MASTER

ANIMAL METABOLIC STUDIES OF STRONTIUM AND CALCIUM
WITH SPECIFIC REFERENCE TO FALLOUT RADIONUCLIDES

Fifth Progress Report

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TABLE OF CONTENTS

	Page
1. SUMMARY: SCOPE OF INVESTIGATION AND SIGNIFICANT RESULTS OBTAINED	1
a. Kinetic Studies of Calcium Metabolism in Goats and Cows	1
b. Retention of Strontium in Pigs as a Function of Age, Dietary Calcium and Phosphorus Levels, and Breed	8
c. Hydroxyproline Excretion in Swine as a Function of Age	9
d. Hypophysectomy of Swine with Yttrium-90	12
e. Effect of Exercise on Mineral and Organic Bone Turnover in Swine	13
f. Effect of Sodium Alginate, Barium Sulfate and Sodium Sulfate on the Gastrointestinal Absorption of Strontium-85 in Swine	14
g. Effect of Time on Distribution of Injected Radio-strontium in Six-Months Old Swine	14
2. TECHNICAL REPORTS PREPARED FOR PUBLICATION	16
3. REPRINTS FOR PUBLICATION	16
4. OTHER ACTIVITIES	17

1. SUMMARY: SCOPE OF INVESTIGATION AND SIGNIFICANT RESULTS OBTAINED

Experimental work during the past contract year was conducted in the seven areas listed in the Table of Contents (p.i.). Results of the two major areas of investigation, (a) kinetic studies of calcium metabolism in goats and cows and (b) retention of strontium in pigs, are considered in more detail than the other five areas. Summaries of these studies follow.

A. Kinetic Studies of Calcium Metabolism in Goats and Cows

A brief historical review of this project will place in better perspective the progress and importance of this line of investigation. The second Progress Report for this contract, covering the period August 1, 1964 through August 15, 1965, reported the beginnings of a pilot project to establish experimental methods using Ca-47 and Sr-85 to study calcium kinetics in domestic animals. Goats were employed in the first determinations of the readily exchangeable calcium pool size (E) and its biological half-life or turnover (T_B) as model animals for the investigation of the cause of hypocalcemia in parturient paresis observed in dairy cows. Results of the first study using two goats and Sr-85 indicated that larger dose levels than the administered 1 to 3 microcuries were necessary for statistically meaningful radiation detection beyond 2 or 3 days post-injection and that only a 5" x 4" NaI (Tl) detector could efficiently handle a dose of 12 to 15 microcuries.

The Renewal Proposal submitted in August 1965 outlined the basic methods and goals of the kinetic studies of calcium metabolism in goats. The techniques developed for and applied in human medicine (Medical Uses of Ca⁴⁷, IAEA Technical Report Series No. 10, 1962 and No. 32, 1964) were modified for the studies using female goats. Through August 15, 1966, fifteen injections of Ca-47 were administered to each of 5 goats. Ca-47 rather than Sr-85 was chosen because of its shorter physical half-life, 45 days, and hence

increased potential for rapidly repeating experiments in the same animals. Pool size and turnover values were summarized in the Progress Report for August 16, 1965 to August 15, 1966. These values provided baseline information for goats of different breeds and during periods of pregnancy, parturition, lactation and non-lactation.

The method used is stated briefly as follows: Approximately 12 μCi of Ca-47 is injected into the jugular vein of each goat and the same quantity is placed in a 15-gallon water-filled barrel which serves as a machine standard. Heparinated blood samples are withdrawn shortly after injection (about 1 hour), at 4 to 6 hours, and six more times between 20 and 64 hours post-injection. Plasma Ca-47 radioactivity and stable Ca (Ca-40) are determined and used in calculating the percent of the injected dose per gram of Ca (specific activity) in the plasma. This calculated value is plotted on the logarithmic ~~co~~ordinate against time on the linear abscissa. From the linear portion of such a plot extrapolated to y-axis (intercept at 0 time), E is obtained by dividing the intercept specific activity into the total dose which is 100%. The biological half-life or turnover (T) of this pool is then determined from the slope of the extrapolated line. E and T values vary according to the animal's physiologic status. In addition to determinations on the blood samples, the goats are whole-body counted, beginning within 2 to 4 hours after injection and for 4 to 5 days thereafter. The whole-body retention values and plasma specific activity values are then used for calculating bone accretion. The specific activity of milk samples is also determined when goats are lactating.

Some of the long-range goals of this project, as originally enumerated in the August 1965 Renewal Proposal, have been met, namely:

- (1) evaluating experimental procedures and mathematical approaches for studying Ca and Sr kinetics in domestic animals,* particularly goats;

* Sr kinetic studies are under investigation in swine.

- (2) determining normal parameters of pool size and turnover rate in goats; and
- (3) studying the effect of the Ca:P ratio of the diet on pool size and turnover rate in goats (this report).

Studies of the effects of other nutritional factors, such as carbohydrate content of the diet, and other physiological factors, such as thyroid, insulin, estrogen or adrenocorticosteroid status, on pool size and turnover rate have not been started. The effect of parathyroidectomy on these calcium parameters has only been studied briefly (this report). It is anticipated that more comprehensive studies of calcium kinetics will be undertaken in goats and cows subjected to various endocrinological stresses during nonpregnant, nonlactating, pregnant and post-parturient lactating states. In addition, it is hoped that pregnancy disease of ewes, eclampsia in dogs and joint and bone diseases in equine animals can be investigated.

The preceding review of this project since the reporting period 1964 to 1965 is preparation for a report on the effects of two abnormal dietary ratios of Ca to P on the kinetic parameters of the size and turnover rate of the readily exchangeable calcium pool in female goats. In addition, these parameters are determined for the first time in 10 bovine animals, including 6 cows, 1 steer and 3 calves.

Last Fall six mature female goats were placed on diets containing different Ca:P ratios from their previous rations containing a 1:1 Ca:P ratio. Three of the goats have been kept on a 4:1 Ca:P ratio, whereas the other three have been on a 1:3 ratio. The absolute amount of phosphorus has been kept constant in these diets and only the quantity of calcium has been manipulated. After an initial period in which all three goats on each diet were fed from the same manger, individual feeding of each goat with weighting-back of the remaining food was undertaken. Better feed consumption records were

thus obtained. The following figures illustrate the changes in the size (E) and turnover time (T) of the readily exchangeable calcium pool.

Changes in E and T of the goats on the 1:3 Ca:P ratio starting in January, 1968, are summarized as follows:

<u>Goat Number</u>	<u>E</u>	<u>T</u>
1	remained constant	increased markedly, then returned slowly to previous level
14	decreased, then increased slowly toward previous level	increased slightly
16	decreased, then increased slowly toward previous level	decreased, then increased toward previous level (fluctuations)

Changes in E and T of the goats on the 4:1 Ca:P ratio starting January 1968 are summarized as follows:

<u>Goat Number</u>	<u>E</u>	<u>T</u>
4	decreased, then returned to previous level	decreased, then returned to previous level (fluctuations)
6	decreased and remained low	increased markedly, then descended slowly toward previous level
7	decreased and remained low	increased markedly, then decreased to previous level

It appears from the limited observations that the goats react rapidly in some way to the abnormal diets by changing the values of the parameters of the readily exchangeable calcium pool, but that adjustment or adaptation to the new diets results in a new steady-state within a couple of months. More observations are being computer processed. In addition, E and T values for three other non-pregnant, non-lactating goats kept on a normal dietary regimen have been calculated during this report period. Their values have fluctuated much like the values plotted in previous reports.

The calcium kinetics of the readily exchangeable calcium pool have been determined for 12 bovine animals. Except for the two Guernsey cows which received 25 μ Ci each of the Ca-47 dose, the cows were intravenously injected with 125 μ Ci of Ca-47. Fifty ml. of blood was withdrawn from the jugular vein and centrifuged and 20 ml. of the plasma was counted for Ca-47 radioactivity and measured for total calcium content. A representative plot of % dose of Ca-47 per gram Ca versus post-injection time in hours for one Holstein cow follows (Figure 7). Estimates of the Ca-47 kinetic parameters are tabulated as follows:

Table 1

Ca-47 Kinetic Parameter Estimates

<u>Number</u>	<u>Bovine Animal</u>	<u>Age</u>	<u>E (gms)</u>	<u>T (hrs)</u>	<u>(E) x (T)</u>
1	Holstein Cow	7 y	333	42	13986
2	Hereford Cow*	5 y	364	32	11648
3	Jersey Cow 420	7 y	286	42	12012
4	Jersey Cow 377	7 y	385	35	13475
5	Jersey Cow 1881	9 y	500	35	17500
6	Jersey Cow 1883	8 y	333	38	12654
7	Guernsey Cow 254**	3 y	108	46	4968
8	Guernsey Cow 307	3 y	95	41	3895
9	Holstein Steer	1.5 y	716	30	21480
10	Guernsey Calf (Steer)	1 y	1000	28	28000
11	Hereford Calf*	5 mos	556	38	21128
12	Hereford Calf 431	6 mos	716	33	23628

All cows non-lactating and non-pregnant except:

* Hereford cow which was concluding nursing of its Hereford calf and

** Guernsey cow which was two weeks pre-parturition.

The cows (#1-8) have pool sizes (E) of about 500 grams or less and pool half-lives (T) ranging from 32 to 46 hours. The younger calves and steers (#9-12) have pool sizes between 500 and 1000 grams and pool half-lives ranging from 28 to 38 hours. As expected, the younger animals have larger pool sizes and shorter half-lives, which indicated a much more metabolically active skeleton. This is shown more clearly when E is multiplied by T, yielding a factor which is highly indicative of calcium turnover potential. It is hoped that further studies with cows over longer periods of observation, including pregnancy, parturition and lactation, will be carried out so that a greater understanding of these kinetic parameters will be obtained.

During the past year two French Alpine goats about four years old were purchased. This pair and a pair of twin Nubians 15 months of age were used in a pilot study to determine the effects of thyroparathyroidectomy on the size and turnover of the readily exchangeable calcium pool.

One goat from each pair (#317, French Alpine, and #31, Nubian) was thyroparathyroidectomized. Ca and P levels in the plasma as well as the calcium pool parameters were determined both prior to and following surgery. The goats were maintained on a normal dietary regimen, but the thyroparathyroidectomized animals were administered thyroxine intramuscularly at weekly intervals.

The data for the younger Nubians, #31 and #35 (control), follow (see Figure 8). The plasma calcium concentrations in these goats remained about 10 to 11 mg% before surgery, but decreased to and remained between 7 and 8 mg% in #31 after surgery. The readily exchangeable Ca pool sizes of these goats paralleled each other closely up to the time of surgery, although they did increase steadily during this time. This increase may be due to the effect of estrogens on the pool size, since the onset of puberty occurred about one month before the start of the experiment. Immediately following

surgery, the pool size of the thyroparathyroidectomized goat decreased by 50%, while the size of the Ca pool in the control animal increased slightly. However, at 100 days post-surgery, the pool size was the same in both. The pool biological half-life of the thyroparathyroidectomized goat seemed to be unaffected by removal of its calcium regulating glands. Thus, following thyroparathyroidectomy there was a marked hypocalcemia as well as a temporary decrease in the size of the readily-exchangeable Ca pool compared to values of a twin control goat.

In the four-year-old goats, #317 and #312 (control), a marked hypocalcemia following surgery was also noted (see Figure 9). At minus 50 days, goat #317 was thyroidectomized and partially parathyroidectomized (as indicated on the graph). Following surgery, the pool size decreased and then returned to normal. It decreased again following subsequent removal of the external parathyroids which were finally discovered in thymus tissue. It is difficult to assess the significance of the decrease, however, since there was also substantial variation in the control animal. As in the younger thyroparathyroidectomized goat, the biological half-life of the older goat appeared unaffected by the surgical removal of its calcium regulating glands.

As in the younger thyroparathyroidectomized goat, hypocalcemia following parathyroid removal was observed and the size of the readily-exchangeable Ca pool was reduced both after thyroidectomy and subsequent total parathyroidectomy. Also in both operated goats, hypophosphatemia was seen following surgery.

The experiment demonstrated, as many others have observed previously, that a marked hypocalcemia follows removal of the parathyroid glands. Although only a small number of animals were used in this study, the results suggested that the readily-exchangeable Ca pool size decreased following thyroparathyroidectomy. This decrease, perhaps only transitory, may not be due only to the loss of

parathyroid tissue but could also be due to surgery alone. Finally, the biological half-life of the readily-exchangeable Ca pool appeared to be unaffected by thyroparathyroidectomy. Before conclusive statements can be made about the effect of thyroparathyroidectomy on the parameters of the readily-exchangeable calcium pool in goats, further experimentation is required.

B. Retention of Strontium in Pigs as a Function of Age, Dietary Calcium and Phosphorus Levels and Breed

This work was initiated during the summer of 1966 and was included under "Scientific Scope" in the Renewal Proposal for December 1, 1966 to November 30, 1967. The first objective, to determine the retention behavior of radiostrontium in the pig as a function of age, dietary calcium and phosphorus levels, and breed, has been partially completed. Still remaining to be initiated under this objective are a retention study using a litter of newborn standard-breed piglets and computer fitting of all the swine retention curves to a modified power function.

Retention data of two litters of Yorkshire-Hampshire pigs raised on the two different dietary levels of calcium and phosphorus was reported last year. In each case the 200-day retention of a pig raised on the diet containing 0.8% Ca and 0.6% P was lower than that of its litter mate pig raised on the higher diet (1.2% Ca and 0.8% P) when each was injected at the same age. No relationship between rate of gain or sex and 200-day retention was discerned.

During the present reporting period, a litter of seven miniature swine have been administered a single dose of strontium-85 at 1, 2, 4 or 6 months of age and then whole-body counted at periodic intervals to 200-days post-injection. The litter has been divided and placed on the two different diets. Although this study remains to be completed, it does not appear that differences in retention between pigs raised on the two dietary levels of Ca and P will be as marked as in the case of the standard pigs, if indeed differences will be found.

Each pig of a second litter of seven miniature swine was injected intraperitoneally at one day of age with strontium-85. Half of the litter will be raised on each of the two diets and their total body retentions will be followed for 200 days.

Another litter of standard-size pigs, eleven Durocs, have been obtained. Four were injected just after weaning at 5 weeks of age, three at 18 weeks of age and four will be injected at 26 weeks of age with a single dose of strontium-85. Whole-body counting is now in progress and the litter, split into two groups, is being raised on the two dietary rations.

Most of this work now in progress will be completed in time for next year's report. Additional litters have been added to increase the number of pigs at each injection age and to examine with much greater statistical precision the retention behavior of strontium in the newly born animal. The so-called "juvenile period," up to about 6 months of age or sexual maturity in pigs, has been quite well covered in this work. It is, however, the neonatal period which is of much interest in studying the behavior of radiostrontium. Using the pig as a model for man is about as close as we can come to simulating the metabolism of strontium-90 in human beings, in which similar experiments can not be conducted.

C. Hydroxyproline Excretion in Swine as a Function of Age

This study also began in the summer of 1966 and was included under "Scientific Scope" in the Renewal Proposal for December 1, 1966 to November 30, 1967. The second objective listed, namely, to measure the urinary excretory pattern of hydroxyproline in the pig as a function of age, dietary calcium and phosphorus levels, and breed, has been partially fulfilled and should be completed for the next report. The third objective, to relate the patterns of radiostrontium retention and hydroxyproline excretion as a function of age in the pig to bone metabolic patterns in man must await further detailed analysis of the first two objectives.

In last year's Progress Report (C00-1339-16) data was presented on urinary hydroxyproline excretion in mg per day as a function of age of standard-sized swine (Figure 5). The data for the first 140 days of the swine have been discarded as invalid. The extremely low values for this period were caused by bacterial degradation of the refrigerated urine samples, which were not acidified. Subsequent samples were acidified.

Urine hydroxyproline amounts have been determined for several sets of standard-breed pigs and the values are given, as follows (the very large standard deviations are not included):

<u>Age in Days</u>	<u>Urine Hydroxyproline (mg/24 hr.)</u>		
1) 46-69	Mean	61.0	(N=40)
4 Durocs	Range	9.2 - 155.5	
2) 68-127	Mean	119.8	(N=14)
1 Duroc	Range	12.2 - 369.0	
3) 128-169	Mean	159.1	(N=19)
1 Duroc	Range	30.9 - 377.4	
4) 152-298	Mean	91.1	(N=41)
12 York.-Hamps.	Range	11.1 - 271.5	
5) 459-479	Mean	180.5	(N=19)
2 York.-Hamps.*	Range	112.5 - 376.9	
6) 531-557	Mean	274.0	(N=8)
2 York.-Hamps.	Range	127.1 - 549.3	

N = Number of measurements

* Kept in metabolism crates continuously as opposed to other pigs which were in metabolic units for only the day of measurement.

In addition, hydroxyproline determinations on urine samples of miniature swine have also been partially completed. It has been difficult trying to reconcile these wide-ranging values from pigs of different ages with bone turnover as measured by strontium-85 retention and with normal growth patterns. Growth in weight of Yorkshire-Hampshire crosses, for example, was as follows:

<u>Age in Days</u>	<u>Number of Pigs</u>	<u>Mean Weight in Kg.</u>
50	12	4.5
100	12	18.2
150	12	45.5
200	12	72.7
500	2	175.0

When these average weights are plotted against age, the growth curve can roughly be broken into the following four phases, which are listed with mean hydroxyproline values (mg/24 hrs.) and strontium-85 retentions:

<u>Growth Phase</u>	<u>Age in Days</u>	<u>Hydroxyproline</u>	<u>Sr-85% Retention</u>
Positive Exponential	0-150	~ 100	28 at 200 days
Linear	150-300	~ 91	12 at 260 days
Negative Exponential	300-400	Est. 100*	18 at 320 days
Plateau	400-	> 200	23 at 380 days

* No values

In summary, it appears that bone collagen turnover in swine is somewhat greater up to about 150 days of age during the positive exponential growth phase than during the linear growth phase which occurs from about 150 to 300 days of age. Since no values are available from 300 to 400 days of age, the negative exponential phase of growth, one can only estimate from later values during the plateau phase of growth that bone collagen turnover

is not changing at all from earlier phases or is only increasing slightly. One would, however, expect bone collagen turnover to decrease, since bone mineral turnover, as measured by an increased strontium-85 retention 200 days after a single injection, i.e., at 380 days, has decreased. Thus, it is not clear yet that in swine the pattern of hydroxyproline excretion relates directly to collagen metabolism, especially degradation, required of growth, as is the case in humans.

From the data presented it is possible to postulate that swine are extremely inefficient in their utilization of newly synthesized bone collagen; in other words, they synthesize a great deal of collagen which never becomes calcified and which instead is degraded into its constituent amino acids, such as hydroxyproline, which in turn are either reutilized in new synthesis or excreted. The very high hydroxyproline values in swine urine throughout most of the first two years of life compared to much lower values in humans can only be explained in this way at this time. Bone mineral turnover, however, is far reduced in swine from reproductive maturity (around 6 months of age) to about one year of age. In swine, then, it is difficult to relate bone mineral and collagen turnover. In a future biochemical study, it is hoped to examine collagen turnover in bone tissue per se.

D. Hypophysectomy of Swine with Yttrium-90

During the past year two more sets of six and seven young pigs in the 20 to 40 pound range, were employed for the implanting of radioactive capsules containing yttrium-90 in the pituitary fossa beneath the pituitary gland. About 42 milligrams of yttrium-90 ensheathed in nylon were made radioactive (2 mCi) in the central core of the University of Illinois Nuclear Reactor. The pellets were removed from the reactor building shortly after activation and placed in the anesthetized pigs the same day.

At this time the anticipated goal of 90% or greater loss of pituitary function has not been attained, although survival of the animals has been close to 100%. Microscopic examination of the hypophysis revealed that cellular destruction has not been greater than 75%. In addition, gross behavioral observation of most of the implanted pigs indicated that they were near normal, and their rate of gain in weight approximated normal. In a few cases the pigs showed behavioral evidence of brain damage although this was not at all as marked as in a previous set of pigs reported last year. This result is due to a reduction in the dose administered the animals from greater than 2.5 mCi to 2.0 mCi.

It appears that the major problem exists in the proper placement of the capsules via a temporal approach of intracranial surgery. When placed in the pituitary proper or in the pituitary fossa, the light capsules are buoyant and as a consequence often become dislodged. Future experiments will therefore employ a self-tapping screw, containing the capsule in one end, which will be driven through the basisphenoid bone via a parapharyngeal approach into the pituitary fossa, so that the capsule will remain in contact with the gland. The time of irradiation of the capsule in the reactor will also be increased so that the resultant radioactivity will be boosted to about 2.5 mCi. The next step will be a dry run to work out the anatomical and surgical problems of the procedure with a non-radioactive capsule in its holding screw. When the new Mark III TRIGA reactor is completed, hopefully by early 1969, experiments with radioactive yttrium will be conducted.

E. Effect of Exercise on Mineral and Organic Bone Turnover in Swine

This investigation was conducted using mature pigs one year of age or older which had previously been employed in the strontium retention study from shortly after birth to 6 to 10 months of age.

The work is in the form of a preliminary draft manuscript, numbered CCO-1339-20, included with this report.

F. Effect of Sodium Alginate, Barium Sulfate and Sodium Sulfate on the Gastrointestinal Absorption of Strontium-85 in Swine

This study used mature and three-and-a-half month-old pigs to evaluate the effect of sodium alginate supplemented feed or a mixture of barium and sodium sulfate on the gastrointestinal absorption of strontium-85.

The work is in the form of a preliminary draft manuscript, numbered COO-1339-21, included with this report.

G. Effect of Time on Distribution of Injected Radiostrontium in Six-Month-Old Swine

This study was designed to examine the skeletal distribution of singly injected strontium-85 in swine as a function of time.

Eight six-month-old Hampshire hogs were intravenously injected, each with 15 μ Ci of strontium-85. The pigs were kept in an open-air pigpen and fed Purina chow adlib. The animals were killed at times up to 6 months post-injection (see schedule below). The entire skeleton of each pig was removed. Only from the pig killed on day 1 post-injection was the entire skeleton cleaned of soft tissue. From the other seven pigs the following bones were selected: skull, mandible, right scapula, right humerus, right radioulna, right femur, right tibia, right fibula, first and second cervical vertebrae, seventh thoracic vertebra, fourth lumbar vertebra and right seventh rib. The bones were ashed for 48 hours, taken up in dilute HCl and diluted to a given volume, which varied according to the mass of the bone. Aliquots were removed for strontium-85 gamma counting in a well-type automatic scintillation detector and also for the determination of stable calcium using a gravimetric procedure.

A schedule of the animals, and the day, weight and whole-body fractional retention at death follows:

<u>Pig</u>	<u>Post-Injection Day Killed</u>	<u>Weight in Kg. at Death</u>	<u>Whole-Body Fractional Retention at Death</u>
1	1	96	0.82
2	10	93	.79
3	28	108	.68
4	60	112	.34
5	90	136	.35
6	120	144	.32
7	137*	---	---
8	184	181	.27

* Pig died of unknown cause before weight and whole-body retention could be determined.

Although a complete analysis of the bone data is not yet available, the specific activity data obtained up to this time is included, as follows:

Specific Activity (% Injected Dose per Gram Calcium)

<u>Bone</u>	<u>Pig#</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Skull	0.115	0.046	0.057	----	0.041	.040	----	----	
Mandible	.229	-----	.051	.055	.045	----	----	----	
R. Scapula	.103	.077	.054	.048	-----	----	----	----	
R. Humerus	.074	.076	.052	.048	.044	----	----	----	
R. Radio-Ulna	.143	.068	.048	.044	-----	----	----	----	
R. Femur	.150	.064	.054	.045	.042	----	.036	----	
R. Tibia	.117	.060	.050	.037	.039	----	.032	----	
R. Fibula	.083	.071	.047	.019	.040	----	.031	----	
R. 7th Rib	.118	.065	.062	.044	.041	.032	.025	.025	
Cervical 1	.113	.078	.061	.045	.041	.034	----	.022	
Cervical 2	.120	.075	.059	.042	.049	.036	.027	.019	
Thoracic 7	.106	.079	.064	.039	-----	.033	.029	----	
Lumbar 4	.098	.067	.057	.044	-----	.035	.023	.023	
Average	0.121	0.069	0.055						

The data will be more carefully analyzed when completed, but it appears that, except for the initial uptake of the radio-label (day one) the specific activity for each of the bones selected approximates an average specific activity for all the bones. This finding is considerably different from that of pigs injected shortly after birth (see COO-1339-17). Skeletal redistribution in the six-month-old swine did not seem to occur as in the young pigs.

2. Technical Reports Prepared for Publication

a. COO-1339-17. "Effect of time on distribution of injected radiostrontium in the young pig," J. J. B. Anderson. Accepted for publication in Health Physics.

b. COO-1339-14. "Cesium-137 retention in cattle, sheep and swine," A. R. Twardock and W. C. Crackel. Accepted for publication in Health Physics.

c. COO-1339-20. "Effect of exercise on mineral and organic bone turnover in swine," J. J. B. Anderson and L. Milin. To be submitted to American Journal of Physiology.

d. COO-1339-21. "Effect of sodium alginate, barium sulfate and sodium sulfate on the gastrointestinal absorption of strontium-85 in swine," L. Milin and J. J. B. Anderson. To be submitted to Journal of Nutrition.

3. Reprints of Publications

a. COO-1339-12. "An inexpensive metabolic unit for baby pigs from birth to four weeks," J. J. B. Anderson, L. D. Baker and A. R. Twardock. Laboratory Animal Care 17: 569-572, 1967.

b. COO-1339-18. "Calcium-47 kinetics in dairy goats," Y. H. Kuo, J. J. B. Anderson, A. R. Twardock, W. C. Crackel and T. G. Lohman. Federation Proceedings 27: 311, 1968.

c. COO-1339-19. "Urinary hydroxyproline excretion in swine as a function of age," J. J. B. Anderson. Federation Proceedings 27: 728, 1968.

4. Other Activities

- a. Book Review by J. J. B. Anderson on "Radioisotopes and Ionizing Radiation in Entomology, Vol. III," I.A.E.A., 1957. In BioScience 18: 343, 1968.
- b. "The effect of parathyroidectomy upon the readily exchangeable calcium pool in goats," L. D. Baker, Y. H. Kuo, A. R. Twardock and J. J. B. Anderson. Oral presentation at 48th Annual Conference of Research Workers in Animal Diseases, Chicago, Illinois, Tuesday, November 28, 1967.
- c. "Strontium retention as a function of age in the dog," J. J. B. Anderson and C. L. Comar. Radiation Research 24: 153-169, 1968.
- d. "Radioactive fallout with particular reference to Strontium-90," J. J. B. Anderson. Illinois Veterinarian 10 (No. 3): 3-5, 1967.
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- f. Attendance by J. J. B. Anderson at a two-week course on "Neutron Activation Analysis" given by Gulf General Atomic Incorporated and The University of California, San Diego, July 8-19, 1968.
- g. Preparation for a conference on "Parturient Paresis in Dairy Animals" to be held on the Urbana campus of the University of Illinois, November 17-19, 1968. J. J. B. Anderson, Conference Chairman.

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Goat No. 1

Figure 1

Ration with Ca:P equal to
1:3 started on Oct. 7, 1967

Individual feeding started
on Dec. 20, 1967

- half-life, hours
- pool size, grams

half-life (hrs.) and Ca pool size (gms.)

Ration with Ca:P equal to
1:3 started on Oct. 7, 1967

Individual feeding started
on Dec. 20, 1967

Lactation ceased Dec. 11, 1967

○ half-life, hrs.
● pool size, gms.

half-life (hrs.) and Ca pool size (gms.)

Individual feeding started
on Dec. 20, 1967

Ration with Ca:P equal to
1:3 started on Oct. 7, 1967

- half-life, hrs.
- pool size, gms.

half-life (hrs.) and Ca pool size (gms.)

Ration with Ca:P equal to
4:1 started on Oct. 7, 1967

Individual feeding started
on Dec. 20, 1967

Lactation ceased Dec. 11, 1967

○ half-life, hrs.
● pool size, gms.

half-life (hrs.) and Ca pool size (gms.)

Goat No. 7 Figure 6

Ration with Ca:P equal to
4:1 started on Oct. 7, 1967

Individual feeding started
on Dec. 20, 1967

○ half-life, hrs.
● pool size, gms.

Lactation ceased Dec. 11, 1967

half-life (hrs.) and Ca pool size (gms.)

Figure 7

Holstein Cow

Figure 8

Changes in plasma calcium, pool size, and biological half-life before and after thyro-parathyroidectomy.

Changes in plasma calcium, pool size, and biological half-life before and after thyro-parathyroidectomy.