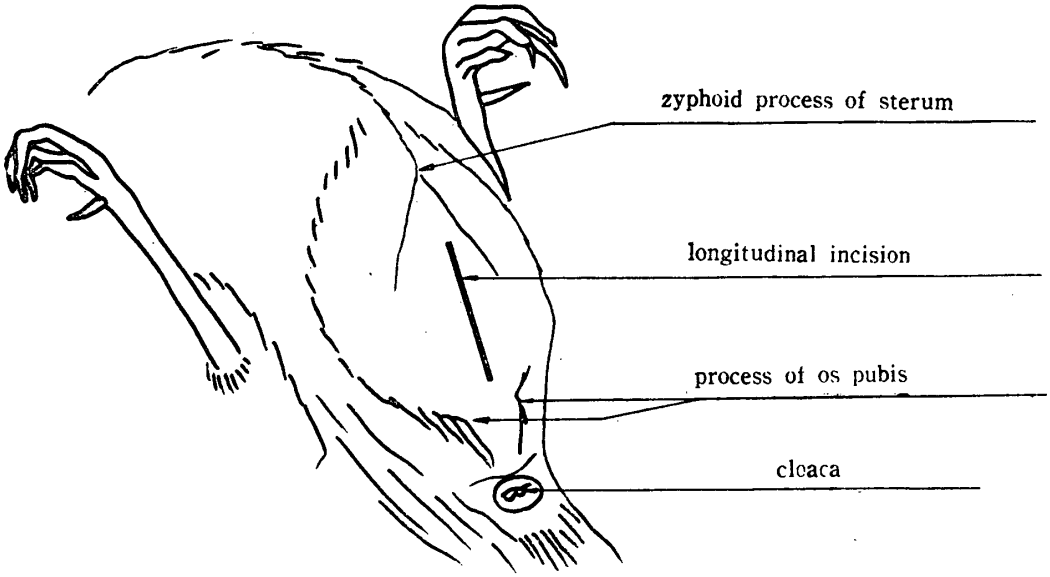


Fig. 2. Portion where the incision is made.

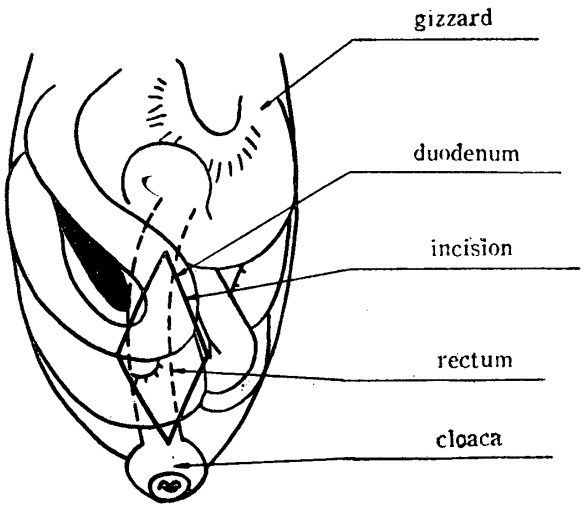


Fig. 3. The distribution of digestive tract observed from the incision.

abdominal wall was sutured. Fowls Nos. 4 and 5 received the same operation as No. 2 fowl. Nos. 6 and 7 fowls received operation with a metal cannula to which the rectum and abdominal wall were sutured. The shapes of the cannula used are shown in Fig. 8.

The fowls operated upon died in about 3 weeks after the operation in the case of No. 1; after two weeks, in No. 3; after three weeks, in Nos. 4, 6 and 7. Nos. 2 and 5 fowls were killed after ten and three weeks, respectively, for other purposes. Autopsy was made in every case.

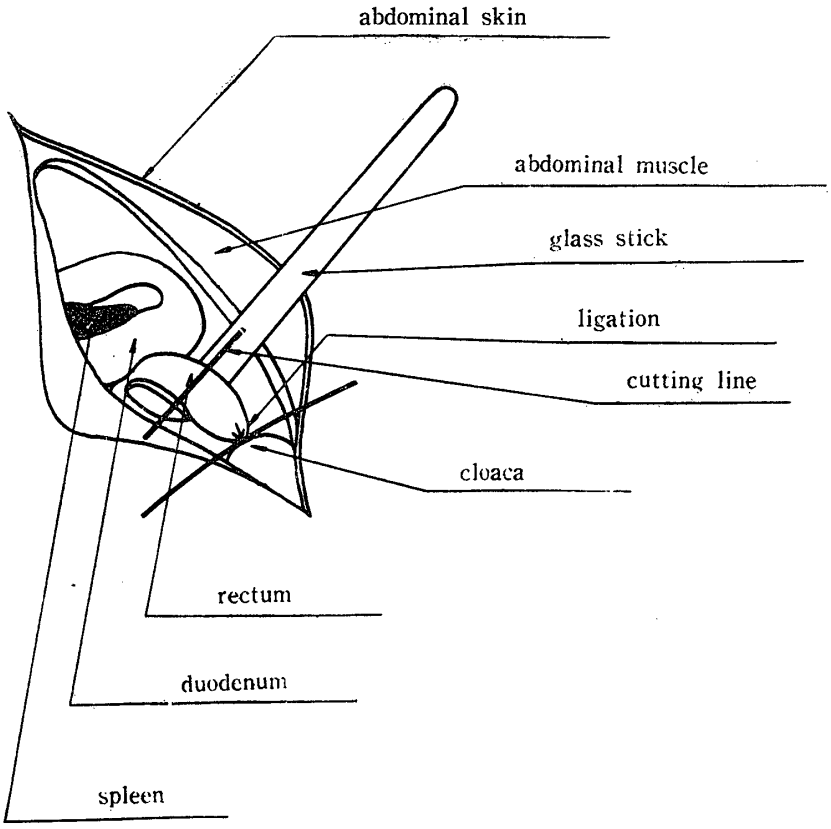


Fig. 4. The ligation of rectum, drawing up with glass stick.

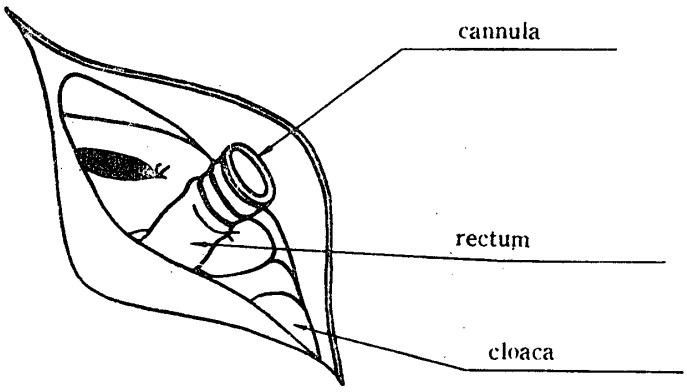


Fig. 5. The binding of cannula with rectum

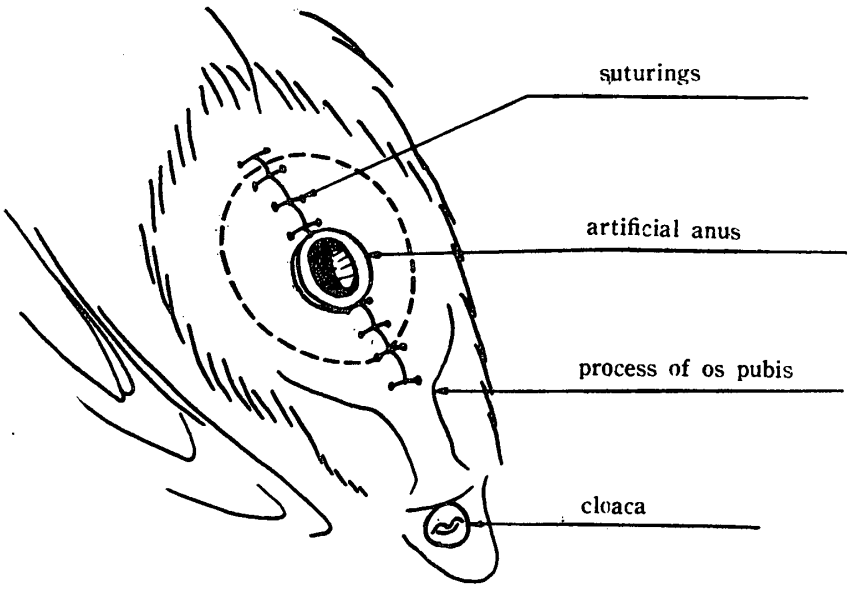


Fig. 6. The relation of artificial anus and cloaca.
The broken line shows the suturing line of feces collector.

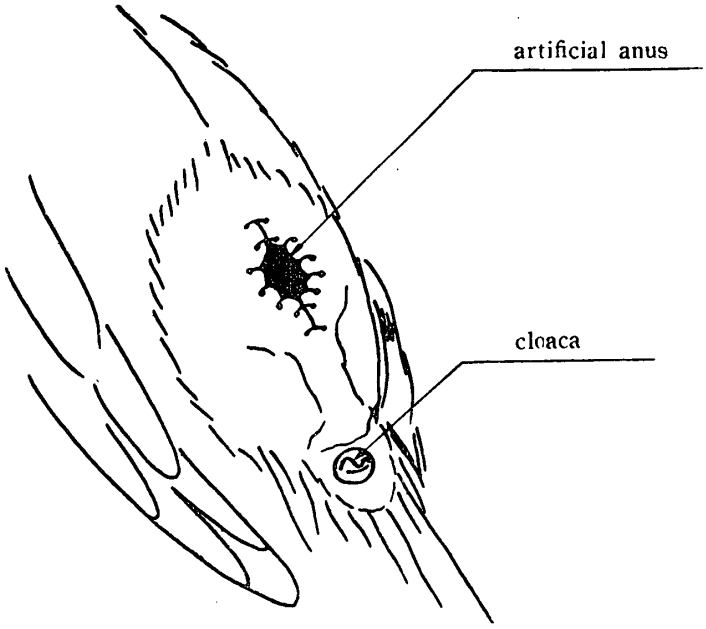


Fig. 7. The relation of artificial anus and cloaca in the case of operation without cannula.

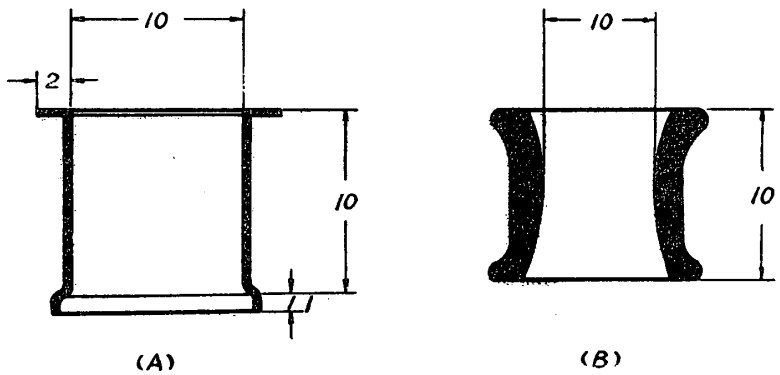


Fig. 8. The cannula used, made from metal (A), and glass (B). (scale in mm)

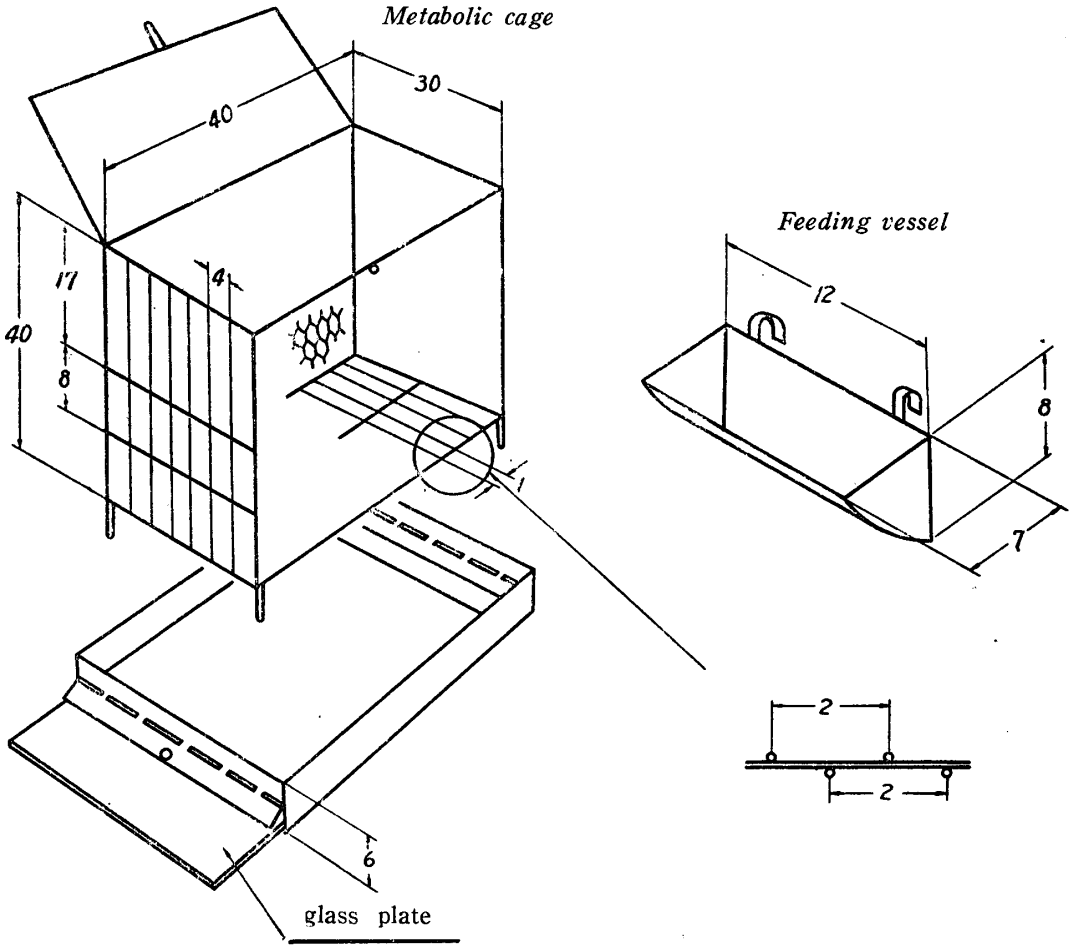


Fig. 9. The metabolic cage and feeding vessels used.
(scale in cm)

Part II. Indicator Experiment

Fowls Nos. 4 and 5 described above were used in this experiment. The feeding condition was the same as described in Part I.

$BaSO_4$ labeled with S^{35} was precipitated together with 5,000 times of stable $BaSO_4$, and was used as the indicator. 100 mg of the labeled $BaS^{35}O_4$ was enclosed with thin wafer and administered into the aesophagus at the time as follows:

Trial 1. and Trial 6.	Administration at 9:00 A.M.
Trial 2. and Trial 5.	Administration at 1:00 P.M.
Trial 3. and Trial 4.	Administration at 5:00 P.M.

The indicator was administered into the aesophagus when half of the feed was taken, by means of the special-made gun shown in Fig. 10. Finally, the indicator was ingested, being sandwiched between a half-and-half of the feed.

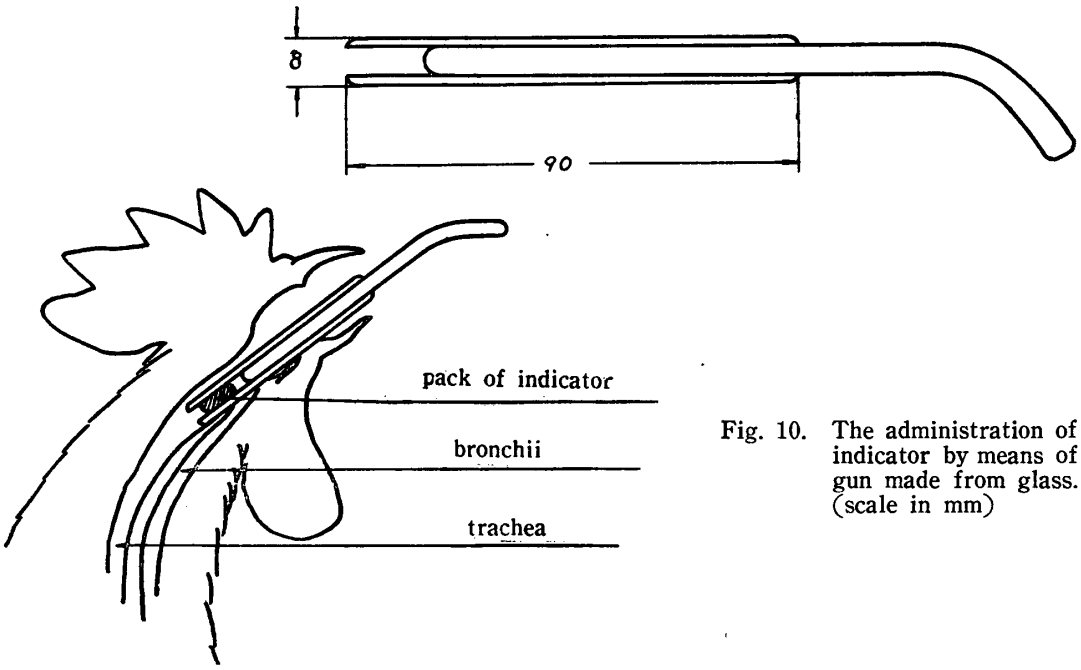
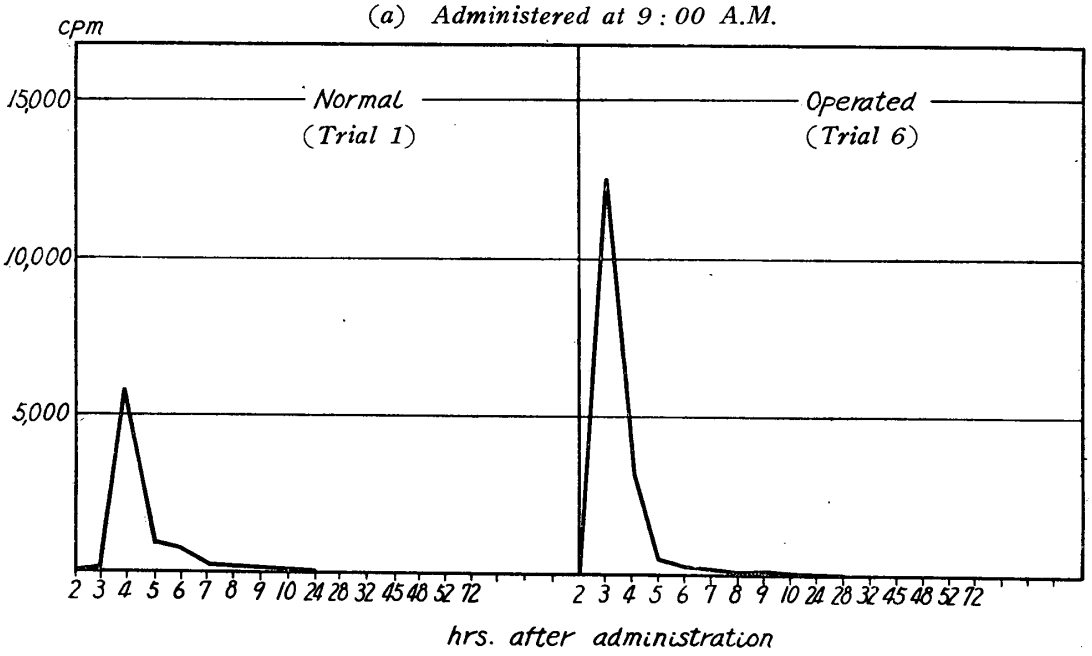


Fig. 10. The administration of indicator by means of gun made from glass. (scale in mm)

No. 5 fowl was used at first in the non-operated condition. The fowl was caged for five days before the first administration of the indicator for Trial 1. Six days thereafter Trial 2 began with administration at 1:00 P.M. Trial 3 was performed seven days of after Trial 2 with administration at 5:00 P.M. Then the fowl was starved for 24 hours before artificial anus operation. Five days after the operation, Trial 4, in the same manner as Trial 3, was carried out, and then Trial 5, as in the case of Trial 2, was begun. Trial 6 was performed as in Trial 1 six days later. Trials 1 to 3 were carried out



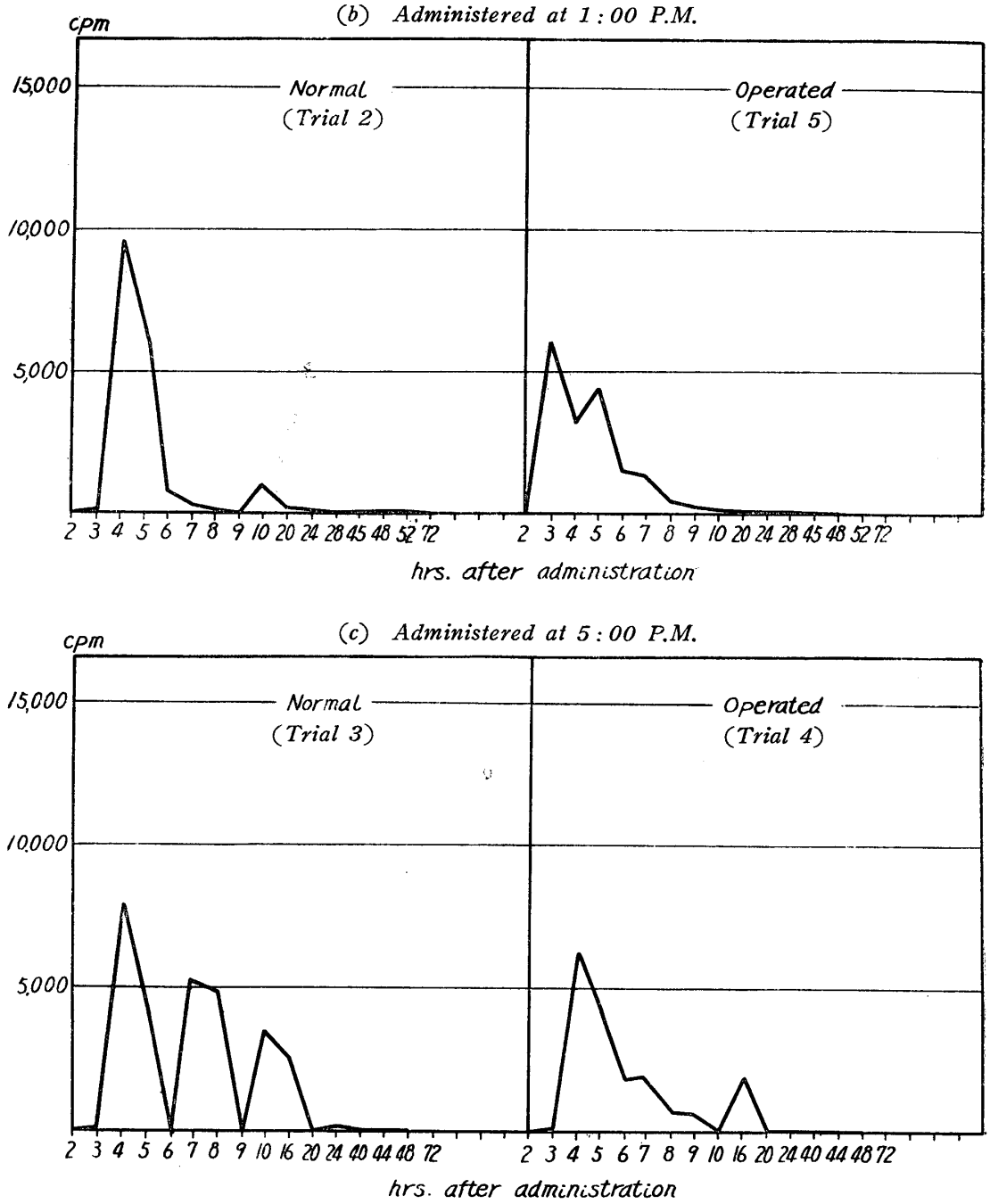


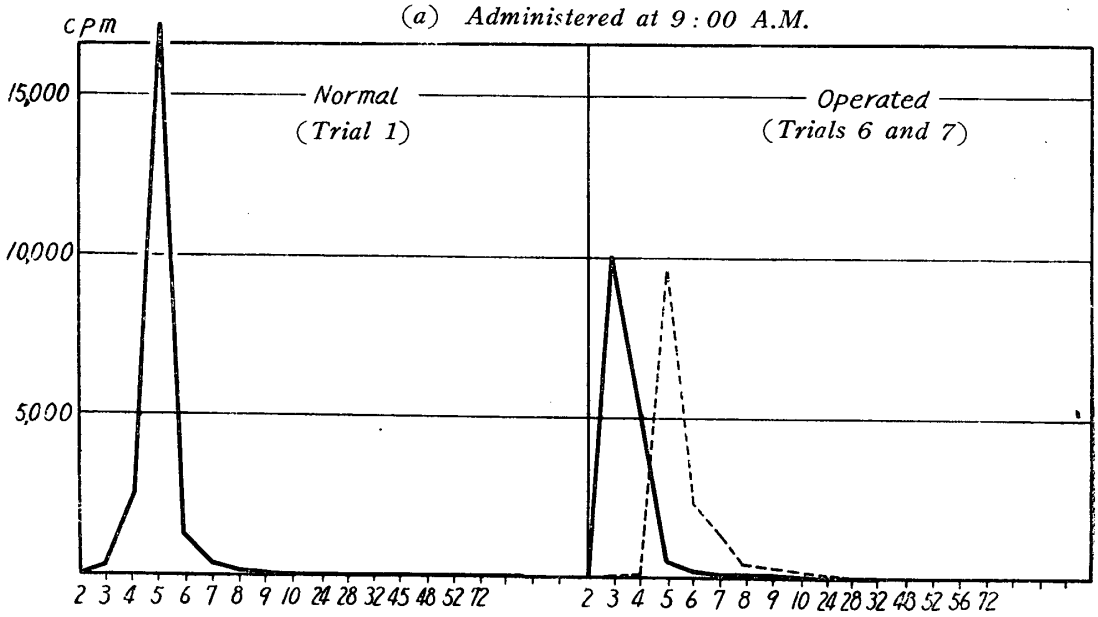
Fig. 11. The specific activity of the indicator appeared in the excreta or feces after the administration. The values are shown count/minute/g of dry matter.

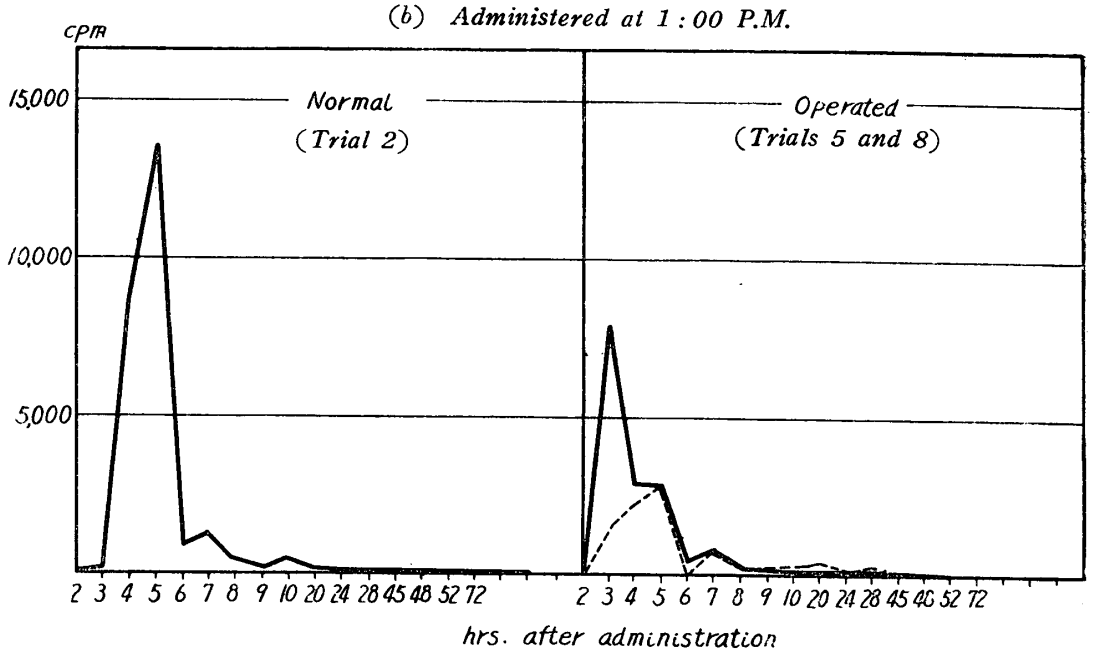
in the nonoperated condition, and Trials 4 to 6, which is the same as Trials 1 to 3, and reversal in its order, were performed in the operated condition.

No. 4 fowl was used as the auxiliary animal, and Trial 7, in the same manner as Trial 1, and Trial 8, as in the case of Trial 2, were carried out in the operated condition.

The feces were collected hourly until one to ten hours after the administ-

ration as is shown in Fig. 11 (a, b, c) and Fig. 12 (a, b, c). To collect the feces, the special-made collector shown in Fig. 13 was used. The collector consists of a columnar acceptor and collecting bottle, and the acceptor which is made from vinyl film was sutured directly to the abdominal wall. The urine, or the excreta in the case of nonoperated condition, were collected by means of the glass plate laid down under the cage, with careful attention for the contamination by the feeds or feather dirts.





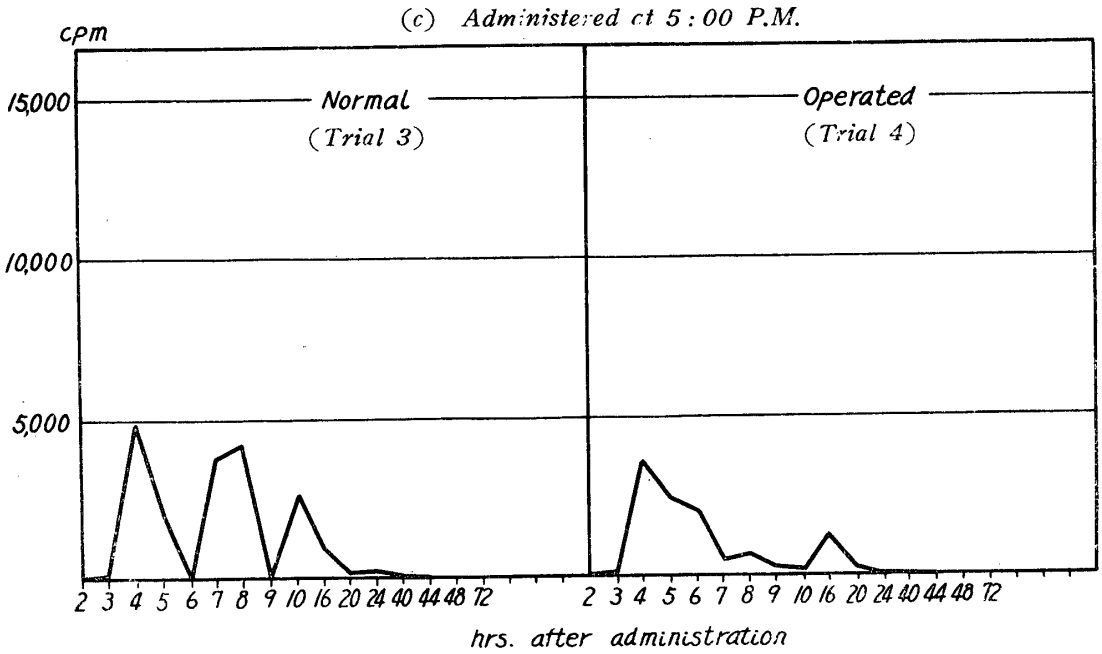


Fig. 12. The total excretion of the indicator in the total excreta in the case of the normal and in the feces in the case of the operated fowl.
The broken line shows the values for No. 4. fowl.

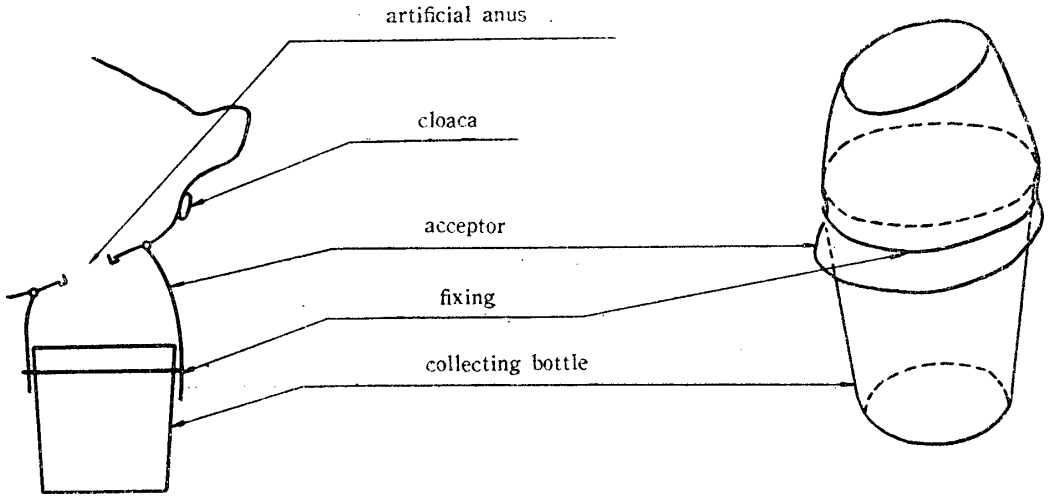


Fig. 13. The feces collector and its acceptor.

Feces collected were weighed and dried in the electric oven at 60°C, and ashed under a dull red flame. At first, about 2 g of the sample was burned, and the ash obtained was mixed with about 1 gm of the crystallin magnesium acetate, and ashed again. Then the ash was mixed with about 10 ml of 10 per cent solution of magnesium nitrate, and placed on the boiling water bath to evaporate, and ashed again. Finally, about two or three drops of concentrated nitric acid was added to the ash, and ashing was continued. By such procedure, fairly pink or white gray ash was obtained.

Both excreta and urine was treated in the same manner.

20 mg of the ash was weighed and placed on a small stainless steel disk (Fig. 14) to measure its radioactivity. The ash was mixed with a few drops of distilled water in the disk, and dried up on the boiling water bath. The radioactivity was measured on this apparatus by means of the Geiger-Müller tube with thin mica window made by the Kobe Kogyo Company. The cpm (count per minute) value was calculated according to the formula described by Kamen (4), depending on the values for five minutes measured four times.

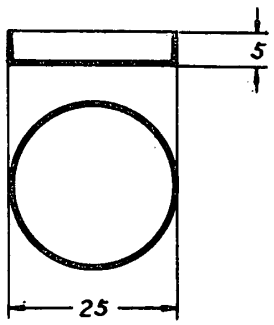


Fig. 14. The stainless steel disk on which the radioactivity of the sample was measured. (scale in mm)

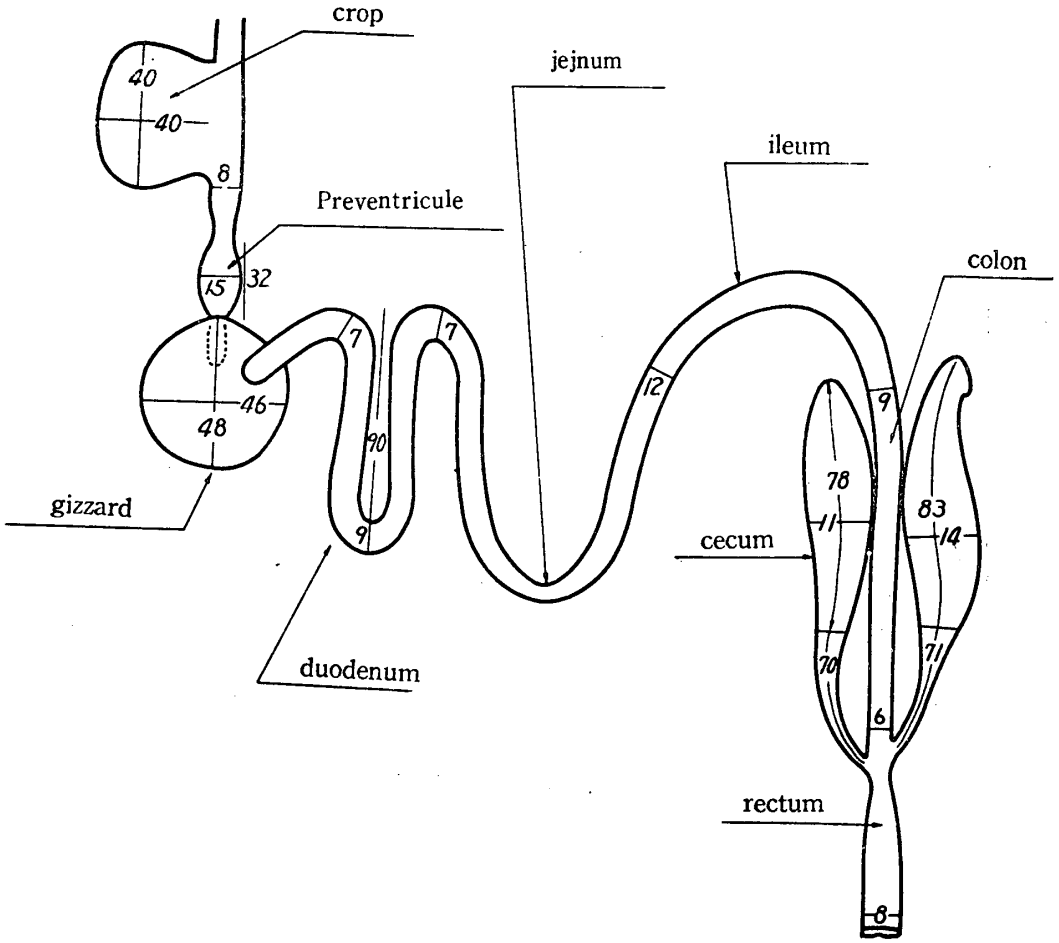


Fig. 15. The diagram of the digestive tract of domestic fowl.
Length: duodenum, 21 cm
jejnum, 26 cm
ileum, 29 cm
colon, 28 cm
rectum, 8 cm
(scale in mm)

$$\text{c p m} = \left(\frac{N}{t} - \frac{N_0}{t}\right) \pm \sqrt{\frac{N+N_0}{t^2}}$$

where N : Number of count measured in time t
N_0: Back ground in time t
t : Time measured in minutes

The results obtained are shown in the value of total radioactivity of the indicator excreted in the feces or excreta hourly, and the specific activity of it for dry matter of the samples (Fig. 11 a, b, c., and Fig. 12 a, b, c). The self-absorption, back-scattering and decay of radioactivity were not calibrated.

No. 5 fowl, after Trial 6, was administered with 100 mg of the labeled indicator at 9:00 A.M., as in the case of Trials 1 and 6, and then it was killed

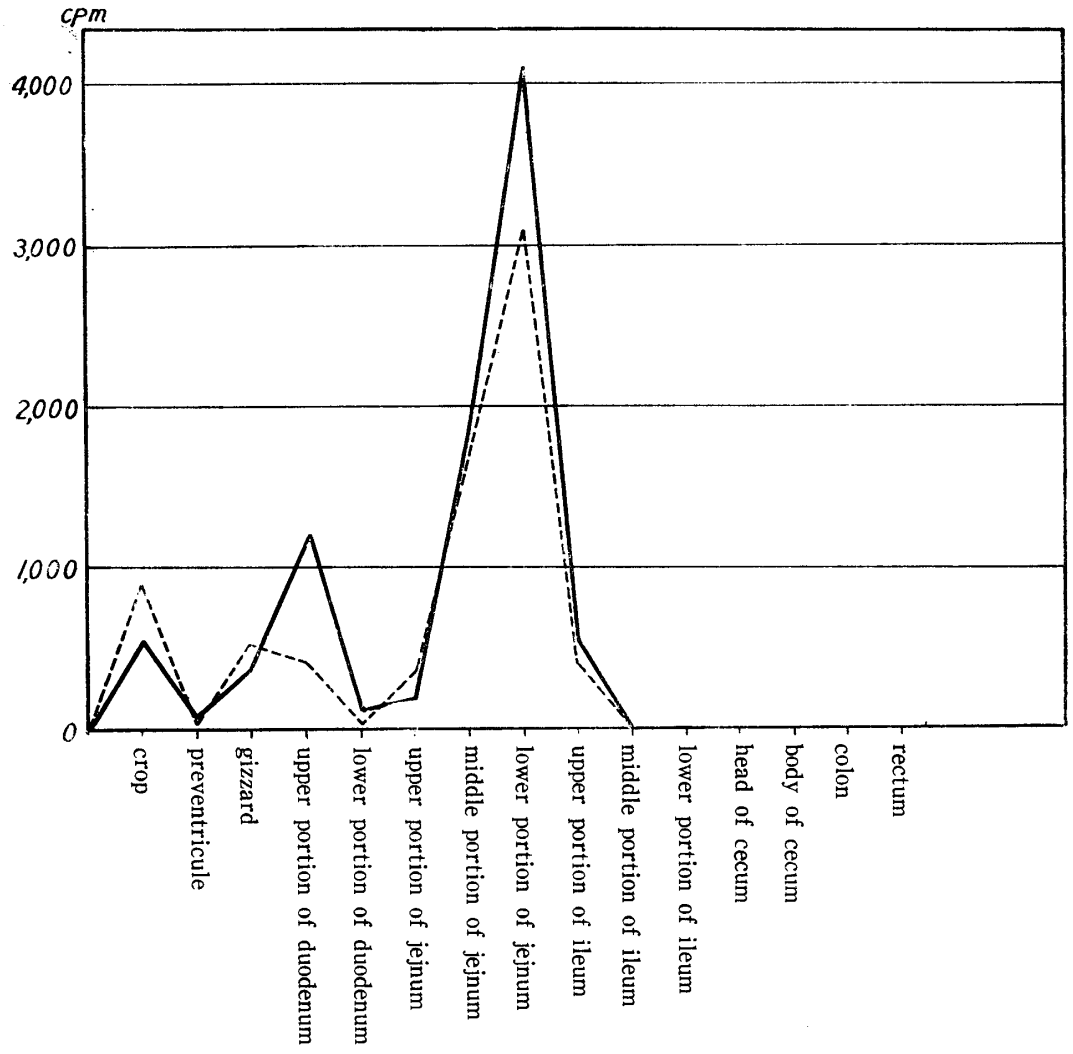


Fig. 16. The distribution of the indicator in the digestive tract of the domestic fowl after two hours of administration of indicator.
——— : specific activity of indicator in the dry matter of the content.
- - - - - : total activity of indicator in the dry matter of the content.

after two hours, and the distribution of the indicator in the digestive tract was observed. The contents of the tract were immediately collected according to the portions of the tract as follows: the crop, preventricules, gizzard, upper portion of the duodenum, lower portion of the duodenum, upper portion of the jejnum, middle portion of the jejnum, lower portion of the jejnum, upper portion of the ileum, middle portion of the ileum, lower portion of the ileum, colon, head of cecum, body of cecum, and rectum. These contents were treated by the same manner as the feces, the radioactivity was measured. On the other hand, the lengths of the each portion of the digestive tract were measured. The results obtained are shown in Figs. 15 and 16.

Results and Discussion

The prognosis of the operation differs according to whether the fowl was operated upon with or without the cannula. In general, the operation wound recovered in about three days, and the feces were excreted rather normally. The appetite and body weight were almost normal. However, after seven days, in the case of without the cannula, a white horny layer was found around the operated portion, and it spreaded closing the artificial anus day by day (Fig. 18, left side). In about three weeks after the operation, the excretion of the feces stopped, and the fowl showed some dullness and sat-down. The smaller

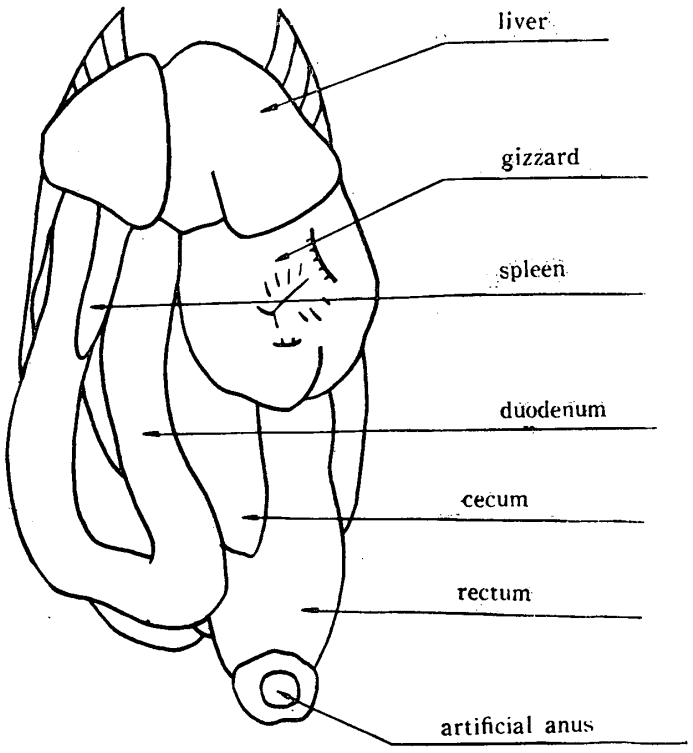


Fig. 17. The swollen rectum in the autopsy of the operated fowl.

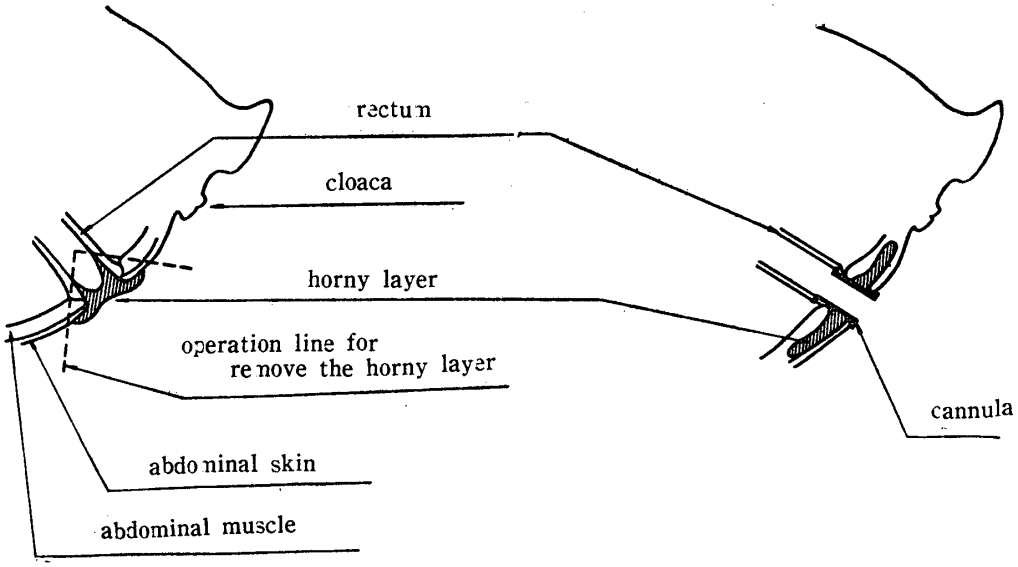


Fig. 18. The formation of horny layer.
It is formed around the artificial anus in the case of the fowl which received operation without cannula, while it is formed subcutaneously in the case of fowl which received operation with cannula.

operation to remove the horny layer was employed at this time, and the intestinal lavage was carried out (Fig. 18, left side). In the persuing the operation, both expansion of the rectum and blocked anus were found (Fig. 17). The horny layer and abdominal muscle were cut off in this operation, and the rectum was sutured to the more expanded wound. After the operation, appetite was recovered, but the excretion of the feces was becoming much less in amount. The fowl died about one week after this operation, in most cases.

The prognosis of the operation with the cannula differs from the former cases in appearance. The horny layer was formed subcutaneously, and the damping of the anus was prevented because of the cannula, but the expansion of the rectum due to unknown reasons was found in every case in about three weeks after the operation. The lavage of rectum and anus was repeated at this time, but this proved to be of little use for the prolonging of life.

The autopsy were made in every case, and the expansion of the rectum and blocking of anus were found. Other changes being assumed as the cause of death could not be found.

Hitherto, there are known three methods to determine the digestibility of feeds of the fowl: (1) the method employing the artificial anus, (2) physical separation of feces from urine against the excreta, and (3) chemical separation of feces depending upon the analysis of excreta. In the third case the digestibility was calculated from the values obtained according to the conversion formula. However, the coeficient for the calculation of digestibility in that method depends upon the analysis of feces obtained by the method of artificial anus operation. Many investigators who tried the artificial anus operation for

the domestic fowl reported their unsuccesfulness due to the death of the fowl, whether comparatively short time after the operation. Bolton (5) suggested that the results obtained from the digestion trials by the aid of the artificial anus operation cannot be regarded as relating to a normal bird. However, he did not pointed out the faults of that method. According to the observation on the fowl which received artifiicial anus operation, it seemed to be almost normal until two weeks after the operation, and then constipation took place suddenly. Even if we assume that the loss of the sphincter muscle of the natural anus would produce some effect to the changes in the physiological condition of the digestion, the mechanism of digestion is not thought to be effected. Further, if we assume that the mechanism of digestion in the operated fowl does not differ from that of the normal condition, it would be proved by measuring the passing time of the feeds through the intestinal tract, and the digestibility obtained from the operated fowl would be related to the normal one.

The results obtained from the indicator experiments lined this assuming. Barium sulfate is a water insoluble crystal with a solubility of 0.00023 g per 100 ml of water at 18°C, and its specific gravity is 4.50 at 15°C. Hitherto, this was often used as an indicator for the digestion experiment, and the method of administration for this indicator have been reported by many investigators. The "Sandwich method" is one of the known ones, and it was used with the expectation that the indicator ingested at the middle part of the feeds will appear in the almost middle portion of the excreted feces. Because of this reason, we measured the indicator's specific activity in the feces, which were collected hourly after the administration and the results thus obtained are shown in Fig. 11(a, b, c), and Fig. 12(a, b, c).

The specific activity of the indicator in the feces showed a characteristic curve following to the administration time and to the collecting time of the feces. With the assumption described above, the feces which have a very high concentration of the indicator should be due to the middle portion of the feed ingested. The time from the ingestion to that of excretion of the indicator which have a very high concentration in the feces would be thought to representing the time required by the feed to pass through out the intestinal tract of the fowl. From the results obtained as shown in Fig. 11(a, b, c), and Fig. 12 (a, b, c), we can know that it takes about four to five hours for the feed to pass throughout the digestive tract of the fowl from the mouth to the anus. However, the excretion of the indicator shows that there is a tendency that the required time would be different according to the time of administration and it would be accelerated in the operated condition.

The most typical curve was obtained in Trials 1 and 6, and that of Trials 2, 5, and 3, 4 were rather irregular. In most cases, excretion of the indicator

begins at two to three hours after the administration, and the specific activity of the indicator in the feces were highest at three to four hours after the administration.

The indicator which was ingested at 9:00 A.M. appeared in the feces three hours after administration; it showed only one peak at four hours after administration in the case of the non-operated condition and at three hours in the operated condition. The excretion of the indicator continued until 24 hours after administration in each case.

The indicator which was ingested at 1:00 P.M. appeared at three hours after the administration in the case of the non-operated condition, and after two hours in the case of the operated condition. The peak of the excretion was found three hours after administration in both the former and latter conditions. It continued until about 48 hours after the administration, but the reduction in the specific activity of the indicator in the feces showed some irregularity.

The indicator which was ingested at 5:00 P.M. excreted at four hours after administration in both the non-operated and operated fowls. The highest specific activity of the indicator appeared at four hours after the administration in every case, and the excretion of the indicator continued until 48 hours after the administration. The reducing curve showed much irregularity comparing with Trials 2 and 5. However, the highest peak agreeded with both non-operated and operated fowls.

The total amount of excreted indicator are illustrated in Fig. 12 (a, b, c), and it showed good analogy for the curve of specific activity of the indicator in the excreted feces.

We can find from these results that the peak according to the highest specific activity of the indicator appeared in the feces in about four hours after the administration in the non-operated condition, but in about three to four hours in the case of the operated condition. The trial was performed in the order of the trial number, but Trial 6 was carried out at the last stage of the operated condition. This design of the experiment prevented any error due to individuality, but the time from the operation effected the results. At any rate, the excretion of the indicator was accelerated according to the time from the operation in the case of the operated fowl. Although the expansion of diameter of the rectum developed during this time, it is not considered to be due to consumption only but to some other physiological factors.

The other charasteristics of the results are the irregularity of the curve obtained by Trials 2 to 5. The irregularity of the excretion of the indicator may be due to the mixing of the indicator with the feeds ingested before or later. It may also be probable that the method of administration as used in these experiments are not convenient for the common digestion trials.

From the results obtained, the fowl which was subjected to artificial anus

operation can be considered a normal fowl at least until two weeks after the operation. However, three weeks after the operation, the excretion of the feces become accelerated and thus the fowl then differs from the normal one. The cause for this acceleration might be the loss of the sphincter muscle of the natural anus --- cloaca, besides other reasons.

On the other hand, the feces which were thought to resulting from the cecum were collected until 144 hours after the administration of the indicator, but no radioactivity could be detected in it.

From the results described above, we assumed that the indicator which is ingested at 9:00 A.M. would appear in the feces after about three hours, in the operated condition. We also attempted to know the distribution of the indicator in the digestive tract just before the excretion. The results obtained are shown in Fig. 16. The highest specific activity of the indicator in the content was detected for the content of lower portion of the ileum, and there was no radioactivity in the content below that portion. It is thought that the content of the lower portion of the ileum is excreted within one hour.

The experiment in which No. 4 fowl was used showed that the peak of the specific activity of the indicator which was ingested at 9:00 A.M. and 1:00 P.M. would appeared within four hours after the administration, and these facts well agreeded with the results obtained from No. 5 fowl, in the non-operated condition. Thus it is considered that the acceleration of the excretion of feces may be related to some kind of physiological changes.

The blood, liver, and kidney were analyzed for the indicator, but no radioactivity was detected in the case of the last experiment.

P. S. Some photographs are presented for the reference.

Summary

(1) The method of "Artificial Anus Operation" for the domestic fowl were examined. The operation with metal cannula is most convenient for this purpose, but more extensive studies are needed with regard to the shape and use of the cannula.

(2) Almost half of the ingested feed are excreted as the feces within four to five hours after ingestion in the domestic fowl. However, the remainder are excreted after 24 to 48 hours according to the ingestion time.

(3) The contents in the lower portion of the ileum is excreted within about one hour.

(4) The fowl which received the artificial anus operation is related to the normal one until three weeks after the operation.

(5) The movement of the indicator to the cecum could not be observed.

References

1) Weiske, H and Mehlis, Th. (1878). Landw. Versuchsstationen 21 Bd. s. 415.
2) Paraschuk, S. (1902). Journal für Landwirtschaft s. 15.
3) Katayama, T. (1918). Res. Bull. Agric. Exper. Station **42**, 1.
4) Kamen, M. D. (1951). Radioactive Tracers in Biology. An Introduction to Tracer Methodology p. 76, New York.
5) Bolton, W. (1954). Progress in the Physiology of Farm Animals (Hammond) p. 111.

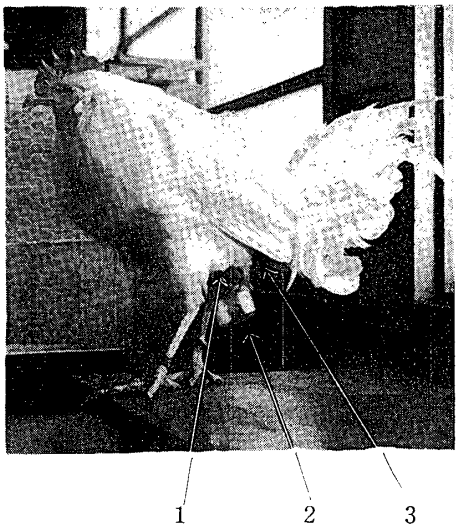


Photo. 1. Operated fowl.
1. acceptor which is sutured to the abdominal wall directly.
2. Collecting bottle.
3. Cloaca.

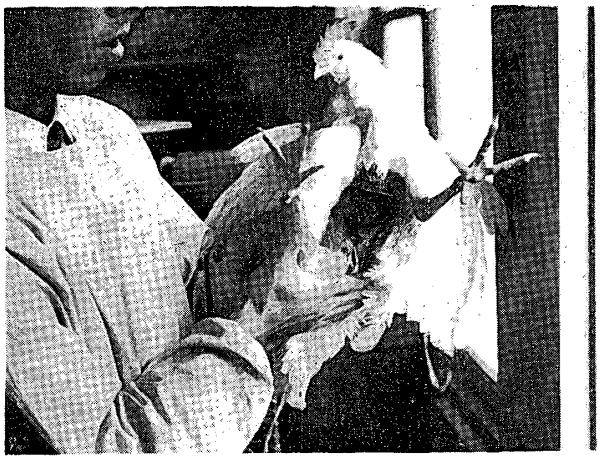


Photo. 2. Relation between artificial anus and cloaca.

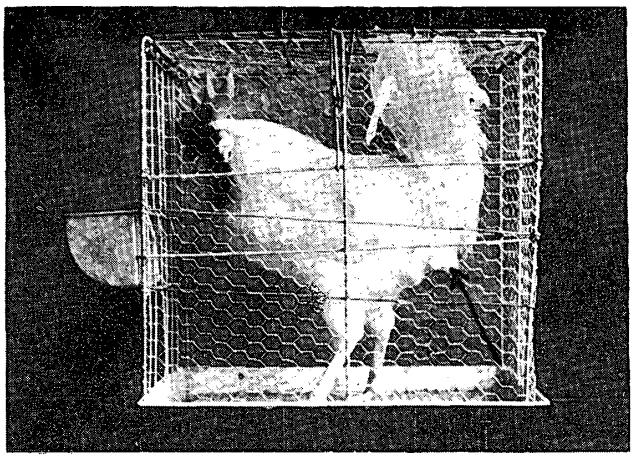


Photo. 3. Metabolic cage and fowl in it. Feces collector is shown by arrow line.

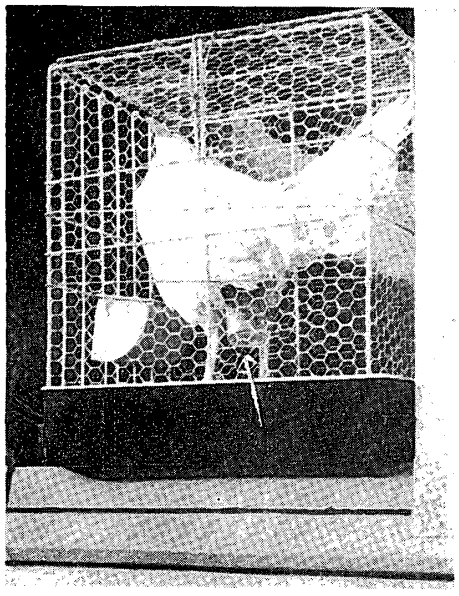


Photo. 4. View of the feces collector attached to the fowl.