ENVIRONMENTAL AND GENETIC VARIATION IN LACTATION IN GUINEA PIGS

by

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INTRODUCTION

Milk secretion is one of the fundamental life processes in all mammals. Because of their extremely short period of infancy, lactation in guinea pigs, in so far as sustenance and growth in the young are concerned, approaches being an exception to this rule. The object of this study has been to develop a technique for the measurement of lactation in guinea pigs, both as to the variation in the amount of milk produced and as to the length of the period of production. It was hoped that the information obtained might be of value in future work dealing with the study of the inheritance of variations in lactation in guinea pigs and this in turn be an aid in studying the inheritance of milk production in cattle.

REVIEW OF THE LITERATURE

No work on lactation in guinea pigs has been published, although extensive studies have been made of the development of the mammary glands in these as well as other rodents. It is a well known fact that guinea pigs are more mature at birth than any other mammal, having hair and teeth and being able to eat solid food from the very beginning. Abderhalden (1908), states that guinea pigs, because of their compara-

tive maturity at birth, scarcely belong in the ranks of the mammalia. Milk plays but a subordinate part in their nourishment. He gives the percentage of organic and inorganic constitutents in the milk. According to his analysis the amount of total protein is slightly over five per cent and the fat content about seven per cent. This is approximately double that given by him for the cow but only about half as much as he found in rabbits' milk. The inorganic constituents did not vary greatly among the animals studied by him. An experiment conducted by Ibsen (1922) shows the small dependence the offspring place on mother's milk as a source of food. The mammary glands of several pregnant females were removed before parturition and eleven of the young that were subsequently born were allowed to remain with their mothers. Eight of these individuals survived, regaining their initial weight by about the tenth day. Some interesting references are given by Richter and Brauer (1914) pertaining to milk secretion, among which may be mentioned citations from Bartsch, Hirsch, Birk, Schaffer, and Edlefsen. Bartsch, in 1859, says that the newly born mammal receives enough nourishment in utero to last it one or two days. All mammals, in so far as known, tend to lose weight for the first few hours to several days after birth. There have been many varied theories as to the cause of this loss. Among

these are: (1) cleaning out of the intestines after birth, Hirsch, 1910; (2) loss of water and tissue, Birk, 1912; and (3) lack of sufficient milk during the first few days, Schäffer. Edlefsen in 1870 found that in 66 guinea pigs at the second weighing, which took place 12-24 hours after birth, only four had not lost weight. They varied in regard to the time after birth necessary to regain their initial weight from 25 hours to over 144, and averaged a little more than three days. He explained the loss by stating that the young do not suckle quietly and continuously as do other mammals and also, since a guinea pig has only two mammae, it probably does not produce enough milk for a large number of offspring. Minot (1891) notes that for a variable period after birth, guinea pigs lose weight, males more than females. His evidence, however, is not conclusive. Kuramitsu and Loeb (1921) find that in rats milk secretion is not fully established until seven days after parturition. Sure (1930) observed that there is little milk flow during the first 24 hours of lactation in rats but that the young invariably gain significantly on the second day of lactation and that occasionally by the end of the third day and often by the end of the fourth, the litter will as much as double its weight. Eaton (1932) noted that in some guinea pig litters the weight at three days of age was actually less

than at birth. During the first three days the young pig begins to obtain its own food and makes the adjustments necessary from pre-natal to post-natal life.

Lane-Claypon and Starling (1906) find that in the rabbit during the greater part of pregnancy from the 9th to the 25th day, a watery fluid can be expressed from the nipples. During the last two or three days of pregnancy this becomes milky in character. Turner (1931) states that cows will begin to secrete milk in considerable abundance before parturition.

MATERIALS AND METHODS

The lactating females studied in this experiment were some that were also used in genetics experiments carried on at the Kansas State College of Agriculture and Applied Science, Department of Animal Husbandry, under the direction of Dr. H. L. Ibsen. The method followed by him is to mate two females to one male in each compartment and to remove the young at about two months of age.

It was proposed to measure the milk production of the females by the gain in weight of the young after suckling. Enough extra cages were provided so that the young from each female being tested could be placed in separate compartments with or without food and water. The mother was placed below

the young in a separate compartment and supplied with ample food, water, and straw bedding. The ration consisted of a grain mixture, a fair grade of alfalfa hay, and some form of green roughage. During the summer and fall the grain mixture contained 50 pounds of rolled oats, one-fourth pound of bone meal, and one-fourth pound of salt. For the winter ration, one pound of cod-liver oil, one-half pound of milk powder, and one and one-half pounds of wheat germ meal, and two ounces of tankage were added.

In summer the green roughage was supplied by green alfalfa, lawn cuttings, cane, sudan grass, or other available soilage crops. During November and the winter months these were replaced by sprouted oats with occasional feeds of volunteer oats.

The animals were placed in a small wire cage and weighed to the tenth of a gram on an equal-arm platform balance. The young were allowed to suckle either in round wire baskets on a table where they could be observed or else mother and young were placed in the empty cage occupied by the young between feeding periods. The bare cages occupied by the young were brushed clean each day to avoid accumulation of excreta.

THE DEVELOPMENT OF A TECHNIQUE

One of the principal objectives of this study was to develop a technique for measuring milk production. Since so little was known as to what would constitute a desirable method, many ideas had to be tried out before anything definite could be determined.

A blank form suitable for keeping records on a dam and three offspring was worked out by Dr. Ibsen and the writer. This form was found quite convenient as it provided space for complete records on cages, dates, ages, weights, and notes for both the female and offspring. A column was also provided for the weight of the young when weighed together. This served as a check on the individual weights. Space was available for further notes on the back of each sheet and here were kept records of previous litters by each female tested, her age and weight at each parturition, and the number of offspring raised to maturity.

Two types of lactation trials were used. These will be designated as "continuous trials" and "one-day trials". The continuous trials, as the name implies, were run continuously from the beginning to the end of lactation and are a complete record of the milk produced by the female. Day trials consisted of a preliminary milking by means of young

animals to get the female dry, followed by from one to three similarly conducted test milkings made during the same day as the preliminary milking. From one to five one-day trials were run during a lactation period. A "milking" in both continuous and one-day trials consisted in weighing the young individually, recording the time and weight, then allowing the young to suckle. After feeding in this manner they were again weighed and their increase in weight noted. Several lengths of feeding period were tried and the number of milkings per day varied from one to five. As checks on the amount of milk secured, both the decrease in weight of the female and the increase in the young when weighed together were used whenever possible. In the continuous trials, the daily variation in weight of the female was expected to show correlation with her physical condition and hence her variation in milk secretion. Except during feeding periods, the young were usually kept in an empty compartment in order to make certain that gain in weight was on milk alone. By this method one should get some indication as to the richness of the milk. In certain cases, however, when the milk supply of the mother was low, it became necessary to feed the young grain and roughage in addition.

Observations were made relative to the particular teat suckled by each young animal in order to determine whether

or not the same animal always suckled the same teat. The presence of urine or feces voided by the mother or young during milkings was also noted and where possible these were weighed.

On several occasions females were tested by means of young taken from other trials to determine whether all of the milk was being removed. When the amount of milk per day dropped to two grams or less, the lactation period was considered to be at an end, and the female with her young were returned to the compartment from which they were originally removed.

As a further check on length of lactation, several physical examinations were made of all of the females in the colony (except those used in continuous trials) having litters between two and thirty-eight days old to determine whether or not they were still lactating. This was carried out by squeezing each teat of a particular female with the thumb and forefinger in a manner similar to that used in "stripping" a cow. A record was kept of whether or not fluid was obtained and if so whether it was normal, thick and viscous, semi-colorless, or colorless. The number of young present at the time of the examination was recorded and the appearance of the glands as to development noted.

Similar records were kept of some of the females used

in the continuous trials, except that the manipulations were carried out daily in order to secure the time required for each change to occur. Examinations of several females for a few days just preceding and immediately following parturition were also made.

DATA AND OBSERVATIONS

In making the continuous and the one-day trials, 68 different females were used. Including those cases where females were tested for more than one lactation period, 87 trials were run for one or more days on separate lactations. Twenty-three of these were begun as continuous trials but only 10 were completed sufficiently to be used in calculating normal results.

Of the 64 one-day trials, 52 were sufficiently completed to calculate the length of lactation. One-day trials were begun at various times during the lactation period, 20 of them beginning between the 10th and the 38th day. In 10 of these 20 trials the females tested did not produce measurable gains in the young although a physical examination at the time showed at least a few drops of milk to be present. It was, therefore, concluded that they had ceased lactating.

In the first continuous trial, the young were left with the female in an empty compartment during the night and

separated during the daytime. Only one milking was made daily and this came between 1:00 and 2:00 p.m. Such procedure did not give complete data on the milk produced. However it was included as a continuous trial, since it was comparable with the other trials when the amounts of milk obtained during each milking were converted into secretion per 24 hours. To do this the amount of milk obtained was reduced to secretion per hour on the basis of the time between the separation from the mother in the morning and after the milking at two o'clock p.m. In another of the continuous trials, Trial No. 56, the young died on the 12th day of lactation. They seemed unable to obtain sufficient food, although placed with the mother during the second night and again during the sixth. Sprouted oats were also supplied to them after the 4th day. In spite of this additional care they were unable to overcome the low and declining milk-flow.

Of the 13 continuous trials in which the dams ceased lactating early, 10 failed because of death of a part or all of the offspring due to a lack of milk before they were five days of age, and two were finished as one-day trials because the dams seemed to lack sufficient milk. This would seem to indicate that some females inherently do not lactate normally. However, tests on later lactations of

several of the 10 females that failed, showed that normal lactations occurred. For this reason it is thought that most of the unfavorable results were due to environmental factors rather than genetic, although there is some evidence that genetic factors may in some cases be the basis for these extreme variations. One continuous trial was purposely finished after the fifth day as a one-day trial to note the effect on production. A slight rise seemed to occur.

The total amount of milk produced per day in continuous trials was obtained by adding all of the gains in weights of the young secured by milkings through the day. If there was excretion during milking, it was weighed where possible and the amount added. Table I. shows for the animals completing continuous tests the relationship of the length of lactation and average amount of milk per day to the age of the dam at parturition, the number of previous litters, the number of offspring in the litter tested, the condition of the dam as to pregnancy and the per cent of offspring born alive to May, 1932 that lived over 18 days. The numbers are too small to justify the drawing of any conclusions.

Since in the one-day trials a complete day's record following the preliminary milking was not always obtained,

it was necessary to calculate the amount of milk secreted per hour and multiply by 24. The amounts thus arrived at were used in comparing continuous trials with one-day trials.

In determining length of lactation from one-day trials, only an approximation could usually be given. Where necessary, the estimate in each case was made by using the day which fell half way between the next to the last and the final milking at which no milk was obtained by the young, but at which time a physical examination showed a small quantity to be present. If weighable increases were produced in the young during the last test, then the length of lactation was estimated to be past the midway point, the amount past depending on the quantity of increase obtained. This, of course, is a subjective value. It is defensible only on the basis of several physical examinations made daily, following the close of lactation. These examinations showed that the "residual" milk first became quite sticky and viscous, then gradually lost color as if being resorbed. Within a week after lactation ceased, the fluid expressed from most of the females examined was colorless. A somewhat similar resorption was observed in cattle by Turner & Frank (1930).

Observations of the young while suckling showed that

Table I. Females on Continuous Trials

Trial Number	Female's Pedigree number	Female's Age at Parturition in Days	Number of Previous litters	Number in Litter tested	Condition of Female as to Pregnancy during the measured lactation	Total offspring born alive to May 1st, 1932	Per cent of those born alive that lived over 18 days	Length of Lactation in days	Aver. milk per day in grams
1	L575.1	201	0	2	not pregnant	7	85.7	15	13.8
2	L408.3	248	1	4	pregnant	20	95.0	17	10.4
4	L924.1	118	0	2	not pregnant	8	37.5	18	9.6
5	L856.2	148	0	3	not pregnant	3	100.0	17	8.1
6	L255.4	331	2	2	pregnant	14	100.0	12	13.3
7	M20.2	106	0	2	pregnant	13	76.9	10	8.8
19	L41.2	426	4	5	not pregnant	20	95.0	34	10.4
24	M56.1	116	0	2	not pregnant	9	88.9	15	9.0
56	M20.2	172	1	4	pregnant	13	76.9	12	7.9
57	L924.1	218	1	2	not pregnant	8	37.5	13	15.0

they do not tend to feed from the same teat. Rather, it appears to be a matter of chance as to which mamma will be suckled by each of the young. Moreover, there are often several changes from one mamma to the other during a "milking."

Amount of Milk Produced Preceding Parturition. A physical examination from one to five days preceding parturition of 28 females not included in the continuous or one-day trials showed no secretion in 24 cases. From three females a few drops of colorless watery fluid were obtained, and from one a few drops of milk-like substance were expressed from the left teat beginning with the third day before parturition. Twenty-two other females examined within six to twelve hours after parturition were found to possess a varying but relatively small quantity of rich viscous milk. This was replaced by milk of normal consistency within less than a day after giving birth to the litter. Three aborting females gave no secretion or at least not for several days following the abortion.

Amount of Milk Produced On the Day of Parturition.

Indications are that the amount of milk produced on the day of parturition varies from none, or practically so, in some cases to a considerable quantity in others. Since litters are born at various times throughout the day, the

difficulty of starting tests at the time of parturition precludes getting an accurate measure of the full first days production. During the first few hours after the litter is born very little milk seems to be secreted. The secretion increases with a varying degree of acceleration, some females reaching their maximum within a few hours, others not for as much as a week after parturition.

Table II shows 6 grams to be the average amount of milk obtained by the young from the time the trials began on the day of their birth to the end of that day. This includes only an unknown part of the total amount produced. However it is a significant quantity, for, when compared with the average of 1.2 grams given by the 10 females whose young died early, a relationship between viability of young and quantity of milk produced by the mother becomes apparent.

Further consideration of the 10 dams whose young died shows that three of them produced no milk on the day of parturition. The maximum recorded for the other seven was 2.7 grams. The minimum first day record for the 10 completed trials was 1.1 grams by female L856.2, trial 5. This female proved to have low intensity of production throughout the lactation reaching a peak of only 11.8 grams. Fourth day averages of production per day shows 2.75 grams for those whose young died as compared to 12-23 grams for

Table II. Daily Milk Production During the Entire Lactation Period by the 10 Females Used in the Continuous Trials.

Days :				:	0				1				
Female tested	Length of Lactation Period	Total milk	Average per day	Total milk per day	No. pigs used for milking	No. milkings per day	Weight of young at beginning of test	Weight of female before first daily milking.	Total milk per day	No. pigs used for milking	No. milkings per day	Total increase in weight per day of young	Weight of female before first daily milking
L575.1	15	193.6	13.8	----	2	-	186.9	678.4	16.4	2	1	0	641.2
L408.3	19	197.3	10.4	7.4	2	4	193.5	766.5	6.6	2	5	-3.8	729.5
L924.1	18	172.2	9.6	3.9	2	3	192.7	650.8	11.6	2	4	-3.2	615.6
L856.2	17	137.1	8.1	1.1	2	1	165.4	661.5	7.2	2	3	-4.3	665.5
L255.4	12	160.1	13.3	16.9	2	4	248.8	790.5	27.3	2	3	-2.0	774.0
M20.2	10	88.2	8.8	5.4	2	2	226.1	623.6	9.4	2	3	-3.4	612.0
L41.2	34	353.5	10.4	3.1	3	2	231.4	754.5	9.5	3	4	-6.6	762.5
M56.1	15	135.1	9.0	----	-	-	207.5	542.5	21.2	2	4	-6.2	533.5
M20.2	12	95.3	7.9	8.0	3	1	166.5	702.0	6.7	2	2	-2.5***	701.5
L924.1	13	194.5	15.0	8.5	2	1	215.0**	851.5	7.5	2	2	-1.5	838.5
Average	16.5	-----	10.6	6.0	-	-	-----	-----	13.0	-	-	----	-----

Days:				2	:				3	:			4		
L575.1	6.0	2	1	3.3	626.9	16.4	2	1	9.1	625.5	27.2	2	1	18.1	617.0
L408.3	12.5	2	5	-6.2	710.5	14.8	2	5	-3.2	723.3	17.8	2	4	+0.5	709.0
L924.1	12.3	2	5	-4.4	611.0	10.9	2	3	-0.4	602.5	13.2	1	3	-5.1	626.5
L856.2	9.9	2	2	-10.8	671.4	9.0	2	2	-12.2	684.0	11.8	1	2	0.3	684.5
L255.4	27.1	2	3	-2.4	774.5	21.3	2	3	-1.5	793.5	16.7	2	3	-4.3	766.5
M20.2	16.7	2	2	-14.3	640.6	13.5	2	2	-21.1	645.0	12.9	2	2	-23.9	647.2
L41.2	17.0	3	4	-5.9	755.0	19.7	3	4	-5.6	756.5	23.1	2	4	+1.1	743.2
M56.1	14.8	2	4	-8.5	527.5	13.5	2	3	-12.0	522.3	13.5	2	3	-15.5	519.0
M20.2	9.6	2	2	-4.0	664.5	12.6	2	2	-8.5	664.5	13.0	2	2	-6.5	678.0
L924.1	21.5	2	2	0.0	839.0	20.0	2	2	-3.0	848.5	21.5	2	3	+20.0	840.0
Average	14.7	-	-	-----	-----	15.2	-	-	-----	-----	17.1	-	-	-----	-----

*Young used for testing other females on days thus indicated. **Water, oats, and hay supplied young on day indicated and thereafter. ***Young placed with mother for the night.

Days:				5					6					7	
L575.1	8.8	2	1	26.6	631.5	20.8	2	1	26.1	622.0	14.0	2	1	26.1	606.0
L408.3	20.8	2	3	+3.2	713.0	19.8	2	3	2.0	717.5	17.3	2	2	3.3	719.5
L924.1	13.5	1	2	-2.2	639.3	15.6	1	2	-2.1	624.5	13.4	1	2	1.3	635.0
L856.2	11.5	1	2	2.5	680.5	10.8	1	2	4.8	676.5	11.8	1	2	6.8	677.0
L255.4	15.9	2	3	-7.8	753.7	11.1	2	2	-13.8	764.5	8.0	2	2	-21.3	740.0
M20.2	8.2	2	2	-28.6	631.0	8.1	2	2	-38.1	634.4	7.3	2	2	-47.7	619.5
L41.2	23.5	2	4	+8.5	753.7	22.6	2	3	+13.5	752.5	23.5	2	3	+17.5	743.0
M56.1	14.0	2	3	-15.7	532.5	9.8	2	3	-15.5**	527.5	10.2	2	3	-14.2	527.5
M20.2	11.0	2	2	-4.0**	692.0	11.9	2	2	-5.5***	699.0	7.0	2	1	-8.5	695.0
L924.1	22.0	2	2	+31.0	830.0	22.0	2	2	+41.0	822.5	14.5	2	2	+55.0	825.0
Average	14.9	-	--	-----	-----	15.3	--	-	-----	-----	12.7	--	-	-----	-----

Days:				8					9					10	
L575.1	13.2	2	1	27.4	585.3	19.6	2	1	32.2	583.0	19.2	2	1	31.9	593.7
L408.3	16.4	2	2	2.6	732.3	11.9	2	2	0	730.0	11.5	1	2	1.6	754.7
L924.1	13.3	1	2	3.3	623.7	13.2	1	2	3.9	631.7	9.0	1	2	4.4*	614.0
L856.2	10.1	1	2	10.3	658.0	6.9	1	2	11.6	660.0	7.5	1	2	11.8	648.7
L255.4	4.3	1	2	-4.5*	730.0	4.2	1	2	-8.0	730.3	4.7	1	2	-12.2*	731.0
L41.2	22.5	2	3	+21.5	749.0	22.3	2	3	23.5	746.7	15.2	2	3	25.0**	737.5
M20.2	4.5	2	2	-52.6	617.7	2.3	1	2	-2.3	635.0	0.2	1	1	-6.0	638.5
M56.1	9.3	2	3	-14.8	540.5	5.0	2	2	-19.0	547.5	7.3	2	3	-22.0	545.5
M20.2	7.5	2	2	-2.5	685.5	5.0	2	1	-6.0	685.5	1.0	2	1	-4.0	682.5
L924.1	14.5	2	2	+71.0	822.5	11.0	2	2	+84.0	827.5	15.0	2	2	+96.5	836.0
Average	11.6	--	-	-----	-----	10.1	--	-	-----	-----	9.1	--	-	-----	-----

Days:				11					12					12	
L575.1	22.8	2	1	37.8	605.6	4.0	2	1	33.7	617.3	2.4	1	1	20.8	631.0
L408.3	7.2	1	2	-.9	753.3	6.6	1	3	-2.2*	759.0	7.2	1	2	-1.7	760.0
L924.1	10.0	1	2	12.5*	630.0	9.4	1	2	12.4*	646.8	7.5	1	2	13.4*	646.0
L856.2	7.2	1	2	11.8*	655.7	6.4	1	2	13.9	664.3	7.1	1	2	16.3	662.3
L255.4	2.6	1	2	-13.6	737.0	----	--	-	-21.0	-----	----	--	-	-----	-----
M20.2	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L41.2	16.0	2	3	24.5	729.0	13.0	2	2	26.0	731.5	11.5	2	3	23.0	721.0
M56.1	4.5	2	3	+12.0	541.0	4.5	1	3	+18.0	552.5	3.0	1	3	+12.0	542.5
M20.2	2.0	2	1	-6.5	699.0	----	--	-	-----	-----	----	--	-	-----	-----
L924.1	4.0	2	2	+112.0	826.0	2.5	2	2	+116.0	824.5	0.0	2	2	+134.0	840.0
Average	8.5	--	-	-----	-----	6.6	--	-	-----	-----	6.6	--	-	-----	-----

Days:					14					15					16	
L575.1	.8	1	1	-3.4	616.3	2.0	1	1	-7.7	-----	----	--	-	-----	-----
L408.3	6.1	1	2	-1.2	767.3	4.5	1	2	3.2*	767.1	3.7	1	2	4.8	760.3
L924.1	7.6	1	2	16.5	632.5	2.0	1	2	17.1	618.7	3.1	1	2	12.6	656.3
L856.2	9.5	1	2	13.2	650.0	4.5	1	2	12.3	640.0	4.3	1	2	13.6*	641.5
L255.4	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
M20.2	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L41.2	13.0	2	3	22.5	723.5	9.0	1	3	1.0	723.2	9.0	2	3	-1.0	713.0
M56.1	2.0	1	2	17.0	532.0	2.5	1	3	26.5	530.0	----	--	-	26.5	-----
M20.2	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L924.1	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
Average	6.5	--	-	-----	-----	4.1	--	-	-----	-----	4.0	--	-	-----	-----

Days:					17					18					19	
L575.1	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L408.3	3.5	1	2	3.8	780.0	2.2	1	2	-2.2	756.0	----	--	-	-----	-----
L924.1	2.7	1	2	9.6	639.0			1	7.6	-----	----	--	-	-----	-----
L856.2	5.2	1	2	-10.2*	631.0	1.2	1	1	-7.2	624.0	----	--	-	-----	-----
L255.4	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
M20.2	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L41.2	4.5	2	3	-1.0	692.5	3.0	2	3	3.0	679.0	7.2	2	3	8.3	700.0
M56.1	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
M20.2	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
L924.1	----	--	-	-----	-----	----	--	-	-----	-----	----	--	-	-----	-----
Average	4.0	--	-	-----	-----	2.1	--	-	-----	-----	7.2	--	-	-----	-----

Data for female L41.2 continued

Days:					20					21					22	
L41.2	8.0	2	3	16.0	718.0	6.5	2	3	30.5	730.0	5.0	2	1	48.0	734.6
Days:					23					24					25	
L41.2	5.0	2	2	56.0	732.0	4.5	2	2	69.5	733.5	5.0	2	3	83.0	722.0
Days:					26					27					28	
L41.2	3.0	2	2	99.0	738.0	5.5	2	2	110.0	737.5	6.0	2	2	117.0	741.0
Days:					29					30					31	
L41.2	3.0	2	2	135.0	732.0	4.5	2	2	147.0	739.5	3.5	2	2	163.0	724.0
Days:					32					33					34	
L41.2	5.0	2	2	171.0	725.0	2.5	2	2	185.0	720.5	0.0	2	2	195.5	696.0

the females which completed the continuous trials.

Amount of Milk Produced During Entire Lactation. The data obtained from the continuous trials show much variation in both the daily amount of milk and the length of lactation. Table II indicates that the peak of production is reached between the second and the sixth day. Some females tend toward high persistency, keeping up their production for three or more weeks. Others lack persistency and become dry in 10 to 15 days. There is also variation in intensity of production. It appears to be a separate and distinct quality from persistency. Certain females, such as female L255.4, continuous trial No. 6, may have high intensity and be quite lacking in persistency. Others may have good persistency but low daily production. Still others may have or lack both qualities. Female L41.2, continuous trial No. 19, is a good example of high intensity and persistence, and female M20.2 in trials No. 7 and 56, of low intensity and persistence.

The question as to whether females vary from one lactation to the next in persistency and intensity cannot be fully answered at this time. A comparison of the two lactations given for female L924.1, continuous trials 4 and 57, seems to indicate only a slight difference which might be explained as due to environmental factors. The same might

be said of differences between the two low lactations shown for female M20.2.

A comparison of most of the females tested during more than one lactation is given in Table III. In case of the one-day trials the calculated amount of milk per day is given for each test followed in parenthesis by the day of lactation on which the test was made. Except where there is variation due to sickness of dam or other environmental factors, these data indicate a fairly consistent agreement between two or more lactations in the same female as to amount of milk produced and length of production.

Individual variation from day to day, although great, tends to follow a definite curve of production. This curve is, in general, slightly convex as production approaches its maximum and tends to be somewhat concave as the drop in production occurs. A graph of average production of all females, totaling 61, for whom length of lactation was obtained shows the tendencies mentioned (Fig. 1).

It would appear that the amount of milk any individual can produce per day is greatly limited by her size. Thus the largest amount secreted by any one female was 35 grams on the seventh day of lactation. This record was produced by female L190.3, one-day trial 52. A total of 19 grams of milk was obtained by four young at the test milking made 13

Table III. Data on females that were tested for more than one lactation.

Trial No.	Female's pedigree No.	Female's age in days at parturition	Female's weight at parturition	No. of previous litters	No. in litter tested	Condition of female as to pregnancy	Total offspring born alive to May 1st, 1932	Per cent of those born alive that lived over 10 days	Length of lactation in days	Continuous trials: Average milk per day	One-day trials (Figures in parentheses represent day of lactation): First test	Second test	Third test	Fourth test	Fifth test
19	L41.2	426	754.5	4	5	not pregnant	20	95.0	34	10.4	--------	--------	--------	--------	-------
76		544	832.0	5	3	pregnant	--	----	23	----	4.5(6)	10.6(11)	12.8(19)	--------	-------
88		616	800.0	6	3	not pregnant	--	----	20	----	7.7(2)	20.6(8)	23.0(16)	--------	-------
1	L575.1	201	678.4	0	2	not pregnant	7	85.7	15	13.8	--------	--------	--------	--------	-------
75		303	735.0	1	2	not pregnant	--	----	26	----	26.4(5)	32.9(10)	21.7(18)	--------	-------
4	L924.1	118	650.8	0	2	not pregnant	8	37.5	18	9.6	--------	--------	--------	--------	-------
57		218	851.5	1	2	not pregnant	8	37.5	13	15.0	--------	--------	--------	--------	-------
7	M20.2	106	623.6	0	2	pregnant	13	76.9	10	8.8	--------	--------	--------	--------	-------
56		172	702.0	1	4	pregnant	13	76.9	12	7.9	--------	--------	--------	--------	-------
77		241	755.0	2	4	not pregnant	--	----	15	----	27.4(6)	24.5(11)	--------	--------	-------
24	M56.1	116	542.5	0	2	not pregnant	9	88.9	15	9.0	--------	--------	--------	--------	-------
66		250	666.0	1	2	pregnant	--	----	27	----	12.8(2)	16.0(11)	12.0(18)	--------	-------
23	L19.1	413	708.5	0	3	not pregnant	17	100.0	24	----	9.4(20)	--------	--------	--------	-------
59		501	808.0	4	2	pregnant	--	----	26	----	23.0(4)	21.6(10)	21.0(16)	11.6(23)	
39	L753.2	207	647.0	1	2	not pregnant	7	100.0	17	----	4.7(15)	--------	--------	--------	-------
67		291	793.0	2	3	pregnant	--	----	14	----	11.5(2)	17.7(11)	--------	--------	-------
51	L700.1	252	660.0	2	5	pregnant	17	94.1	20	----	22.0(4)	16.5(9)	14.0(17)	--------	-------
73		317	648.0	3	5	not pregnant	--	----	27	----	29.5(4)	14.6(13)	12.3(18)	6.9(24)	-------
46	L399.3	287	813.5	0	3	not pregnant	5	80.0	14	----	11.3(9)	--------	--------	--------	-------
71		372	940.0	1	2	not pregnant	5	80.0	25	----	10.4(5)	11.6(16)	--------	--------	-------
44	L469.4	282	717.5	2	3	pregnant	18	83.3	25	----	6.9(9)	9.9(17)	2.0(25)	--------	-------
80		422	686.5	4	2	pregnant	--	----	25	----	15.3(4)	13.1(11)	8.2(18)	--------	-------
37	L762.2	214	825.0	1	1	pregnant	13	38.5	10*	----	2.5(0)	6.5(1)	4.3(2)	--------	-------
61		282	880.0	2	3	pregnant	--	----	32	----	21.4(2)	31.0(7)	32.2(13)	9.3(21)	7.4(29)
48	L826.1	195	734.5	1	3	not pregnant	10	100.0	20	----	31.0(8)	18.2(15)	--------	--------	-------
72		282	856.5	2	3	pregnant	--	----	16	----	24.2(2)	30.7(13)	--------	--------	-------
84		352	876.0	3	2	not pregnant	--	----	21	----	19.5(3)	20.9(11)	15.3(18)	--------	-------
50	M89.2	113	499.0	0	2	not pregnant	4	100.0	20	----	17.0(10)	7.6(17)	--------	--------	-------
74		229	696.0	1	2	not pregnant	--	----	18	----	9.6(1)	18.5(6)	20.0(14)	--------	-------

*Female was sick.

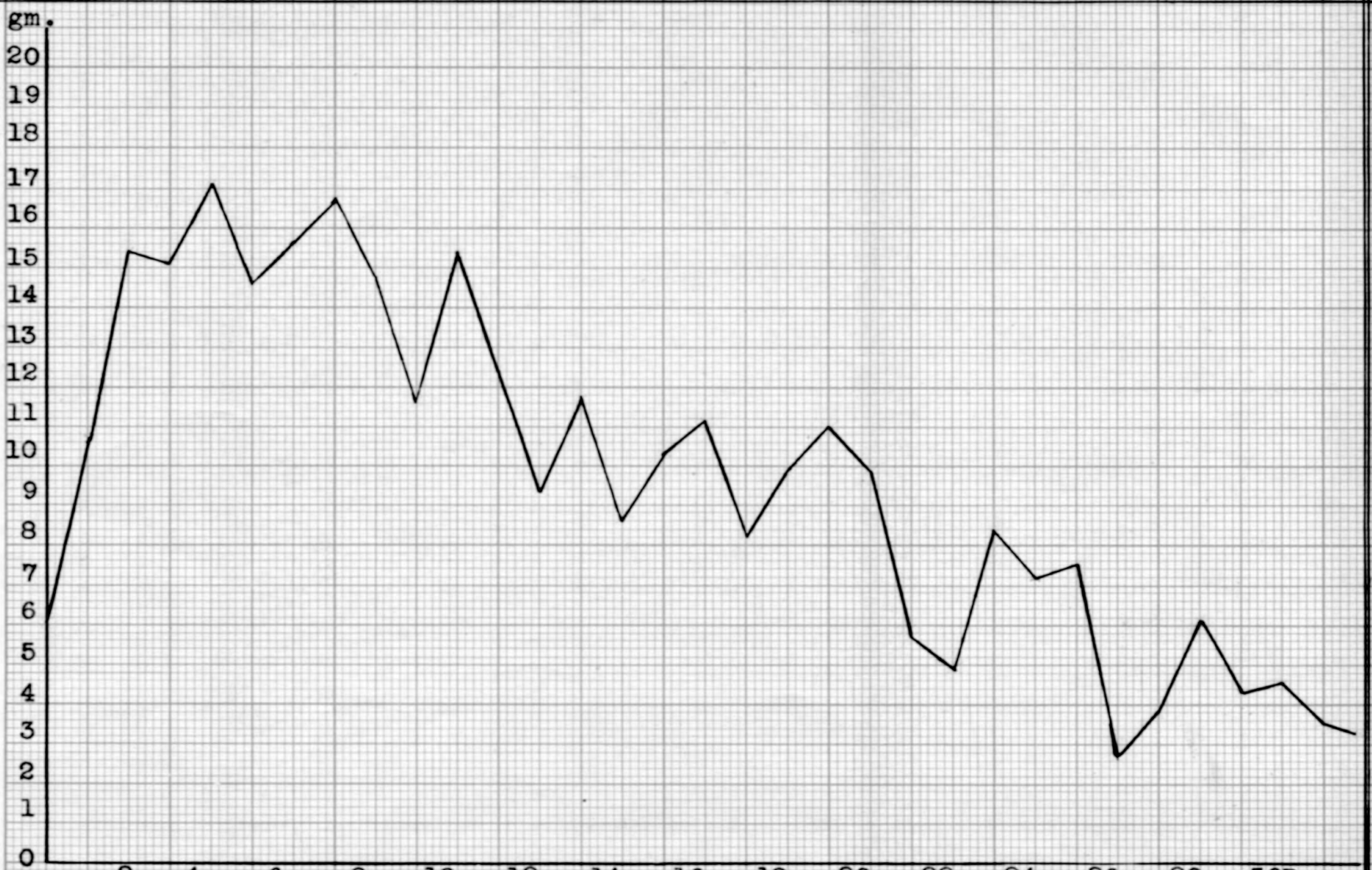

Fig. 1. Average Daily Milk Production of 61 Guinea Pigs

hours after the preliminary milking. This would be at a secretion rate of 1.462 grams per hour or 35.08 grams per day. The female weighed 870.0 grams at parturition. It is interesting to note that her lactation period was 32 days and in five one-day tests at approximately seven-day intervals averaged 17.04 grams. The first three one-day tests including the 15th day averaged over 30 grams.

Thirteen other females weighing over 700 grams produced more than 20 grams of milk at their peak of production as recorded by one-day trials, while for 10 weighing less than 650 grams only three secreted over 20 grams in any one day. Two of the latter were sisters. Moreover, the production was recorded in each of the three by one-day trials which tend to give higher results than corresponding days in continuous trials.

The significance of the weight of the dam is well illustrated in the continuous trials, Table II. Four of the dams used, (trials 2,6,19,and 57) weighed over 750 grams at parturition and all produced over 20 grams of milk at their peak. Only one of the four was extremely lacking in persistency. In trials 4,7,and 24, the females weighed less than 650 grams. Only in one trial, No. 24, for one day was the 20 gram mark reached. In trials 5 and 56, a low intensity is also apparent. The second lactation recorded

for female M20.2 is even lower than the first in intensity but is somewhat more persistent for the amount produced. In a later one-day trial on this female, at the beginning of which she weighed 755 grams, her peak was 27.4 grams.

The amount of milk produced by females with litters of four or over as compared with those with litters of one is somewhat higher for the females with larger litters during the first week but little difference is shown thereafter. However, the numbers are too small to be of any significance statistically though this difference may be connected with the fact that there is higher mortality in litters of one than in litters of two or three (Haines, 1931). The mortality may be due to a failure in milk flow due to insufficient stimulation of the mother by suckling.

The average production of the continuous trials is compared to that of the one-day trials in Figure 2. The extreme variation shown in one-day trials is due to the small number of females tested on some of the days and to the fact that each day's average represents a different set of females from those used for the days just preceding and following it. This is due to the fact that tests were made at about, and not exactly at, seven-day intervals. However, the one-day trials are seen to give a higher average than the continuous trials, and since the females on one-day

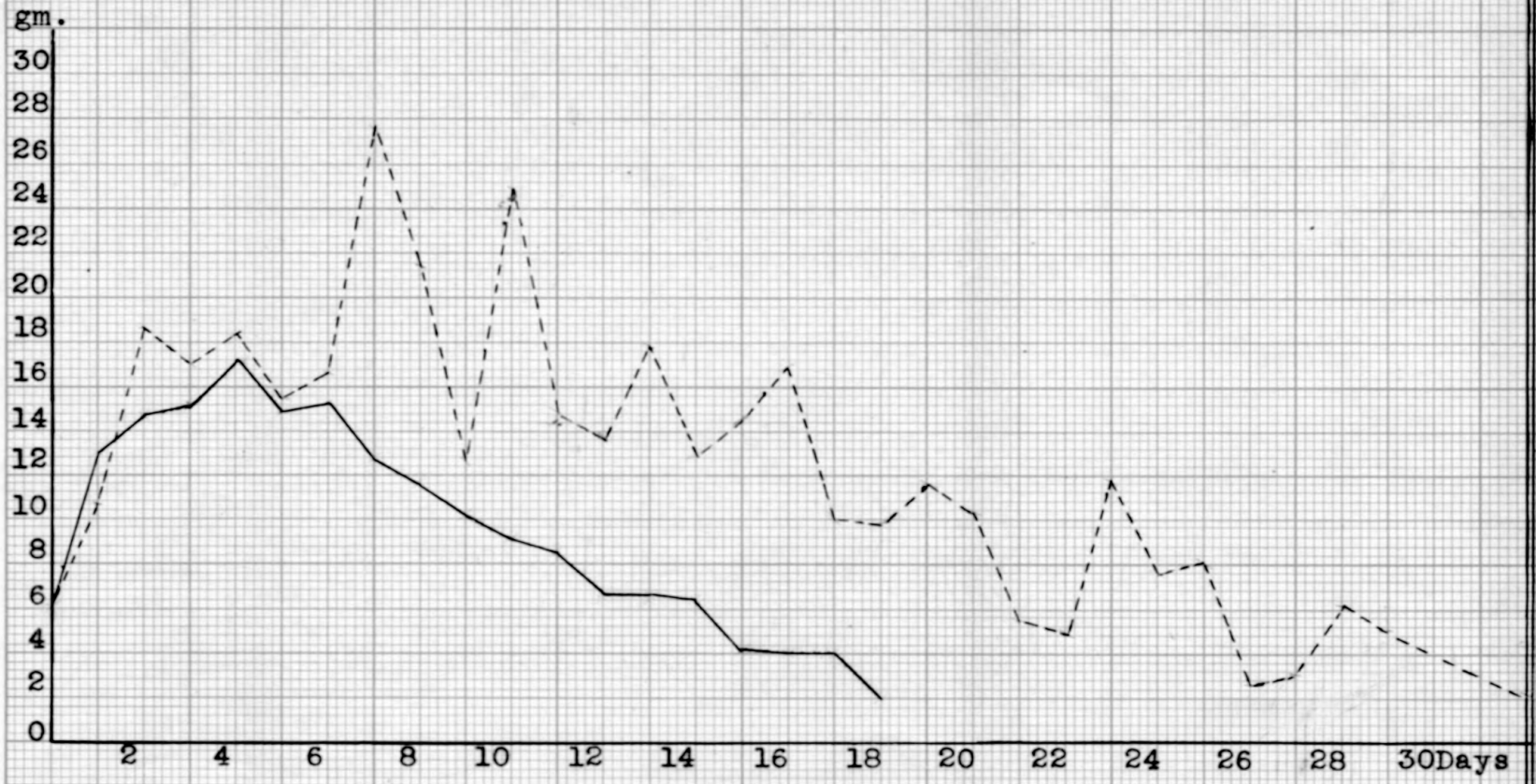

Fig. 2. Average Daily Milk Production--Comparison 10 Continuous and 52 One-Day Trials

--- One-Day Trials

___ Continuous Trials

tests were under more natural conditions the results are probably nearer the actual production.

The weight of the female, as might be expected because of the heavy drain on her reserve, drops during early lactation and continues low as long as milk production is high. As soon as the quantity of milk being produced is again within the limit allowed by maintenance requirements of the female she usually recovers quite rapidly the weight lost during high production. This is shown by the weights given for the females used in continuous trials (Table II).

Length of Lactation. The length of milk production in guinea pigs is inherently short because of the early independence of the offspring as far as milk is concerned. Our data show that the first three days production is highly correlated with early mortality but that lactation after 10 days is unnecessary to the development of the young if sufficient green feed is provided. However, females having lactation periods of less than 15 days and yet producing enough milk to sustain their young are in the minority. The average lactation for 61 production periods, where enough milk was produced to prevent the offspring from dying, was 22.08 days with a maximum lactation of 34 days (continuous trial No. 19), and a minimum of 12 days. The average lactation for 10 continuous trials was 16.5 $\pm$ 1.373 days and for

the 52 one-day trials, 23.1 ± 4.064 days. On first sight this seems to be a significant difference, but by statistical methods it was found that the difference, 6.6, has a probable error of 4.289, thus demonstrating that no importance can be attached to it at present.

The effect of age, weight, previous lactations, season, and state of pregnancy on length of milk production is given in Tables IV, V, VI, VII, and VIII. There seems to be no very significant correlation, but this may be due to the small numbers of individuals involved. The average length of lactation for seven females having four or more pigs and five having only one were compared and found to be the same, 22.6 days.

A check on the length of lactation by single physical examinations of 95 females having litters in the mating compartments, between two and 38 days old, showed very close agreement with the results secured by the continuous and the one-day trials. These data are presented in Table IX. They indicate that the majority of the females examined ceased lactating between the 25th and 29th day. Only a few produced milk longer than 30 days. Their average number of offspring was 2.2.

Comparison With Cattle. Lactation in guinea pigs is similar in many respects to that found in cattle. Two days

Table IV. Relation of age of female at parturition to length of lactation.

Age of female at parturition	Length of lactation in days					Totals	Dams whose young died early	Total tested
	9-14	15-19	20-24	25-29	30-34			
Less than 200 days	1	4	8	4	-	17	4	21
200 - 299	3	6	3	7	1	20	2	22
300 - 399	2	-	2	4	-	8	1	9
400 - 499	-	1	3	1	2	7	1	8
500 - 599	-	1	1	2	-	4	-	4
600 - 699	-	-	1	-	-	1	-	1
700 - 799	-	-	1	1	-	2	-	2
800 - 899	-	-	-	1	-	1	1	2
900 and over	-	-	-	-	1	1	1	2
Total	6	12	19	20	4	61	10	71

Table V. Relation of weight of female at parturition to length of lactation

Less than 400	-	-	-	-	-	-	-	--
400 - 499	-	-	2	-	-	2	-	2
500 - 599	-	2	-	3	-	5	1	6
600 - 699	2	5	4	6	1	18	1	19
700 - 799	2	2	10	4	1	19	3	22
800 - 899	2	2	3	4	2	13	2	15
900 - 999	-	-	-	3	-	3	3	6
1000 and over	-	1	-	-	-	1	-	1
Total	6	12	19	20	4	61	10	71

Table VI. Effect of previous lactations on length of lactation.

Lactation tested	Length of lactation in days					Totals	Dams whose young died early	Total tested
	9-14	15-19	20-24	25-29	30-34			
1st lacta. period	3	4	6	5	-	18	3	21
2nd " "	1	4	4	5	-	14	3	17
3rd " "	2	2	1	3	2	10	1	11
4th " "	-	1	3	2	1	7	3	10
5th " "	-	1	1	4	1	7	-	7
6th " "	-	-	2	1	-	3	-	3
7th " "	-	-	2	-	-	2	-	2
Total	6	12	19	20	4	61	10	71

Table VII. Relation of season to length of lactation

Month of parturition								
July	1	-	-	-	-	1	-	1
August	2	3	1	-	-	6	3	9
September	1	3	8	7	1	20	6	26
October	-	1	2	1	1	5	1	6
November	1	1	1	1	-	4	-	4
December	1	1	1	7	2	12	-	12
January	-	2	1	2	-	5	-	5
February	-	1	4	2	-	7	-	7
March	-	-	1	-	-	1	-	1
Total	6	12	19	20	4	61	10	71

Table VIII. Relation of pregnancy during lactation to length of lactation.

Condition of female	Length of lactation in days					Totals	Dams whose young died early	Total tested
	9-14	15-19	20-24	25-29	30-34			
Pregnant	3	3	4	9	2	21	4	25
Non-pregnant	3	9	15	11	2	40	6	46
Total	6	12	19	20	4	61	10	71

Table IX. Data obtained from 95 females in regard to the length of lactation by a single examination of each female.

Result of examination	Number of days after parturition							Totals
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	
Milk obtained	14	20	9	15	5	2	0	65
No milk obtained	2	3	3	5	2	9	6	30
Total	16	23	12	20	7	11	6	95

lactation in the guinea pig corresponds to about one month in cattle, since the lactation period of the cow is about 11 months. Of the dairy breeds, Jerseys most resemble the guinea pig in the relative amount of milk and the actual butter fat percentage. A good Jersey cow will give approximately 45 pounds of milk per day at her peak of production. For a 900 pound Jersey this would be 5 per cent of her body weight. High producing guinea pigs will secrete about 4 per cent of their body weight in a day. Jersey milk tests about 5-7 per cent butter fat as compared with about 7 per cent for guinea pigs (Abderhalden, 1908).

Because of the long term of selection for persistency, Jerseys are probably the highest of any breed in this respect. Guinea pigs, however, are quite variable in regard to persistency because no selection has as yet been practiced with them.

SUGGESTIONS FOR FUTURE WORK

Each of the methods used in obtaining lactation records has its advantages and disadvantages. The ideal system should give as complete a record of the dam's production as possible with as little disturbance of her normal environment as is consistent with this aim.

The "continuous trial" system gives a complete record

of the amount of milk produced throughout the lactation period. By either using the same young to suckle more than one female or by supplying known amounts of solid food, provided the kind of food be kept constant, an indication of the richness of the milk could probably be determined by means of the growth of the young. The continuous trial method seems to shorten the lactation period and decreases the amount of secretion, probably due to the lack of frequent stimulation normally provided the dam by the offspring. It thus does not give a true measure of a natural lactation. However, it must be noted that dairy cattle have been placed in a somewhat similar situation for many years without an ultimate loss in milk flow. This may be due to their proportionately greater "storage space".

The one-day trial method does not give a complete record of production. Although it allows the animals to be under more natural conditions for a greater part of the time, there may be an added effect due to the changes made at testing which cause a higher or lower secretion rate during the test. Moreover, the length of lactation must in most cases be an estimate. By placing the tests at closer intervals, say three days apart for the first fifteen days, and at five day intervals thereafter, and by running the tests for all females the same number of days after parturi-

tion, a much better basis for comparison could be obtained. By proper selection of females so that a certain number would be tested each day, a large number of tests could be run with less time and space than is required by the other methods.

A modification of the continuous trial method, similar to that used in trial 1, is also suggested for future work. The young are to be placed with the dam in an empty compartment at eight o'clock in the evening and removed at eight in the morning. The mother and offspring should be weighed at the time of the morning separation in order to obtain data on the growth of the young and losses in the female during the night. The mother should be placed in a separate compartment during the daytime and supplied with ample food and water. Two milkings per day are to be made, one beginning at 1:00 p.m. and one just before placing the young with the mother for the night. The amount of milk obtained at these two milkings could be used in estimating the amount produced for a 24-hour period, and should be accurate enough if the secretion rate at night is the same as that during the daytime. It is thought that a preliminary milking in the morning will not be needed since the mother will be dry at the time of the separation if the young are kept hungry by not supplying them with too much

food. A milking period of 30 minutes is considered sufficient, since the young are able to remove all of the milk that the female has in less than this time. The extra stimulation found lacking in the former continuous tests is provided at night by this method. A short milking period reduces the errors caused by the animals excreting during milking. Solid food may be supplied the young if they continue to lose weight after the fourth day, but its amount should be weighed and the same kind used consistently if an estimate of the growth in the young is to be attempted.

If the offspring are unusually inactive or show signs of weakness at birth, or if they weigh less than 80 grams, they should not be used for "milkers". If the dam shows unusually low production for the day of parturition and the first day thereafter, the offspring must be supplied with extra milk by using them as "milkers" in other trials, by decreasing the number of offspring being used in the test, or by feeding them solid food, preferably in known quantities.

It is believed by the writer that an apparatus could be invented for milking guinea pigs. This would be useful not only in measuring amounts of milk produced but also for obtaining samples for making chemical analyses. The amounts of the more important constituents, such as butter fat, and

protein, could thus be determined and the inheritance of these qualities could be studied.

SUMMARY AND CONCLUSIONS

The inheritance of milk production in guinea pigs, as in other mammals, appears to be a complex problem. We have not attempted to solve it in this study, but we feel that a satisfactory beginning has been made. The technique followed in obtaining the amount of milk produced was in general found to be satisfactory. A modification of the one-day test, in which the number of days between the tests be shortened and in which each successive test for the different females be made at the same number of days after parturition is suggested for future work. Another suggestion is a modification of the continuous test in which the young be allowed to remain with the dam overnight, weighed at separation in the morning and "milked" for 30 minutes at 1:00 p.m. and at 8:00 p.m. The latter method is probably the more preferable as it would give a more complete record of production.

Lactation in guinea pigs was found to correspond in many ways to lactation in cattle, two days in the lactation of the former corresponding approximately to one month in that of the latter. There was also a similarity in regard

to the variations in the intensity and the persistency of the lactation.

The largest amount of milk per day produced by any one guinea pig in the continuous trials was 27.3 grams on the first day. One female, however, in a one-day trial produced 35 grams on the seventh day. Females having extremely low production (about 3 grams per day) were unable to raise their litters. The offspring of such females lost weight rapidly and usually died before five days of age.

The length of lactation was found to vary from 9 to 34 days. Very few females lactating less than 15 days were able to sustain their young. This was due to the low initial lactation rather than to the length of the lactation period. The average length of milk production for the nine females completing lactation in the continuous trials was 16.2 days as compared to 23.1 for the 52 females in the one-day trials. The average for all the females used was 22.1 days. Of the 61 females tested, 49 ceased lactating between the twentieth and thirtieth day.

These results were borne out by a physical examination of 95 other females in the colony which had litters that were between two and thirty-eight days of age. The dam's teats were compressed in a manner similar to that used in "stripping" a cow and the presence and nature of the fluid

obtained was recorded.

The weights of lactating dams were found to drop considerably as lactation progressed. They regained their weights only after the peak of production had been passed.

In most of the cases studied, the weights of the young dropped considerably during the first three to five days and it was often necessary to feed them solid food. Gains on milk alone were, in general, quite low.

Because of the variation both in the intensity and the persistency of lactation in guinea pigs and because of the comparative ease with which these can be determined, it seems justifiable to recommend these animals as suitable material for a laboratory study of the inheritance of milk production. In future work it would also be necessary to determine the fat percentage and the percentage of other ingredients, if possible.

ACKNOWLEDGMENT

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