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F. B. MUMFORD, *Director*

GROWTH AND DEVELOPMENT

With Special Reference to Domestic Animals

XLIX. Growth, Milk Production, Energy Metabolism, and Energetic Efficiency of Milk Production in Goats

SAMUEL BRODY

With the Cooperation of Mrs. Carl Sandburg and S. A. Asdell

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FOREWORD

The special investigation on growth and development is a cooperative enterprise in which the departments of Animal Husbandry, Dairy Husbandry, Agricultural Chemistry, and Poultry Husbandry have each contributed a substantial part. The parts for the investigation in the beginning were inaugurated by a committee including A. C. Ragsdale, E. A. Trowbridge, H. L. Kempster, A. G. Hogan, and F. B. Mumford. Samuel Brody served as Chairman of this committee and has been chiefly responsible for the execution of the plans, interpretation of results and the preparation of the publications resulting from this enterprise.

The investigation has been made possible through a grant by the Herman Frasch Foundation, now represented by Dr. F. J. Sievers.

F. B. MUMFORD
Director Agricultural Experiment Station

ABSTRACT

Data are presented on goats, with analytical comparisons to dairy cows, on: (1) growth in body weight; (2) rise and decline of milk production with advancing stage of lactation; (3) energetic efficiency of milk production; (4) seasonal variation in metabolism and growth; (5) energy metabolism during growth with reference to body weight and time after feeding. The energetic efficiency of milk production (ratio of milk energy produced to TDN energy consumed) is of the same order in goats, cows, and rats. The rate of approach to maturity (or rate of decline in growth with increasing age) is about $2\frac{1}{2}$ times as great in goats as in cows. The rate of decline of milk production with the advance of the stage of lactation is too variable for unqualified quantitative conclusions, but it tends to be more rapid in goats than cows. Metabolism ("resting" heat production) in goats increases with (about) the $\frac{2}{3}$ power of body weight during growth, but this varies with the season of birth (below $\frac{2}{3}$ if born in February, over $\frac{2}{3}$ when born in July). The metabolic peak coincides with the breeding trough in early spring.

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I. THE DATA.

The data analyzed in this bulletin were obtained cooperatively. The measurements on energy-metabolism of the goats were initiated with the assistance of Dr. C. W. Turner of this Station who was interested in the seasonal metabolism rhythm of the goat as possibly related to its seasonal breeding rhythm. The bulk of the excellent growth and milk-production data was furnished by Mrs. Sandburg and Miss Helga Sandburg, Chikaming Goat Farm, through the kind introduction of Dr. C. W. Turner. Dr. Asdell from Cornell University generously furnished data on feed consumption as well as milk production of lactating goats for computing the energetic efficiency of milk production. Several University students helped with the measurements of the energy metabolism, with the computation work, and with the preparation of the charts. Special acknowledgments are made to: Jack Parsell and Paul Whitson for metabolism measurements, Miss Margaret Sappington for computations, Hudson Kibler and John Campbell for computations and charting, Dr. L. E. Washburn for the gas-analysis measurements included in Figs. 9, 10, and 11.

II. AGE CURVES OF GROWTH IN WEIGHT. COMPARISON OF RELATIVE GROWTH RATES IN GOATS AND COWS.

The numerical data on growth are given in Tables 6 and 7 in the Appendix. The growth data shown in Fig. 1, accumulated in connection with our energy-metabolism measurements, are extremely irregular. For this reason we made no attempt to investigate our own growth data mathematically. The curves in Fig. 1 are presented only by way of record of the growth of the animals that were the subjects of the rather extensive metabolic investigation reported in

THIS IS PAPER 176 IN THE HERMAN FRASCH FOUNDATION SERIES.

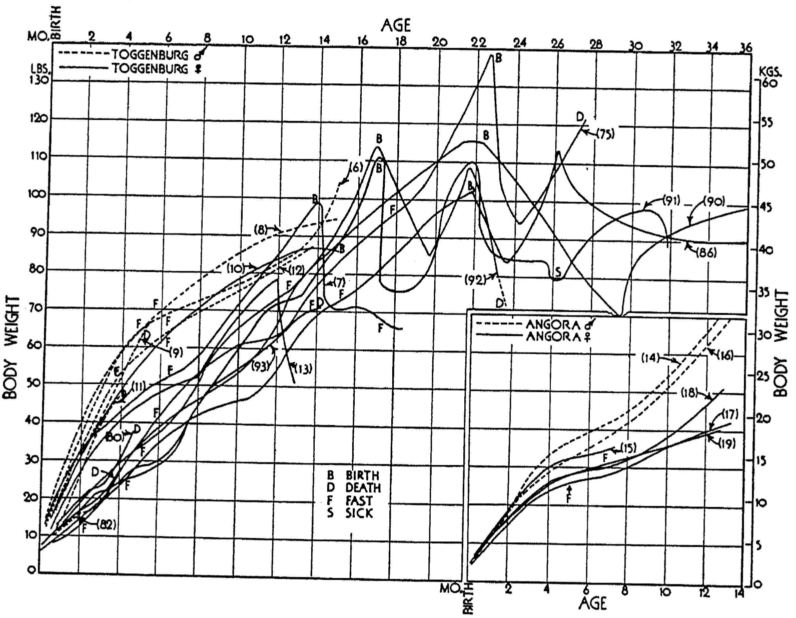


Fig. 1.—Age curves of growth in weight of experimental goats on which the metabolism data were secured.

a later section of this bulletin. Most of the Sandburg growth data in Fig. 2 are distributed more regularly, but still not regularly enough for mathematical analysis.

The distribution of the Sandburg growth data in Fig. 3 are much better and we have consequently carefully investigated these data mathematically.

We have fitted to these Sandburg data our growth equation[1]

$$W = A - Be^{-kt} \quad (1)$$

in which W represents live weight (pounds) at age t (months), A is mature weight, k is the (monthly) rate of decline in growth (or speed of approach to maturity), and e is the base of natural logarithms. The results of fitting equation (1) to the data are shown in Fig. 3.

The value of k in the above equation for the females is of the order of 0.10 to 0.17, which is close to the values of k we previously reported for sheep (page 11 Missouri Research Bulletin 101), and about three times as great as for cows (the value of k for cows is shown in Research Bulletin 101 to be of the order of 0.05). This means that goats approach maturity 2 to 3 times as rapidly as dairy cows, or that a month in the life of a goat is from the growth-in-weight view-

[1]For a detailed discussion of this equation see Univ. Missouri Agr. Exp. Sta. Res. Buls. 97 and 101, 1928.

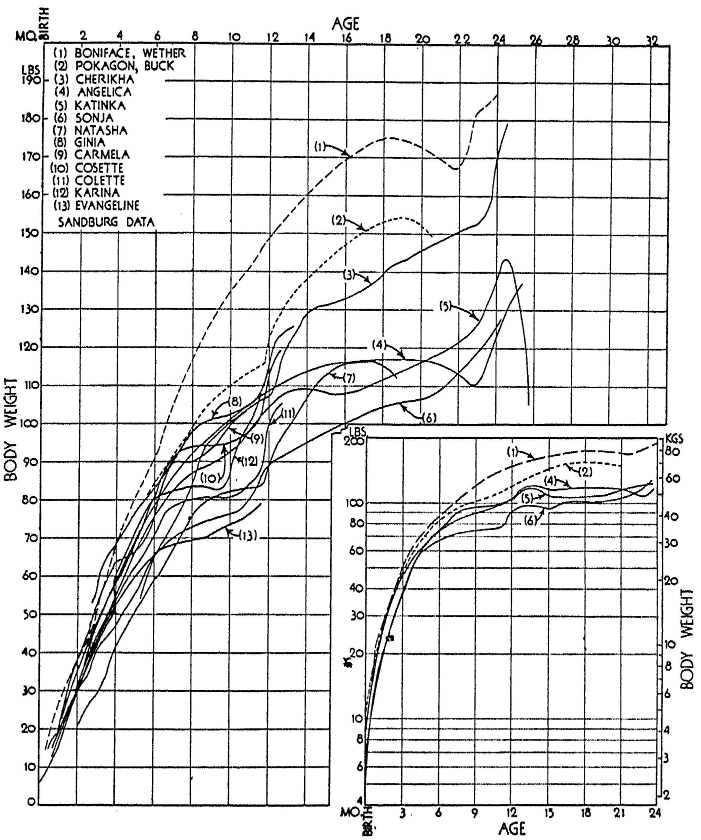


Fig. 2.—Age curves of growth of some of the Sandburg goats. The insert is on an arithlog grid to indicate that while the *absolute* weight curves are not parallel, the *relative* curves are parallel (for same sex).

point equivalent to 2 to 3 months (depending on sex individuality and age) in the life of a cow. This fact is brought out in striking manner in the equivalence chart in Fig. 4, in which the age curves of the cows and goats are made to coincide.[2] The upper axes represent the ages when equivalent fractions of mature weights are reached in the cows and goats.

An interesting item about Figs. 3 and 4 is that the male and the wether are not only larger by about 50 pounds but they also appear to mature more slowly than the females, as indicated by the values of k in the equations, in Fig. 3, and in Table 1. The value of k for the male and wether is of the order of 0.10, of the females 0.15; which theoretically means that from the standpoint of speed of approach to

[2]For a detailed explanation of the method employed to make age curves of animals to coincide, and the results obtained thereby, see Missouri Res. Buls. 97 and 102.

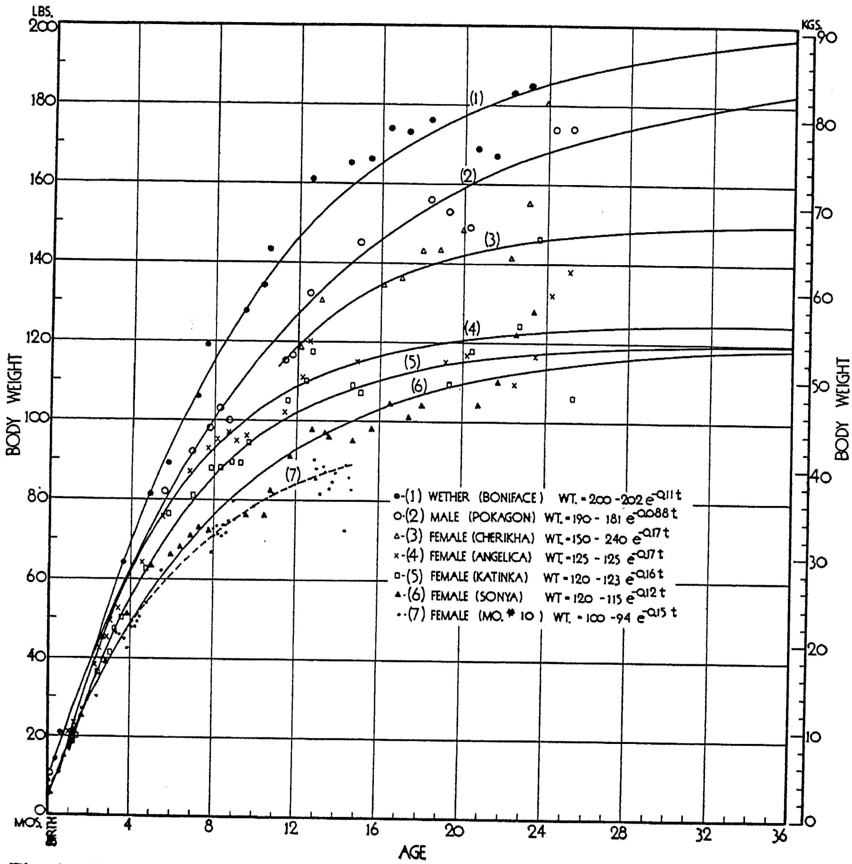


Fig. 3.—Age curves of growth in weight of some of the Sandburg goats. (The smallest animal represents one of the Missouri-metabolism goats.) The fitted equation of the curves are given on the chart. The first value in each equation represents the mature weight which is seen to range from 200 pounds for goat 1, the wether, to 100 pounds for goat 7. The exponent when multiplied by 100, represents the percentage decline in growth rate. Thus the growth rate of goat 2 declines at 8.8% per month, while the growth rate of goat 3, is 17% per month.

mature weight, a month following puberty in the female is equivalent to about $\frac{.15}{.10} = 1.5$ months in the male or wether. It seems unbelievable that females should approach maturity 50% more rapidly than males, and we shall await with interest further accumulation of data on growth of males, wethers, and females of the same breeding and under similar conditions.

We close this section on growth by presenting Table 1 for "predicting" weight from age of each of the goats represented in Fig. 3, predicted from the corresponding equations in Fig. 3. In one sense the values predicted from the equation are fairer than the observed

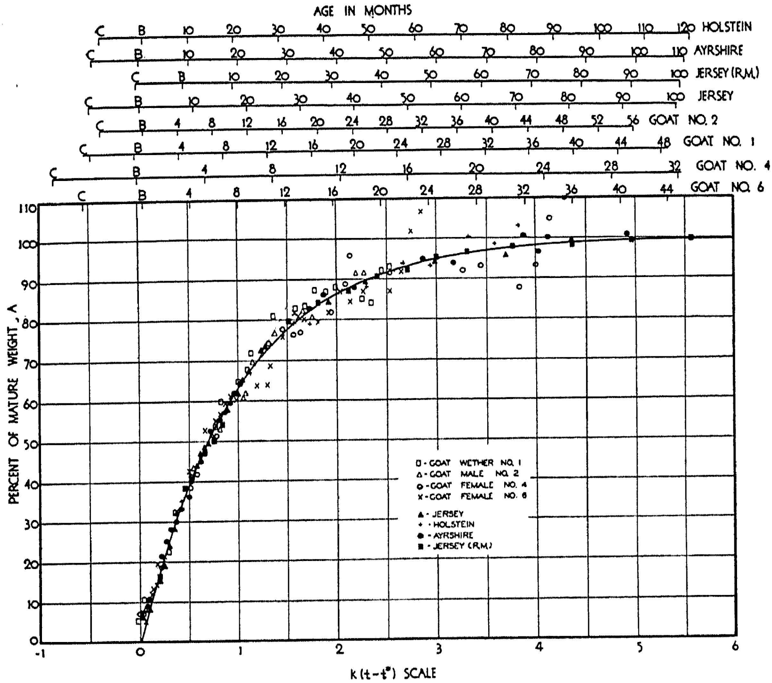


Fig. 4.—Equivalence of age for Holstein, Ayrshire, and Jersey cows and Toggenburg goats 1, 2, 4, and 6 plotted in Fig. 3. A 50 to 60-month old cow appears to be in the same stage of maturity (as measured by growth rate) as a 20 to 30-month old goat.

TABLE 1.—BODY WEIGHTS OF GOATS REPRESENTED IN FIG. 3 COMPUTED FROM THE FITTED EQUATION SHOWN ON THE CHART.

Age Months	# 1 Boniface Wether	# 2 Pakagon Male	# 3 Cherikha Female	# 4 Angelica Female	# 5 Katinka Female	# 6 Sonya Female	# 7 (Mo. # 10) Female
Birth*	8.8	10	8.8	8.8	6.8	5.1	5
1.5	34	31		28	23	24	25
2.0	43	38		36	31	30	30
2.5	51	45		43	38	35	35
3.0	59	51		50	44	40	40
3.5	67	57		56	50	44	44
4.0	74	63		62	55	49	48
4.5	81	68		67	60	53	52
5.0	87	73		72	65	57	56
6	99	83		80	73	64	62
7	109	92		87	80	70	67
8	119	100		93	86	76	72
9	127	108	98	98	91	81	76
10	135	115	106	102	95	85	79
11	142	121	113	106	99	89	82
12	148	127	119	109	102	93	84
13	153	132	124	111	105	96	87
14	158	137	128	113	107	99	88
15	162	142	131	115	109	101	90
18	173	153	139	119	113	107	94
20	178	159	142	121	115	110	95
22	183	164	143	122	116	112	97
24	186	168	146	123	117	114	97
26	189	172	147	123	118	115	98
28	191	175	148	124	119	116	99
30	193	177	149	124	119	117	99
32	194	179	149	124	119	118	99
34	195	181	149	125	119	118	99
36	196	182	149	125	120	118	100

*The weights given at birth are observed values.

TABLE 2.—AGE (MONTHS FROM BIRTH) WHEN 50%, 75%, 90%, 95%, AND 98% OF MATURE WEIGHTS ARE REACHED IN THE GOATS AND COWS REPRESENTED IN FIG. 4.

	50%	75%	90%	95%	98%	Mature Weight lbs.
# 1 (Wether) goat	6.4 mos.	12.7 mos.	21.0 mos.	27.3 mos.	35.7 mos.	200
# 2 (Male) goat	7.3	15.2	25.6	33.5	43.9	190
# 4 (Female) goat	4.1	8.2	13.5	17.6	23.0	125
# 5 (Female) goat	4.2	8.5	14.2	18.6	24.3	120
# 6 (Female) goat	5.4	11.2	18.8	24.6	32.3	120
# 7 (Female) goat	4.2	8.8	14.9	19.6	25.7	100
Holstein cows	14	30	49	64	84	1215
Ayrshire cows	14	28	46	60	78	1014
Jersey cows	13	26	42	55	72	926

The numerical data for the cattle were published in Missouri Agr. Exp. Sta. Res. Bul. 96 (1926) pp. 20-21.

values because they discount short-time (day-to-day) fluctuations, and because they discount variations due to gestation and lactation. All the original data are presented in the appendix.

III. TIME CURVES OF MILK PRODUCTION WITH THE ADVANCE OF THE STAGE OF LACTATION. COMPARISON OF RELATIVE DECLINES IN GOATS AND COWS.

The time curves of milk production within a lactation period are presented in Fig. 5.

On the left, the data are plotted in terms of pounds milk per day; on the right in terms of milk per day after reducing the milk to 4% fat by Gaines' formula.[3] Calorie values are given on the right axis indicating the amount of milk-*energy* produced per day.

The light broken curves on the left side of Fig. 5 represent average curves (as contrasted to the Sandburg individual curves) of the British-Goat-Society data compiled by H. J. Brooks in Asdell's laboratory.

The three broken curves on the right side of Fig. 5 represent: (6) Asdell's highest-milking Goat No. 6, (13) Asdell's lowest-milking Goat 13, and (7) the average of 7 of his goats (Numbers 13, 6, 46, 40, 44, 16, 41).

The amount of milk produced during a lactation period depends on: (1) the maximum daily production achieved, and 2) persistency of production of which the inverse is the steepness or rate of decline from this maximum as the lactation period advances.

We have previously[4] shown that cows differ enormously in their milking persistency. In one herd of cows the milk production was found to decline about three times as rapidly as in another. It seems

[3]Gaines, W. L., Univ. Ill. Agr. Exp. Sta. Bul. 308, 1928.
[4]See page 22 in Missouri Agr. Exp. Sta. Res. Bul. 105.

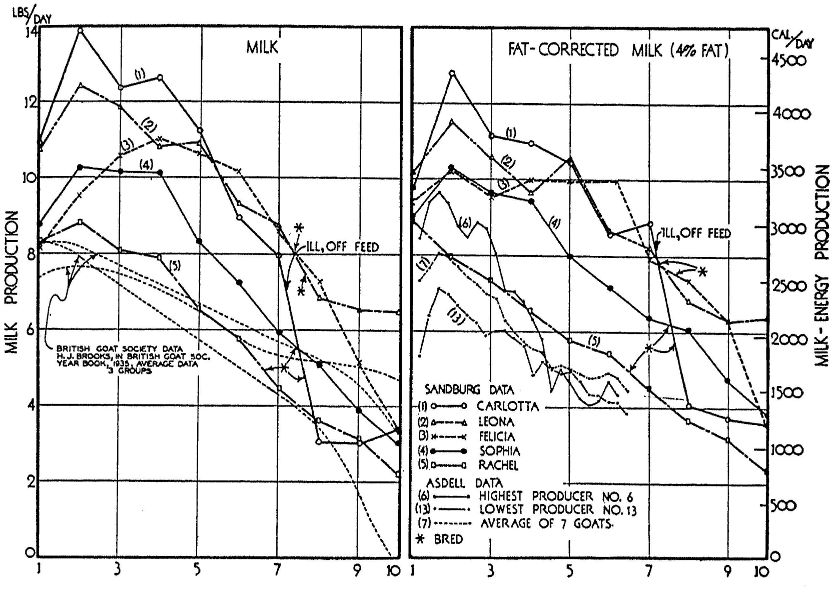


Fig. 5.—The decline of milk production in the goat with the advance of the period of lactation. The left side represents milk production per day of the Sandburg individual goats and the average British Goat Society data compiled by Brooks. The right side represents milk adjusted to 4% fat of the Sandburg goats numbers 1, 2, 3, 4, 5, and Asdell's data as indicated on the chart.

instructive to compare the relative persistencies, or the relative declines, in milk production in the Sandburg and Asdell goats, and also in goats and cows, something on the style in which we compared in Fig. 4 growing goats and cows with respect to the relative approaches to their mature body weights.

There are several methods for comparing the *relative* declines in milk production with the advance of the stage of lactation. One is to divide the milk production during any one month by that of the preceding month. Thus in one group of Advanced-Registry dairy cattle (see Curve 1, Fig. 6), we found that on the average each month's production was about 95% of the preceding month; which means that production declined at the rate of 5% per month. In another group of cattle (see Curve 6, Fig. 6) each month's production was about 83% of the preceding month's production; which means that the production declined at the rate of 17% per month. The milk production in the second herd of cows thus declined three times as fast as in the first. If comparisons are made by this method on individual animals, the results are likely to be erratic because the condition of a given animal varies from day to day for many reasons other than advance of the stage of lactation, and with the variation in the animal's condition there is a corresponding variation in milk production.

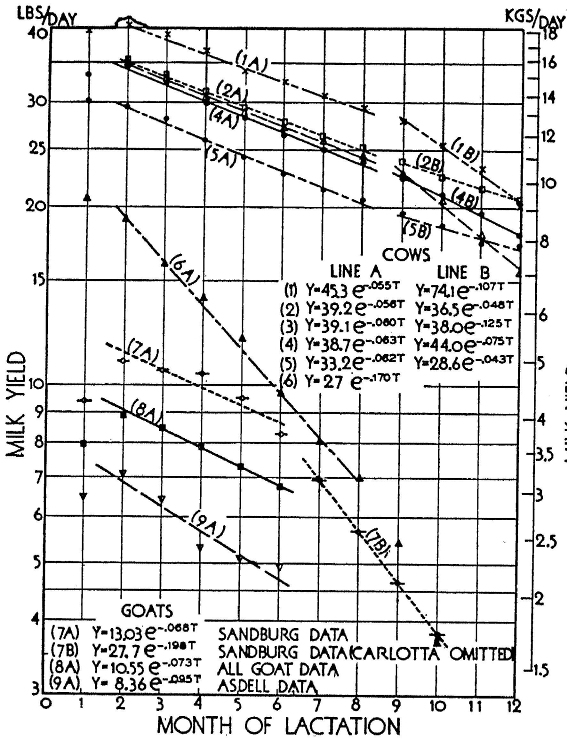


Fig. 6.—A comparison of the declines in milk production in cows (curves 1, 2, 4, 5, 6) and goats (curves 7, 8, 9) plotted on arithlog paper. There seems to be a break in the curves (perhaps due to pregnancy) between 8 and 9 months in cows, and 6 to 7 months in goats. The curves preceding the break are indicated by A, and those following the break by B. The exponents multiplied by 100 represent the monthly percentage declines in milk production, which are seen to range (for segments A) from 5.5 to 17% for cows, and from 6.8% to 19.6% for goats.

A better method for comparing production declines consists in plotting milk production against time on semi-logarithmic paper.[5] On this kind of paper *equal slopes represent equal relative,* (or when multiplied by 100, *percentage*), declines. The declines in milk production of two individuals are represented in proportion to the slopes of their respective curves. Moreover, the equation

$$Y = ae^{-kt} \tag{2}$$

can be fitted to the data. The numerical value of k represents precisely the average relative (or when multiplied by 100 percentage)

[5]See Missouri Agr. Exp. Sta. Res. Buls. 97, 98, and 105 for detailed discussion of the philosophy and method of such plotting and curve fitting.

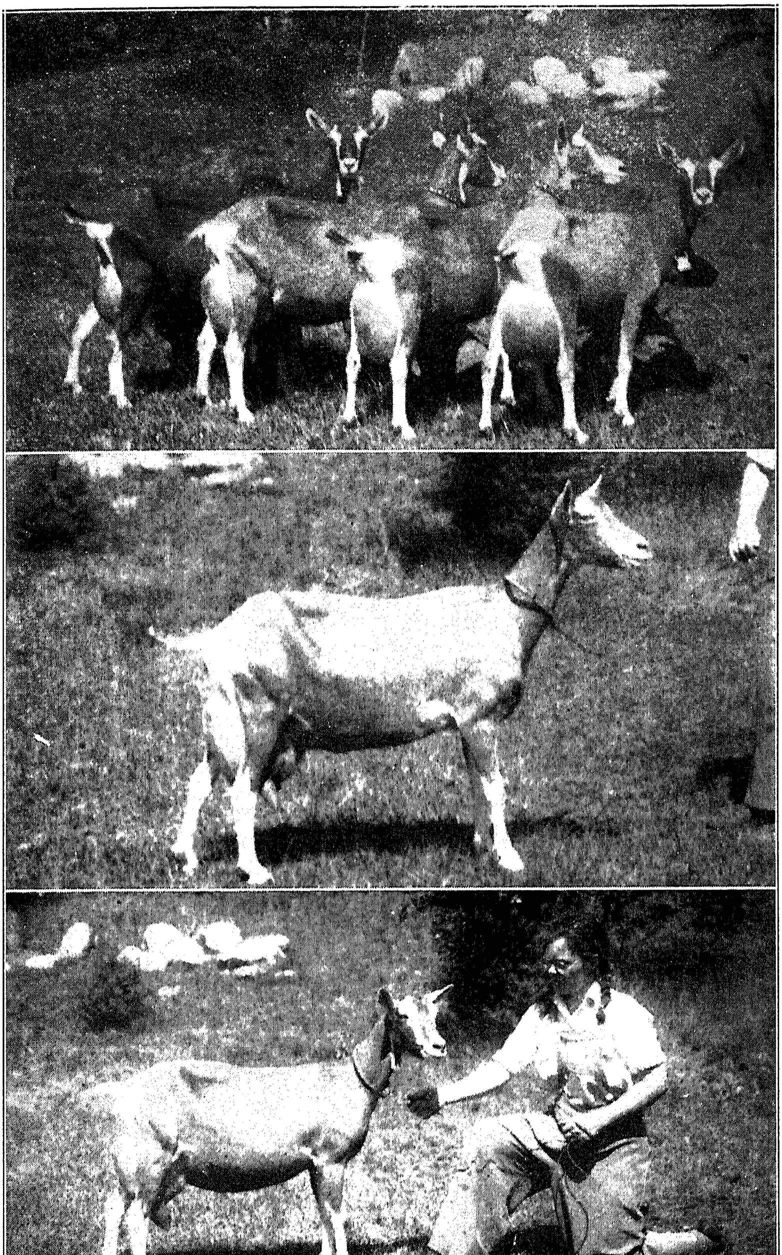


Plate I.—Outstanding individuals among the Sandburg goats. Upper section Left to right: Betty, Felicia, Carlotta, and Glory. Middle: Carlotta. Lower: Felicia, with her owner, Miss Helga Sandburg.

decline in milk production with advance of the time, t. We plotted the data on such arithlog paper, and fitted equation (1) with results shown in Fig. 6.

In Fig. 6, curve 1 composed of segments 1A and 1B represents non-selected Advanced-Registry Guernseys, 2A-2B Farrow Guernseys, 3A-3B Guernseys bred 3-4 months after calving, 4A-4B Missouri Jersey data, 5A-5B Missouri Holstein data, 6A Iowa Scrub cows,[6] 7A-7B average of the Sandburg lactation data, 8A average of all goat data, 9A Asdell's data. The numerical data for milk production in the goats are given in the appendix.[6]

Segments 1A and 1B represent the same group of cows, 7A and 7B represent the same group of goats, and so on for the other A and B segments. The A segments represent milk production prior to the time gestation becomes an influencing factor, while the B segments represent milk production after gestation becomes an influencing factor. The breaks between the A and the B segments of the curves are thus attributed to pregnancy. Thus in curve 1, the value of the exponent k is 0.055 for segment 1A, and 0.107 for segment 1B; meaning that preceding 8 months the milk production declined at the instantaneous percentage rate of 5.5% per month, and following 8 months it declined at the instantaneous rate of 10.7% per month. Gestation increased the rate of decline of milk production from 5.5% to 10.7% probably because some of the available nutrients which would be used for milk production if the animals were not pregnant were diverted for the nutrition of the fetus during pregnancy. For this reason separate equations were fitted to the A and B segments.

Let us compare the relative declines in milk production in the A segments of goats and cows in Fig. 6. Curve 9A, representing the average of Asdell's data, declines at the instantaneous rate of 9.5% per month (that is the value of the exponent k in equation 2 is 0.095); curve 7A, representing the average of the Sandburg data, declines at the instantaneous rate of 6.8% per month. This means that the Sandburg goats were more persistent in their production—their decline was 2.7% less—than the Asdell goats. The average decline of both groups of data is 7.3% per month.

Now consider the decline of the A segments for the cows. The decline for the scrub cows, curve 6A, is 17% per month, a decline which is about 2½ times as rapid as in the goats. That is, the goats held up their production very much better than the scrub cows. However, the decline in the pure-bred cows (curves 1A, 2A, 3A, 4A, and 5A), which ranged from 5.5% for the Advanced-Registry Guernseys to

[6]The numerical data for milk production in the cattle are given in University of Missouri Agr. Exp. Sta. Res. Bul. 96, 1926 (page 61).

6.3% for the Missouri Jersey and Holstein cows, was considerably less than the 6.8% decline for the Sandburg and the 9.5% for the Asdell data. The decline for the Asdell goats (curve 9A) is near 10%, and of the A. R. Guernsey cows is near 5%, so that the decline for Asdell's goats was nearly twice as great as for the Guernsey cows. We may recall from Figs. 3 and 4 that the approach to maturity, that is the decline in growth rate with increasing age, is two to three times as great in goats as in cows; which would lead one to expect that the decline in milk production with advancing stage of lactation is also two to three times as great in goats as in cows, and such appears to be the case when comparing the decline in Asdell's goats and the A. R. Cows. On the other hand, as shown in Fig. 6, the decline in milk production with the advance of the stage of lactation in the Sandburg data, 6.8%, is only slightly greater than of the Missouri cattle, 6.3%, and only 1% greater than in the A. R. Guernsey cattle. In other words we are not in a position to say definitely whether or not the relative biologic time units (the k's in equation 1) deduced from the age curves of growth in weight in Figs. 3 and 4 are the same as the biologic time units for decline in milk production with the advance of the stage of lactation (the k's in equation 2). We can only say tentatively that the persistency of milk production with advancing stage of lactation tends to be rather less, or the percentage decline in milk production tends to be greater, in goats than in cows. More data are urgently needed for the solution of this problem of relative decline of milk production in goats and cows with the advance of the stage of lactation.

The above tentative interpretation is for the A segments, before the influence of gestation became marked. In the B segments, that is the segments following the impact of gestation (beginning with 7 months in the Sandburg goats and 9 months in the cows), the decline is very much greater in the goat (near 20%) than in the cow (7 to 13%). This may be due to the more rapid growth of the goat fetus than cow fetus, and to the greater birth weights of the kids than calves in comparison to the weights of their respective mothers. Note that Carlotta, the best-milking animal, was ill during this phase of lactation, and therefore was omitted.

Before closing this section a word may be said concerning the meaning of the phrase decline of milk production at the *instantaneous* rate of 5% per *month*. On first consideration *instantaneous* and per *month* appear to be contradictory, yet if one thinks of money which draws interest at, say, 5% *per year* which may be compounded either *annually* or *semi-annually*, or *quarterly*, or *monthly*, this situation

RELATION BETWEEN THE VALUE OF k IN THE EQUATION $Y = ae^{kt}$ AND "SIMPLE" PERCENTAGE RATE OF CHANGE, THAT IS $100 \frac{Y_2 - Y_1}{Y_1}$.

K is positive				K is negative			
100 k	%	100 k	%	100 k	%	100 k	%
0	0	67	95.4	— 2	— 2.0	— 75	—52.8
2	2.0	70	101	— 4	— 3.9	— 80	—55.1
4	4.1	73	108	— 6	— 5.8	— 85	—57.3
6	6.2	75	112	— 8	— 7.7	— 90	—59.3
8	8.3	80	123	—10	— 9.5	— 95	—61.3
10	10.5	85	134	—12	—11.3	— 100	—63.2
12	12.7	90	146	—14	—13.1	— 110	—66.7
14	15.0	95	159	—16	—14.2	— 120	—69.9
16	17.4	100	172	—18	—16.5	— 130	—72.7
18	19.7	110	200	—20	—18.1	— 140	—75.3
20	22.1	120	232	—22	—19.7	— 150	—77.7
22	24.6	130	267	—24	—21.3	— 160	—79.8
24	27.1	140	306	—26	—22.9	— 180	—83.5
26	29.7	150	348	—28	—24.4	— 200	—86.5
28	32.3	160	395	—30	—25.9	— 220	—88.9
30	35.0	180	505	—32	—27.4	— 240	—90.9
32	37.7	200	639	—34	—28.8	— 260	—92.6
34	40.5	220	803	—36	—30.2	— 280	—93.9
36	43.3	240	1002	—38	—31.6	— 300	—95.0
38	46.2	260	1246	—40	—33.0	— 400	—98.2
40	49.2	280	1544	—42	—34.3	— 500	—99.3
42	52.2	300	1909	—44	—35.6	— 600	—99.75
44	55.3	400	5360	—46	—36.9	— 700	—99.91
46	58.4	500	14741	—48	—38.1	— 800	—99.97
48	61.6	600	40243	—50	—39.3	— 900	—99.99
50	64.9	700	109563	—55	—42.3	—1000	—99.995
55	73.3	800	297996	—60	—45.1		
60	82.2	900	810208	—65	—47.8		
65	91.6	1000	2202547	—70	—50.3		

The table was prepared from the equation $\frac{Y_2 - Y_1}{Y_1} = e^k - 1$, derived as follows: Let $Y_1 = ae^{kt_1}$, and $Y_2 = ae^{kt_2}$, then $Y_2 - Y_1 = a(e^{kt_2} - e^{kt_1})$, and $\frac{Y_2 - Y_1}{Y_1} = \frac{e^{kt_2} - e^{kt_1}}{e^{kt_1}} = \frac{e^{kt_2}}{e^{kt_1}} - 1 = e^{k(t_2-t_1)} - 1 = e^k - 1$ (when $t_2 - t_1 = 1$).

Example: when $k = -.107$, $\frac{Y_2 - Y_1}{Y_1} = e^{k} - 1 = e^{-.107} - 1 = -1 + 0.8985257 = -0.10147 = -10.15\%$ (app.). Note that while there is no limit to the range in the numerical value of k, the decline in the "simple" *percentage*, $100 \frac{Y_2 - Y_1}{Y_1}$, can never exceed 100%.

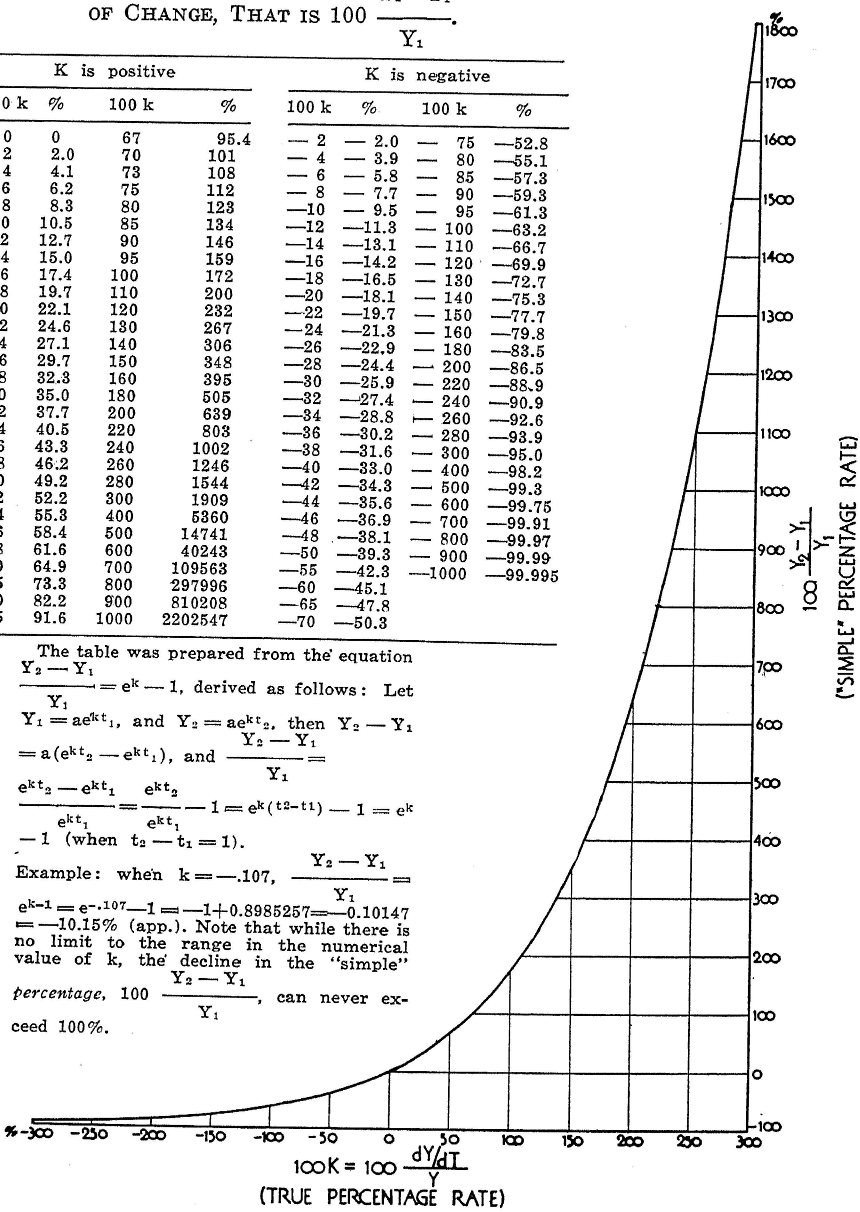


Fig. 7.—The relation between "simple" interest, $100 \frac{Y_2 - Y_1}{Y_2}$, and instantaneous interest, 100 k. The k is the constant in the equation $Y = ae^{kt}$. The value of k may be positive, or negative (in case of depreciation or decline).

clears up. In nature, however, compounding is done not annually, semi-annually, or quarterly, or monthly, but *instantaneously*. The "instant" is the ultimate unit of time for compounding and not the half year, quarter year, or the month. 5% per year (or per month) compounded instantaneously is basically similar in computation method to 5% per year compounded monthly except that the instantaneous method is carried to extremely small time units—to infinitesimals. Equations (1) and (2) embody this infinitesimal interest-compounding principle. The relation between the *instantaneously compounded monthly* interest and *simple monthly* interest is shown in Fig. 7.

IV. NOTE ON AGE CURVES OF MILK PRODUCTION.

The rise and fall of milk production with increasing age reflects the rise and fall of body function with growth and senescence. We have carefully studied the growth and senescence of the lactation function in dairy cattle,[7] and it seemed instructive to compare the lactation curves of goats and cows. As previously noted (Fig. 4) maturity (i. e., mature body weight) appears to be approached 2 to 3 times as rapidly in goats as cows. This observation prompts the guess that maximum milk production in goats would be reached at about half the age reached in cows. Maximum milk production is reached at about 7 years in cows; is it reached at half this age, that is between 3 and 4 years, in goats? Then there is the question of relative speed of decline of milk production from the maximum in goat and cow. Does the average goat also age twice as rapidly and die at about half the age as the cow?

It is not possible to answer these questions at this time because of lack of data on age changes in milk production of goats and on life expectancy. We are familiar with recorded data on milk production on only two goats and only up to 7 or 8 years.[8] Even in these two sets of data, the lengths of the lactation periods varied from 190 to 319 days so that the productive potentialities at different ages can not be conveniently compared. This note thus only calls attention to the need for: 1) collecting life records for milk production in goats; 2) having all published records of comparable lengths; 3) comparing the age curves of production in goats and cows. If the rates of rise and decline of production with increasing age in goats proceeds with double the speed as in cows—as is the case with growth in weight—than the long-range energetic efficiency of milk production is probably of the same order in goats and cows; if, however, the rate of senescence

[7]See Mo. Agr. Exp. Sta. Res. Bul. 105.
[8]Addington, L. H., and Cunningham, O. C., Milk Goat Breeding. New Mexico Agr. Exp. Sta. Bul. 229, 1935 (see pp. 46 and 48).

in the goat is less rapid than is thus guessed—as it may be—then the long range efficiency (which includes longevity and fertility) is greater in goats than cows.

V. ENERGETIC EFFICIENCY OF MILK PRODUCTION. COMPARISON OF EFFICIENCIES IN GOAT, COW, AND RAT.

The available data on milk production in goats (Fig. 18) indicate that a 120-pound goat may attain the productive level of 15 pounds of milk a day. If cows were to produce as much milk in comparison to body weight, then a 1200-pound cow would produce 150 pounds of milk a day, which appears improbable. One might even be tempted to claim that the smaller the animal the more efficient it is and substantiate this claim by citing the rat which in three weeks raises a helpless mass of 12 newborn to independent sturdy juvenility. *In comparison to body weight,* the milk production in the rat must be very much greater than in the cow or goat. We thus have apparently clear-cut evidence that the smaller the animal the greater her ability to produce milk. However, the sponsor of larger animals such as cows finds equally good arguments to support the claims of the superiority of large dairy animals. In the first place, *per unit weight,* the basal metabolism is very much less in large than small animals, and therefore the overhead maintenance cost per unit body weight is likely to be less in the large than in small animals. It is entirely possible that the *efficiency, that is the amount of milk produced per unit feed consumed* (rather than per unit body weight), is no less in large than small animals; and if the efficiency is the same in large and small animals, then price per unit milk being the same, the large animal is the more profitable because the management cost (housing, milking, bookkeeping, etc.) would be less in handling a few large than many small animals producing the same amount of milk.

The question as to whether the milk produced per unit digestible feed consumed, termed *gross energetic efficiency* of milk production, is the same in small and large cows is a difficult one. But the data in Table 3, which are mostly self explanatory, shed a good deal of light on this question. The goat data were furnished by Dr. Asdell as explained in the introduction. The cow[9] and rat[10] data were previously published. Let us summarize the results in Table 3 in the form of answers to three questions.

[9]Cf. Brody, S., Procter, R., and Cunningham, R., Studies on energetic efficiency of milk production and the influence of live weight thereon. Missouri Agr. Exp. Sta. Res. Bul. 222, 1935, and Res. Bul. 238, 1936.

[10]Brody, S., and Nisbet, Ruth, A comparison of the amounts and energetic efficiencies of milk production in rat and dairy cow. Missouri Agr. Exp. Sta. Res. Bul. 285, 1938.

1. *Which produces more milk-energy per unit body weight, a goat, cow, or rat?* Table 3 shows that the ratio of milk-Cal. produced to kg. body weight is of the order of 200 in rats, 50 in goats, and 25 in very good dairy cows. In brief, the *milk-production intensity,* that is productivity per unit body weight, is very much higher in small than large animals. It is higher in rats than goats, and in goats than cows.

TABLE 3.—GROSS ENERGETIC EFFICIENCY (WITH RESPECT TO TDN CONSUMED) OF MILK PRODUCTION IN GOATS, DAIRY COWS, AND WHITE RATS.

	Milk Production					
	Goats	Dairy Cows			White Rats by methods A and B	
	Asdell's goats (Cornell U.) Observed data	"Ordinary" (Superior) All breeds	"Extraordinary" Champion Holstein	Champion Jersey	Arithmetic average of all litters A	B
No. of goats, cows, or rat-litters...	7	368	1	1	7	5
Body Weight, Kgs................	42.5	513	771	318	0.291	0.295
Av. milk production Cal./day (Length lactation period range in goats 11 to 25 weeks; cows ¼ to 1 yr.; in rat ave. between 10 to 18 days lactation inclusive in 4 to 9-rat litters.)	2114	11440	34000	24140	71.5	60.1
Gross Energetic Efficiency of Milk Production with Respect to TDN Energy..........................	34.9 (32.0-40.5)	31	44	48	48	44
Estimated basal metabolism Cal./Day	1100	6700	9000	4700	29	29
Ratio basal metabolism Cal./day to body weight, Kg.................	26	13	11.7	12.3	99	99
Ratio milk Cal. to basal metabolism Cal........................	1.9	1.7	3.8	5.1	2.1	2.1
Ratio milk Cal. to body weight, Kg.	49.8	22	44	63	207	149
$(Wt.)^{0.73}$..........................	15.4	95.1	128	67.1	.406	.411
Ratio milk Cal. to $(Wt., Kg.)^{0.73}$..	136.9	120	266	360	148	147

2. *Which produces more milk-energy per unit basal-energy metabolism and per unit of feed maintenance, a goat, rat, or cow?* The enormously higher *milk-production intensity* of rats as compared to cows is associated with an enormously higher *metabolic intensity* (heat production per unit weight) in rats as compared to cows with the net results, shown in Table 3, that the milk-Calorie production with respect to the basal-metabolism-Calorie production is the same in goats, rats, and cows.

Table 3 shows that the ratio of milk Calories produced to basal heat Calories produced is of the order of 2 in goats, rats, and also in cows. Goats, like rats and cows, tend to produce about twice as many milk Calories as basal-metabolism Calories. The typical goat's basal metabolism is of the order of 1100 Calories per day, and the milk-energy production is of the order of 2200 Calories per day. The typical rat's basal metabolism is of the order of 30 Calories per day, and the milk-energy production is of the order of 60 Calories per day. The typical cow's basal metabolism is of the order of 6000 Calories per day, and the milk energy production is of the order of 12,000 Calories per day. There are of course tremendous individual variations, but the average values in Table 3 illustrate the apparently general biologic principle that the ratio of milk-energy production to basal metabolism is independent of body weight or even of species, provided that the "inherited impulse for milk production" is of the same order.

Since the basal-energy metabolism of mature animals of different species tends to be directly proportional to the 0.73 power of body weight[11] and since milk-energy production tends to be directly proportional to basal energy metabolism, the milk energy production should also tend to be directly proportional to the 0.73 power of body weight. In other words, the ratio of milk-energy production to the 0.73 power of body weight should be of the same order in rats and cows, and Table 3 shows that this is roughly the case.

We have no reliable data on the energy cost of maintenance of goats, rats, and cows of different weights. However, in the absence of evidence to the contrary, it is reasonable to assume that the ratio of maintenance energy to basal-metabolism energy is of the same order in the three species, and that consequently the ratio of milk-energy production to maintenance energy is of the same order in the three species.

3. *Which produces more milk-energy with respect to food (TDN) consumption a goat, rat, or cow?* In other words, does a goat, rat, or cow produce milk at greater energetic efficiency? Table 3 furnishes a clear-cut answer to this question. The gross energetic efficiency of Asdell's goats is of the same order as of the "ordinary" cows. "Extraordinary (champion) goats, such perhaps as Sandburg's Carlotta, would perhaps have the same efficiency as the champion cows tabulated in Table 6. The average gross energetic efficiency of milk production in *rats* in the flush of the lactation period, was estimated to be[10] on the average in between 44% and 48%, which happens to be between the same limits as the gross energetic efficiency of milk production in champion cows.

The fact that the gross energetic efficiency of milk production in rats is the same as in champion, not ordinary, cows, is probably without biologic significance, because of the many assumptions that were

[11]Cf. Brody, S., Procter, R. C., and Ashworth, U. S., Basal metabolism, endogenous nitrogen, creatinine and neutral sulphur excretion as functions of body weight. Missouri Agr. Exp. Sta. Res. Bul. 220, 1934.

made in computing the results, such as that the fuel value of rat milk is uniformly 2.3 Cal. per gram, that the fuel value of body-weight gain in litters is uniformly 1.5 Cal. per gram, that the digestibility of given feed stuffs is the same in rat and cow, that the fermentation losses (methane) are the same in ruminants as in rats.

We therefore conclude that while *with respect to body weight* the milk-energy production in the rat is very much greater than in the goat, and in the goat greater than in the cow, the basal metabolism and probably maintenance in the rat is greater than in the goat, and in the goat greater than in the cow by proportional amounts with the net result, as shown in Table 3, that the *energetic efficiency* of milk secretion is of the same order in the rat, goat, and cow.

This conclusion that the gross energetic efficiency of milk production tends to be the same in rats, goats, and cows, substantiates the generalization that other conditions being the same, the gross energetic efficiency of milk production tends to be independent of size of animal not only within the species (large vs small cows) but also in different species (dairy goats, dairy cows, rats).

The data from which the efficiency of milk production in the goat was computed are tabulated in the appendix. Similar data for cattle and rats were previously published.[9, 10]

VI. ANNUAL METABOLISM AND GROWTH RHYTHMS.

While there are, of course, exceptions, most animals tend to breed in accordance with a definite seasonal pattern presumably evolved to be most helpful to the young. The spring is normally the most favorable season for survival, and most animals tend to breed so as to give birth in the spring. Accordingly, animals having a short gestation or incubation period breed in the spring, and those having a long gestation period breed in the autumn. Practically all birds, and such mammals as the ferret, fox, wild cat, field mouse, hedge hog are spring breeders, while such mammals as deer, cattle, sheep, goats, tend to be autumn breeders. Because of domestication, cattle lost the seasonal breeding pattern, but wild cattle breed in the summer (July) so as to calve next spring. There is of course a physiologic mechanism of sex-function response to seasonal environmental factors, and these mechanisms are at present under active investigation.[12]

[12]Cf. *inter alia*: Marshall. F. H. A., Sexual periodicity and the causes which determine it. Trans. Phil. Soc. *226B*, 423, 1936. See also Marshall, On the change over in the oestrus cycle in animals after transference across the equator, with further observations on the incidence of the breeding seasons and the factors controlling sexual periodicity. Proc. Roy. Soc. *112B*, 413, 1937. Baker, J. R., and Ranson, R. M., Factors affecting the breeding of the field mouse, Proc. Roy. Soc. *110B*, 313 *112B*, 39, and *113B*, 486, 1933. Then there are the numerous papers by T. H. Bissonnette, too many to cite by title on photoperiodicity, and mechanisms which are discussed in Biol. Bul. *68*, 300, 1935; J. Exp. Zool. Aug., 1935; Anat. Rec., Sept., 1935; Proc. Roy. Soc. *110B*, 322. 1932; Quart. Rev. Biol. *8*, 210, 1933; J. Exp. Biol. *12*, 315, 1935; J. Heredity, *27*, 171, 1936; Endocrinology, *22*, 92,

Goats usually breed in this country in the autumn (mostly in September, October, and November), and but rarely in the spring (April, May, and June). The breeding during the other months are intermediate between the autumn crest and spring trough. Asdell,[13a] and Turner,[13b] published data on the seasonal distributions of birth frequencies and therefrom estimated the seasonal conception frequencies, which are, in round numbers, about 30% of all conceptions in October, 25% in November, 20% in September, 16% in December, 5% in each January and August, 3% in February, 1% in March, and less than 1% in each of the other months (0.1% May, 0.2% June, 0.4% April, 0.8% July).

When in 1932 we published data on sheep showing a seasonal energy metabolism rhythm,[14] Dr. C. W. Turner thought that this seasonal metabolic rhythm might have a significant bearing on the seasonal sex rhythm, and suggested that we extend the metabolism measurements to include his goats. We have not succeeded in obtaining the seasonal distribution of metabolism of *mature* animals uncomplicated by gestation and lactation because of housing, fencing, and economic difficulties, but we have analyzed the metabolism and growth data from the seasonal viewpoint of young animals prior to the first lactation (lactation increases metabolism enormously, thus confusing the seasonal metabolic rhythm), with the results shown in Fig. 8.

Before discussing Fig. 8 we may note that there is a large literature indicating the presence of an annual metabolic rhythm[15] and an an-

1938. See also: Rowan, W., Nature, *115*, 494, 1925, *119*, 351, 1937, *122*, 11, 1928; Proc. Boston Soc. Nat. History, *38*, 147, 1927, *39*, 151, 1929; Proc. Nat. Acad. Sc. *16*, 520, 1930; The Riddle of Migration, Baltimore 1931 (Williams and Wilkins). Moore, C. R., Simmons, G. F., Wells, L. J., Zalesky, M., and Nelson, W. O., On the control of reproductive activity in an annual breeding animal. Anat. Rec. *60*, 279, 1934. Wells, L. J., Seasonal sexual rhythm and its experimental modification in the male ground squirrel. Anat. Rec., *62*, 409, 1935.

[13a]Asdell, S. A., Variation in onset of the breeding year in the goat. J. Agr. Sci., *16*, 632, 1926.

[13b]Turner, C. W., Seasonal variation in the birth rate of the milking goat in the United States. J. Dairy Sc., *19*, 619, 1936. Turner cites the following references on the sex cycle in the goat: Kupper, M., The sexual cycle of female domesticated mammals. The ovarian changes and the periodicity of oestrum in cattle, sheep, goats, pigs, donkeys, and horses. Union. So. Africa Dept. Agr. 13th and 14th reports, Director of Vet. Education and Research, Part II, p. 1211, 1928; Villegas, V., The trend of sexual and reproductive seasons among horses, cattle, water buffaloes, sheep and goats under Los Banos conditions. Philippine Agr. *17*, 477, 1918.

[14]Brody, S., and Procter, R., Missouri Agr. Exp. Sta. Res. Bul. 176, 1932 (page 23). See also Res. Bul. 283, page 14.

[15]Cf. *inter alia*: Maignon, F., and Guilhon, J., Influence des saisons sur les combustions respiratoires chez le chien. C. R. Ac. Sci., *192*, 1410, 1931. Hoogenhuyze, C. J. C. V., and Nieuwenhuyse, J., Der Einfluss der Jahreszeit auf den respiratorischen gaswechsel in Ruhe und bei Muskelarbeit. Jahresbericht f. Tier-Chemie, *42*, p. 499. Gustafson, L. F., and Benedict, F. G., The seasonal variation in basal metabolism. Am. J. Physiol., *86*, 43, 1928. Davis, J. E., Age and metabolism in rats. Am. J. Physiol., *119*, 28, 1937.

nual growth rhythm.[16] There are serious difficulties in interpreting the data because factors other than season as such (i. e., length of day, angle of the sun rays, temperature and related cosmic[17] influences) confuse the picture. Gestation and lactation, for example, are such confusing factors in interpreting seasonal goat data.

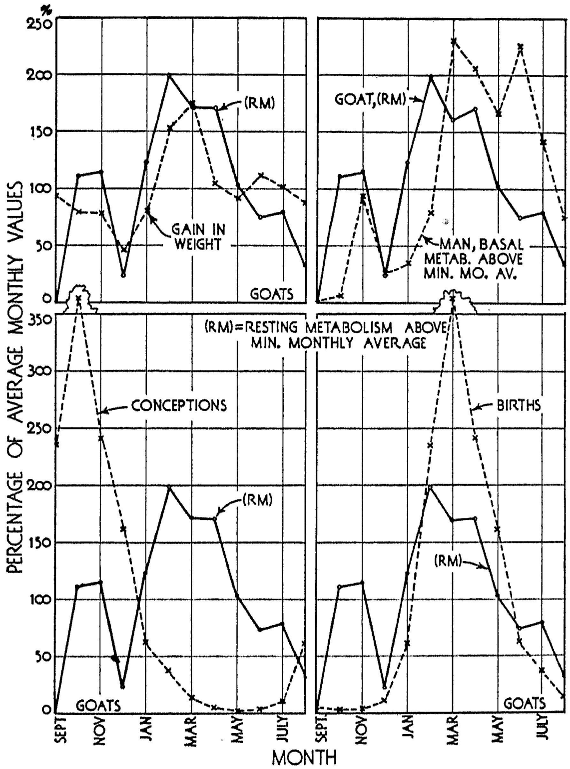


Fig. 8.—Annual rhythms of resting metabolism (R M) and conceptions in goats (lower left), metabolism and birth in goats (lower right), metabolism and gain in weight in goats (upper left), and resting metabolism (R M) in goats and basal metabolism in man (upper right). See text and Table 4 for methods of computation.

Having the difficulties clearly in mind, let us discuss briefly the interrelations between the metabolic (energy metabolism) and breeding rhythms.

[16]Cf. *inter alia*: Porter, W. T., The seasonal variation in the growth of Boston School children. Am. J. Physiol., *52*, 121, 1920. Palmer, C. E., Seasonal variation of average growth in weight of elementary school children. Public Health Reports, *48*, 211, 1933. Nylin, G., Periodical variations in growth, standard metabolism, and oxygen capacity of the blood in children. Acta Medica Scandinavia, Supplementum, 31, Stockholm, 1929. Fitt, A. B., The human energy-rhythm through the year. Report 16th Meeting Australasian Assn. for Adv. Sc., *16*, 704, Wellington, N. Z., 1924. Berkson, J., Evidence of a seasonal cycle in human growth. Human Biology, II, 523, 1930.

[17]Cf. Arrhenius, S., Die Einwirkung kosmischer Einflusse auf Physiologische verhaltnisse. Skand. Arch. f. Physiol., *8*, 367, 1898.

TABLE 4.—SEASONAL RHYTHMS OF: BREEDING, RESTING-METABOLISM AND WEIGHT-GAIN IN THE GOAT, AND BASAL METABOLISM IN MAN.

	Breeding rhythm				"Resting" Metabolism rhythm					Basal metabolism rhythm in man		
	Percentage of Total Population		Percentage of Monthly Average					**Weight-gain rhythm				
Month	Births	Conceptions	Births	Conceptions	Percentage of Av. Cal./Day* (1)	Percentage of Av. Cal./Day above lowest such percentage Col. 1 less 89.4 (2)	Percentage Difference / Av. Difference: Col. 2 / 10.83 x 100	Av. Weight Gain lbs./month	Percentage of Av. Weight Gain	Av. O_2/ Minute (A)	O_2/Min. less lowest O_2 rate (Col. A less 207.1) (B)	Difference / Av. Difference: Col. B / 3.18 x 100
Sept.	0.39	19.66	4.7	235.9	89.4	0.0	0	4.8	94	207.1	0.0	0
Oct.	0.18	30.43	2.2	364.0	101.4	12.0	111	4.1	80	207.3	0.2	6
Nov.	0.27	20.11	3.2	241.3	101.9	12.5	115	4.0	78	207.4	0.3	95
Dec.	0.87	13.47	10.4	161.6	91.9	2.5	23	2.4	47	207.9	0.8	25
Jan.	5.08	5.20	61.0	62.4	102.7	13.3	123	4.1	80	208.2	1.1	35
Feb.	19.66	3.03	235.9	36.4	110.9	21.5	199	7.8	153	209.6	2.5	79
March	30.43	1.17	364.0	14.0	107.9	18.5	171	8.9	175	214.4	7.3	230
April	20.11	0.39	241.3	4.7	107.8	18.4	170	5.3	104	213.6	6.5	205
May	13.47	0.18	161.6	2.2	100.6	11.2	103	4.7	92	212.4	5.3	167
June	5.20	0.27	62.4	3.2	97.4	8.0	74	5.7	112	214.3	7.2	227
July	3.03	0.87	36.4	10.4	98.0	8.6	79	5.2	102	211.6	4.5	142
Aug.	1.17	5.08	14.0	61.0	92.9	3.5	32	4.5	88	209.5	2.4	76
Av./Mo.	8.33	8.33				10.83		5.1				

*Av. Cal./Day were computed from the equations $Y = 97.5\ X^{.676}$ for males and $Y = 96.8\ X^{.638}$ for females, where Y is Cal./Day and X is body weight in pounds.
**Toggenburg Female Goats only.

In Fig. 8 are plotted on the same scale the annual metabolic and growth rhythms in young goats and also the breeding rhythm of adults.

It is awkward to plot *absolute* values (involving the use of different units) for metabolism, body weight, and breeding frequency, so we plotted the data in terms of percentages as follows: In the case of metabolism, we assumed that the lowest monthly metabolism during the year is the annual base line which may be assumed to be independent of season. This lowest, base metabolism was then deducted from each monthly metabolism average and the differences were plotted against the corresponding months as percentages of the average monthly metabolism increment. Similarly the monthly weight gains were plotted as percentages of the yearly average of the monthly weight gains, and the monthly breeding frequencies were plotted as percentages of the yearly average of the monthly breeding frequencies. This way the metabolism, growth, and sex activity rhythms become comparable. The details of computation are shown in Table 4.

Fig. 8 shows that the metabolic peak in goats (as it is in sheep[14]) occurs in early spring. The weight gains in growing goats are also maximum in early spring. The breeding peak on the other hand, as previously noted, occurs in the autumn. The tentative conclusion therefore is that there is an inverse relationship between high breeding level and high energy-metabolism level.

In this connection we may make reference to seasonal metabolism data on humans generously placed at our disposal by Professor Fred R. Griffith, Jr., Physiology Department, University of Buffalo, who published a notable series of papers on various types of annual rhythms in humans.[18] We plotted Griffith's data in the upper right corner of Fig. 9 as we did the goat data in terms of percentages of average annual metabolism increment above the base level (see also Table 4). The time curve of metabolism of humans is similar to that in the goat in spite of the fact that humans do not have an annual sex rhythm in temperate zones.[19]

The reason for the apparently inverse interrelation between heat-production and breeding activity in goats is not clear. It may be

[18]Cf. *inter alia*. Griffith, F. R., Jr., and his associates, Studies in human physiology (with the following abbreviated titles): I. Metabolism and oral temperature, Am. J. Physiol., *87*, 602, 1929; II. Pulse rate and blood pressure, Id., *88*, 295, 1929; III. Alveolar air and blood gas capacity. Id., *89*, 449, 1929; IV. Vital capacity, respiratory rate and volume, and composition of expired air. Id., *89*, 555, 1929; V. Urine chemistry. J. Nutrition, *5*, 131, 1934; VI. Blood chemistry, Id., *6*, 169, 1934.

[19]Humans—regardless of race—are said to have a sex rhythm when living in the Arctic (see Llewelyn, L. T., Nature, *129*, 868, 1932), and primitive man is said to have had an annual breeding season in the spring (see Marshall, F. H. A., The physiology of reproduction, London, 1922).

that both rhythms in seasonal breeders are conditioned by one complex, such as the thyroid[20]-pituitary[12] complex which is in turn conditioned by environmental temperature[20] or/and sunlight.[12] All we

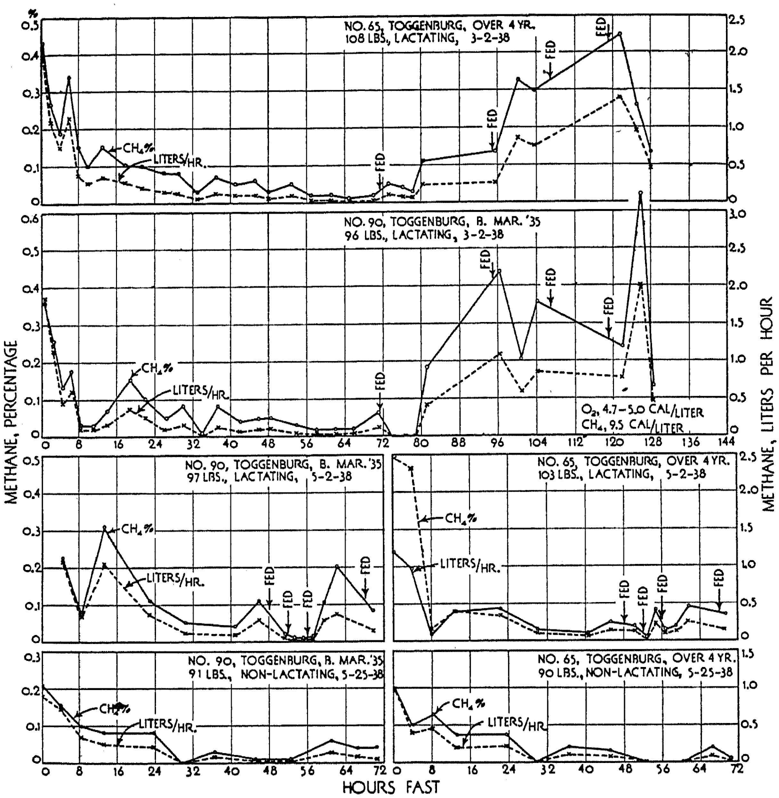


Fig. 9.—The course of methane (combustible gas) exhalation with time after feeding in goats. The methane exhalation was determined by the mask open-circuit methods[22]. The methane is represented as percentage of exhaled air (left axis) and liters of exhaled methane (right axis). The combustion value of methane is about 9.5 Cal. per liter as compared to oxygen of 4.7 to 5.0 Cal. per liter.

can say at this time is that in goats there appeared to be annual metabolic, growth, and sex rhythms, and that there is an opportunity for investigating possible interrelations between them and the mode of action of cosmic factors (light, temperature, possibly diet) on each.

[20]Cf. Kuschinsky, G., and Tang, Sii Über dem Einfluss verschiedener Temperaturen auf die secretion des thyreotropen hormone. Arch. f. exper. Path. u. pharmakol. *179*, 726, 1935; Riddle, O., Seasonal variations in thyroids and adrenals, Am. J. Physiol., *73*, 5, 1925; Zalesky, M., A study of the seasonal changes in the thyroid in the ground squirrel. Anat. Rec. *62*, 109, 1935. Dawbarn, M. C., Seasonal variation in the iodine percentage of the thyroid glands of sheep in Australia. Aust. J. Exp. Biol. and Med. Sc., *6*, 65, 1929. Friedman, M. H., and Friedman, G. S., The influence of environmental factors on the rate of restitution of gonadotropic factor in the discharged rabbit pituitary. Proc. Am. Physiol. Soc. 50th Meeting, March, 1930.

VII. ENERGY METABOLISM DURING GROWTH.

1. *The Methane and Respiratory Quotient (R. Q.) Errors.*

The energy metabolism (heat production) of our goats was measured by the oxygen-spirometer method previously described.[21] It consists in measuring the rate of oxygen consumption while the trained animal is lying quietly, then multiplying the volume of oxygen consumed by its heat value, assuming that 1 liter of oxygen (S. T. P.) consumption is associated with 4.825 Calories heat production.

This is a simple method for measuring heat production, but it suffers from two defects which need be clearly understood.

The first defect is that the heat value of oxygen is not 4.825 Cal. per liter as we assumed, but that it ranges from about 5.05 Cal. per liter shortly after a carbohydrate-rich meal to about 4.69 Cal. per liter after a fat meal or some time following the attainment of the post-absorptive stage. We measured our animals for "resting metabolism" in the early morning about 12 hours after the preceding evening's regular feeding. In clinical metabolism measurements it is customary to assume that the heat value of oxygen when measuring humans 12 hours after the preceding meal is 4.825 Cal. per liter. We adopted this 4.825 heat value for oxygen. The deviation of the "true" heat value of oxygen thus varies with the time after feeding, and it may range from zero to about 3.5%:

$$\frac{5.0 - 4.825}{4.9} = 3.5; \frac{4.825 - 4.69}{4.9} = 3\%$$

However, 3% is well within the limits of the inherent biologic and individual errors.

The second error in this work is that goats, like other ruminants, exhale considerable amounts of methane produced by fermentation in the rumen. We measure metabolism by the rate of oxygen consumption by the reduction in the spirometer volume. If methane is exhaled into the oxygen spirometer, then the apparent oxygen consumption is too low by the amount of methane accumulated in the spirometer. The rate of methane production is not constant, but is highest shortly after feeding, and rapidly declines with time of fasting as illustrated in Fig. 9.

The apparent metabolism thus tends to be too low shortly after feeding for two reasons: (1) our assumed heat value of oxygen may be too low as compared to the actual value; (2) we ignored the methane accumulation in the spirometer thus resulting in an apparently low oxygen consumption.

[21]Missouri Agr. Exp. Sta. Res. Bul. 143, 1930.

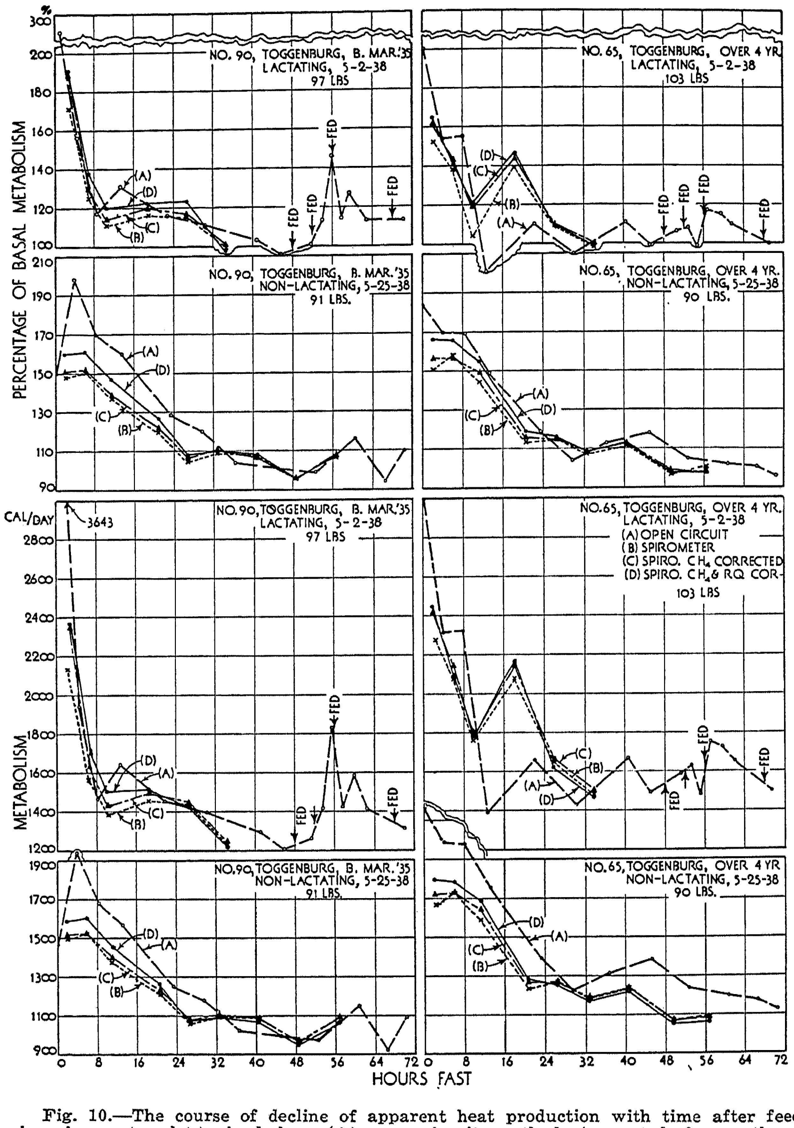


Fig. 10.—The course of decline of apparent heat production with time after feeding in goats, determined by: (A) open-circuit method (corrected for methane, CH_4[22]); (B) spirometer method[21]; (C) spirometer method corrected for methane by analyzing the residual air in the spirometer for methane; (D) spirometer method corrected for methane as described in (C) and also corrected for changes in the respiratory quotient (R. Q.) determined on alternate 30-minute periods by the open-circuit method. The lower half represents heat production in Calories per day, the upper, percentages of the low basal metabolism taken at 100%.

Fig. 10 illustrates the situation. The metabolism values in Fig. 10 were obtained by three methods: *A*. Open-circuit method[22] corrected for both methane and heat value of oxygen (the R. Q. was determined); *B*. Oxygen spirometer method (our customary method) not corrected for either methane or heat value of oxygen (R. Q.); *C*. Spirometer method corrected for the methane accumulation (by analysis of the residual air in the spirometer for methane percentage). *D*. Spirometer method corrected for both methane (analysis of residual air in spirometer) and for the heat value of oxygen. (R. Q. obtained by open-circuit method run on alternate periods with the spirometer method). The data are presented both in the form of Calories per 24 hours, and also in the form of percentages of the basal (average lowest) values.

Fig. 10 shows that the open-circuit method (corrected for both R. Q. and methane) tends to give higher metabolism values not only when compared to the uncorrected spirometer method (method B), as was expected, but also higher than the spirometer method corrected for both R. Q. and methane which was not expected, and which can be attributed only to some undetermined instrumental error or physiologic influence of the accumulating methane in the spirometer. However, following 12 hours after feeding (our "resting metabolism" data were secured in the morning about 12 hours after the preceding evening feeding) the *percentage* differences between the three methods of measuring metabolism is within the accepted limits of physiologic variability.

2. *The Relation Between Basal and Resting Metabolism.*

As noted above, the *basal metabolism* is the stabilized base value reached sometime after the postabsorptive condition is reached, and the *resting metabolism* is obtained 12 hours after the preceding evening feeding, both in resting (lying down) condition.

Because of the specific dynamic action or (heat increment of feeding) the metabolism is highest shortly after feeding and declines with fast. Fig. 10 shows such decline of metabolism by 4 methods (A, B, C, D) in 4 mature lactating and non-lactating goats.

Fig. 11 is a continuation of Fig. 10 on mature goats.

Fig. 12 represents spirometer-method data on young growing goats.

Figs. 10, 11, and 12 show that the resting heat production obtained about 12 hours after the preceding evening's feeding, is 20 to 30% higher than the basal metabolism. This statement does not say much, and we hope to discuss it in greater detail in a future paper. We are

[22]For description of the open-circuit method see Washburn, L. E., and Brody, S., Methane, hydrogen, and carbon dioxide production in the digestive tract of ruminants in relation to the respiratory exchange. Missouri Agr. Exp. Sta. Res. Bul. 263, 1937.

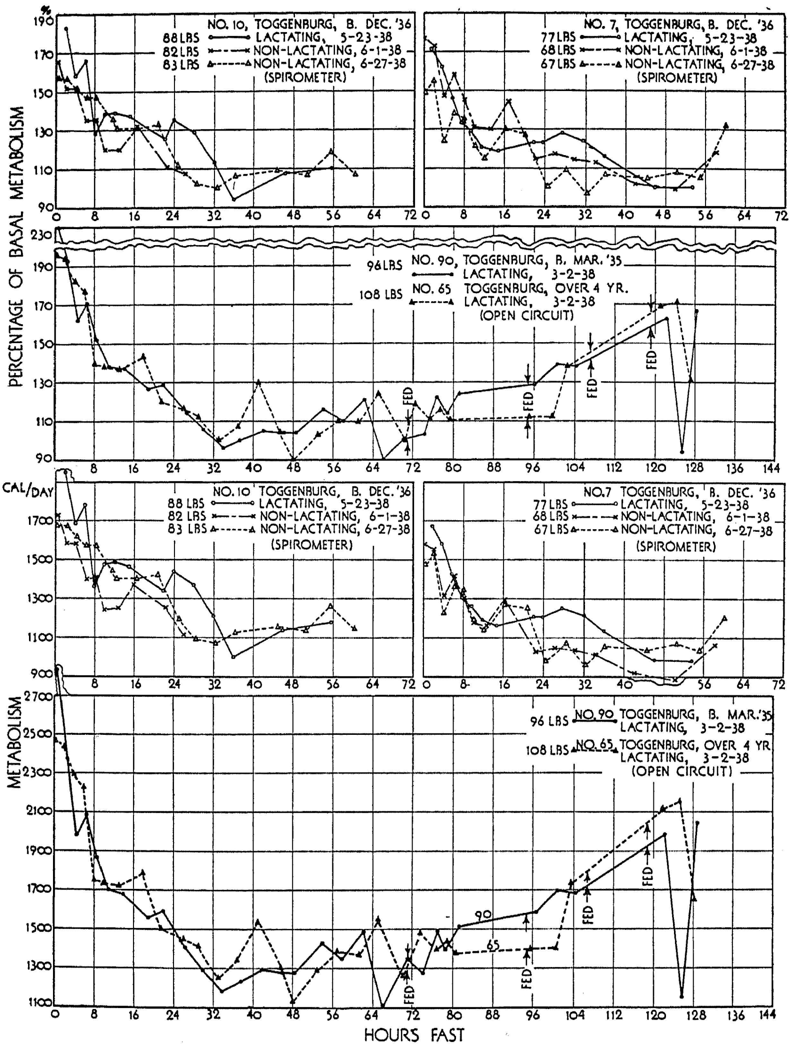


Fig. 11.—Decline of heat production with advancing time of fast in mature dry and lactating goats. The lower curves represent metabolism in Calories per day, the upper percentages of the low basal metabolism which is taken as 100%. Goats 90 and 65 were measured by the open-circuit method (corrected for methane production and R. Q.); goats 7 and 10 were measured by the spirometer method (not corrected for either methane production or R. Q.).

presenting these as basic data on the goat, and leave its interpretation with regard to the science of nutrition to a future paper.

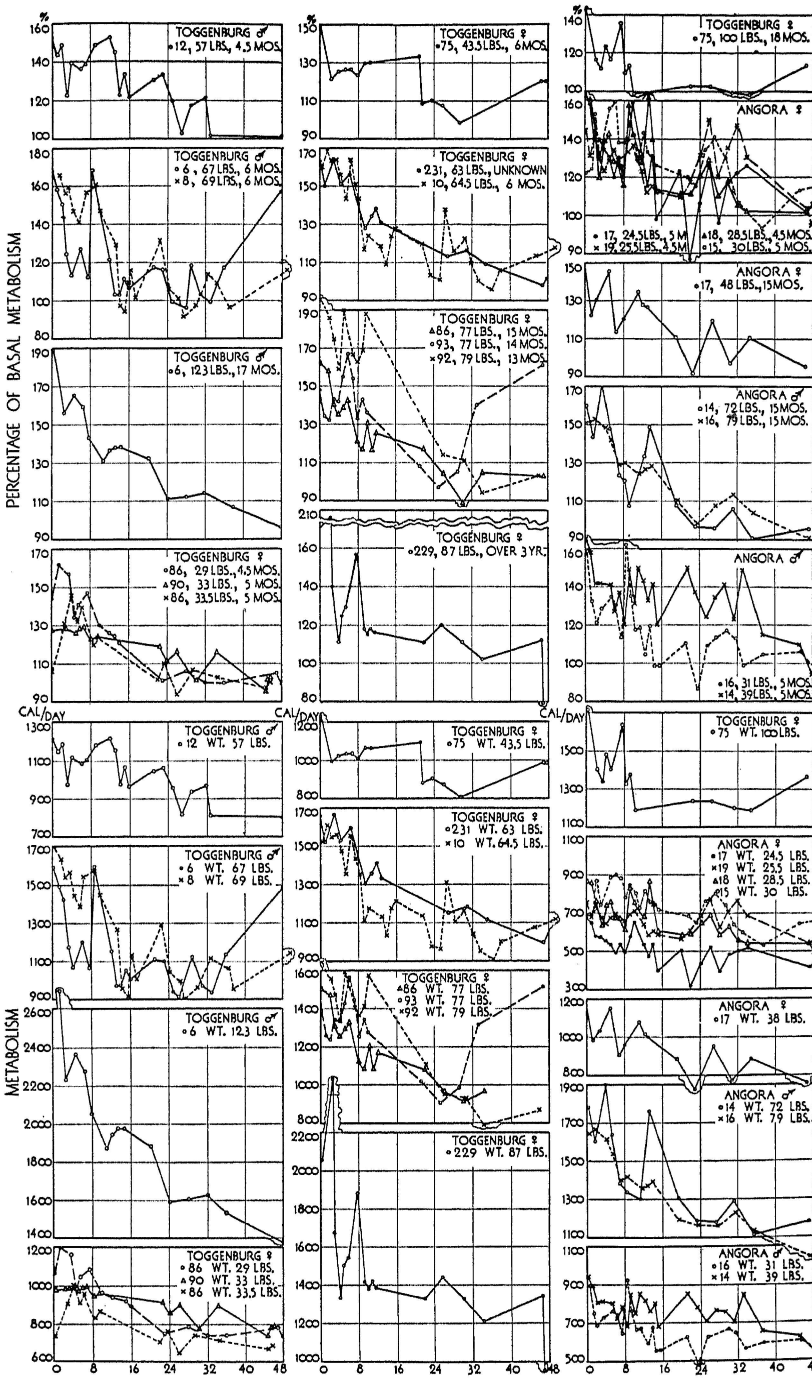


Fig. 12.—The decline of heat production with time after feeding in immature (growing) male and female Toggenburg and Angora goats. The lower half represents metabolism in Calories per day, the upper in percentages of the low, basal, metabolism taken to be 100%. All data were obtained by the spirometer method (not corrected for methane or R. Q.).

3. *Metabolism During Growth.*

A plot of simple metabolism (heat production) against age, ignoring weight, would be indeterminate because metabolism varies not only with age, but also with body weight, and individuals differ in body weight at given ages.

A plot of metabolism per unit body weight against age is also objectionable because metabolism does not vary with simple body weight, but more nearly perhaps with surface area, or with some fractional

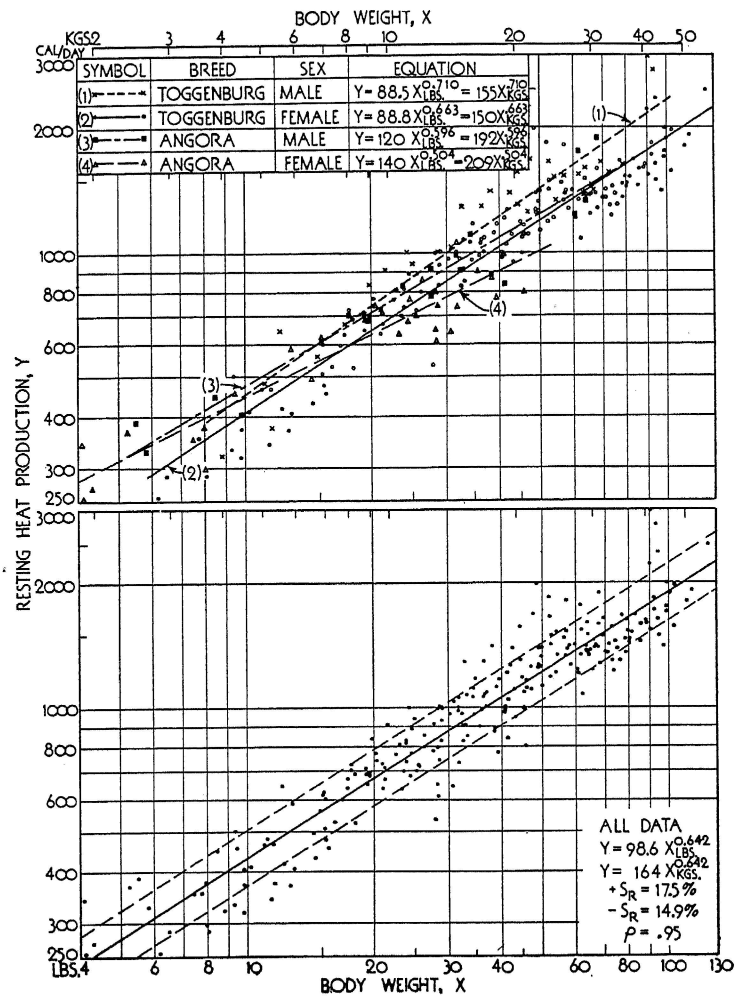


Fig. 13.—"Resting" heat production as function of body weight of 22 growing Toggenburg and Angora male and female goats. The standard error of estimate, Sr, of the general equation of all data is seen to be +17.5 and —14.9. The index of correlation, ρ, is .95. The upper half gives the equations by breed and sex. The differences in the values of the constants are due in part at least to the annual metabolic rhythm and month of birth.

power of body weight. We previously found[11] that basal metabolism in *mature* animals of *different species* varies with the 0.73 power of body weight. How does metabolism vary in *immature* (rapidly growing) animals of the *same species?*

The lower half of Fig. 13 presents the monthly average heat production of 22 growing goats plotted on a logarithmic grid on the assumption that metabolism, Q, varies with body weight, X, according to the equation

$$Y = aX^n \quad (3)$$

The distribution of the data in Fig. 13 is not very orderly, but the average slope,[23] n, of the data is of the order of ⅔. This means that metabolism does not increase as rapidly as does body weight, but only with the ⅔ power of body weight. Another way of saying the same thing is that the ratio $\frac{\text{metabolism}}{\text{body weight}}$ decreases with increasing body weight during growth, but that the ratio $\frac{\text{metabolism}}{\text{⅔ power of body weight}}$ tends to remain constant during growth.

For purposes of further analysis we investigated the relation between metabolism and body weight for each animal separately with the results shown in Figs. 14, 15, and 16.

The dots represent individual observations and the light circles represent monthly averages. The months are indicated on the charts by their initials. The given equations were fitted to the data by the method of least squares.

Figs. 14 to 16 show that the values of the exponent, n, range in individual animals from .5 to over 1, with an arithmetic average[23] and median of ⅔.

It is surprising to the writer, but may not be to others, to find that energy metabolism in growing goats varies with the ⅔ power of body weight, because it is generally known that surface area tends to vary with the ⅔ power of body weight, and energy metabolism tends to vary with surface area. It is especially surprising and even disturbing that the numerical value of the exponent *n* (and consequently the coefficient *a* because *a* and *n* tend to vary inversely)

[23]If the equation $Y = aX^n$ is fitted to the individual data by sex and breed, the values of the exponent, n, range in value from 0.555 to 0.676 as follows:

All data: $Y = 98.6\ X^{.642}$
All females: $Y = 96.8\ X^{.638}$
All males: $Y = 97.5\ X^{.676}$
All Toggenburgs: $Y = 90.8\ X^{.666}$
All Angoras: $Y = 126\ X^{.555}$

If the ns of the equation fitted by the method of least squares to data of *each* of the 22 goats are averaged, the average value of n is 0.68 (or 0.67 if the angles of the slopes are averaged instead of the slopes).

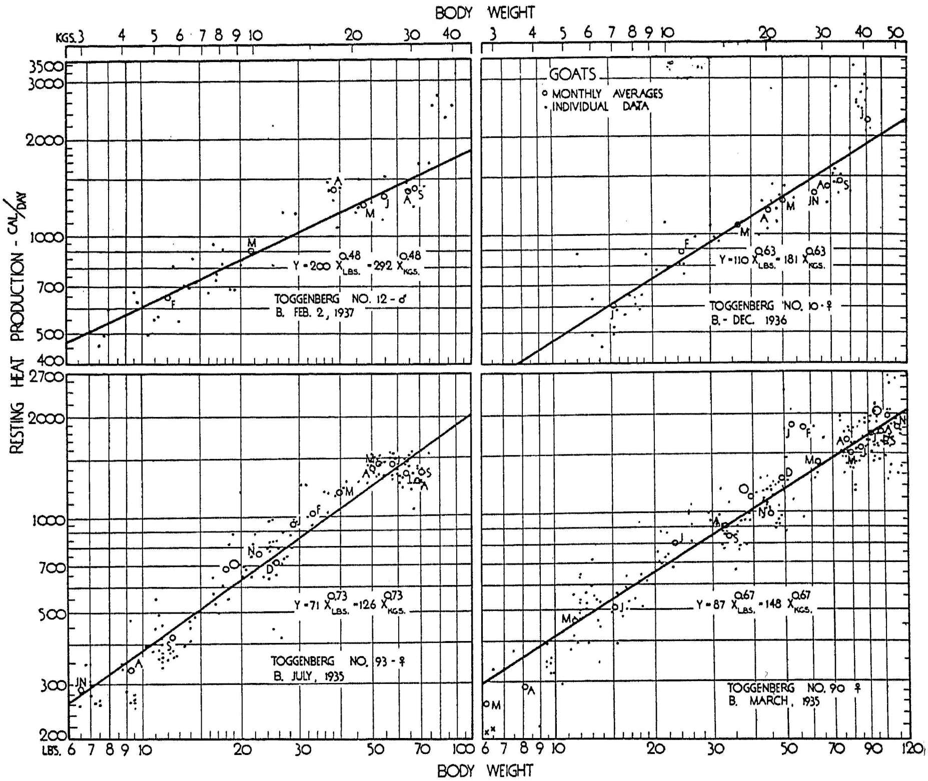


Fig. 14.—Resting metabolism as function of body weight in growing goats. Note that the value of the exponent, n, ranges from 0.48 in a male born in February to 0.73 in a female born in July. Month of birth taken with the annual metabolic rhythm affects the value of the slope n. Note that the higher the numerical value of the slope, *n*, the lower the numerical value of the coefficient *a*. There is a necessary mathematical relationship between slope and coefficient. Small dots represent individual observations, larger light circles monthly averages. The months are indicated by their initials.

varies within so wide a range, from 0.50 to over 1. What is the cause of the wide range in the value of n?

Tables 5 and 5a indicate the possible dependence of the value of n on the month of birth and on sex. Goats born in February tend to have a lower average value of the exponent than those born in July. Males tend to have a higher value of exponent than females. No breed comparison can be made because all Angoras were born in February. If there is a seasonal metabolic rhythm, such difference in the value of n are understandable.

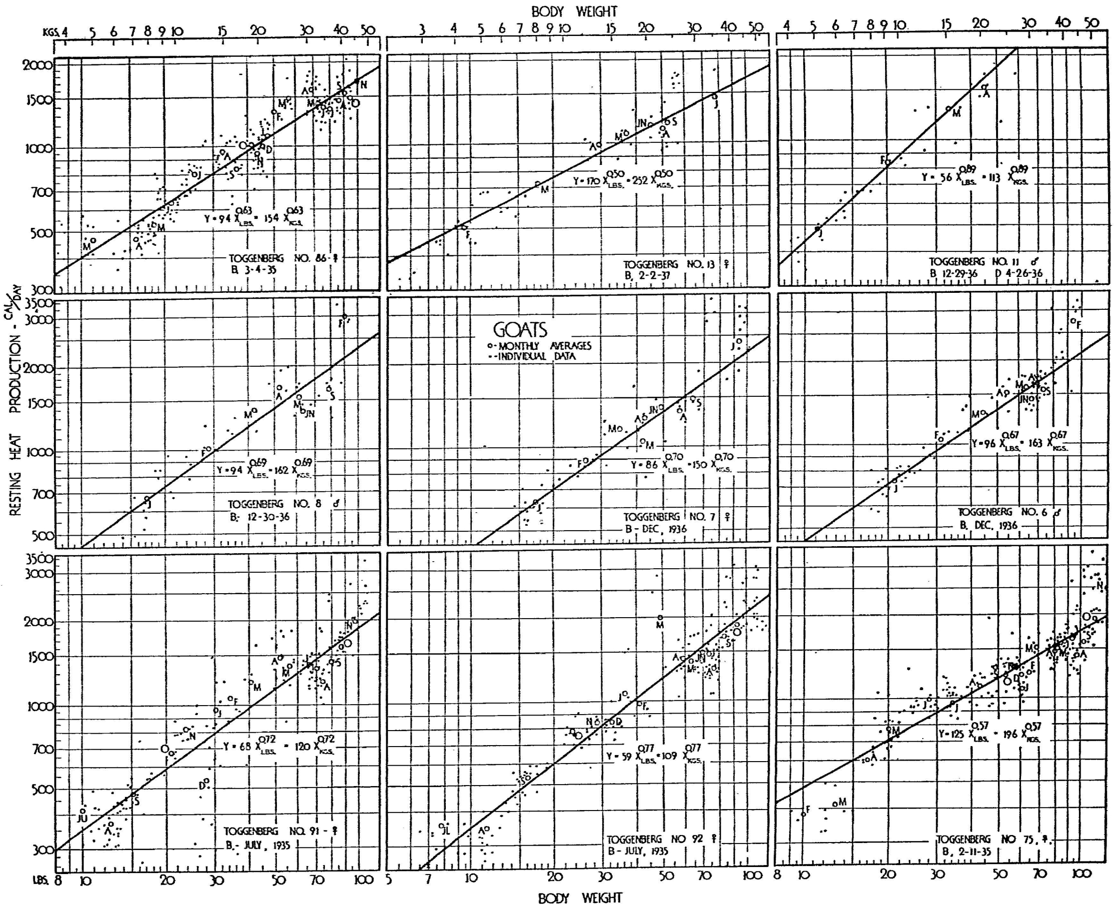


Fig. 15.—Continuation of Fig. 14.

TABLE 5.—RESTING METABOLISM OF GOATS COMPUTED FROM THEIR CORRESPONDING FITTED EQUATIONS $Y = aX^n$. VALUES IN PARENTHESES ARE EXTRAPOLATED BEYOND THE RANGE OF OBSERVED VALUES. SOME OF THE EXTREMELY UNREASONABLE EXTRAPOLATED VALUES (ESPECIALLY WHEN THE VALUE OF n IS OVER 2/3) ILLUSTRATE FORCEFULLY THE DANGERS OF EXTRAPOLATION IN BIOLOGIC ANALYSIS. ANIMALS HAVING VERY HIGH VALUES OF n DIED EARLY. THE AVERAGES WERE OBTAINED BY FITTING THE EQUATION TO THE MONTHLY AVERAGE DATA FOR INDIVIDUAL GOATS. IN THE CASE OF THE 22 EQUATIONS FOR INDIVIDUAL GOATS THE EQUATIONS WERE FITTED TO WEIGHTED MONTHLY AVERAGES.

SECTION 1

		Toggenburg Females								Toggenburg Males							
Goat No.		13	75	86	10	90	7	91	93	92	80	12	6	8	9	11	82
Month of Birth		Feb.	Feb.	March	Dec.	March	Dec.	July	July	July	Feb.	Feb.	Dec.	Dec.	Dec.	Dec.	Feb.
No. measurements		70	232	250	63	233	67	177	161	174	63	52	64	56	77	45	46
Mos. observed		12	22	21	13	21	14	17	15	16	6	8	14	14	5	4	5
Value of n		.50	.57	.63	.63	.67	.70	.72	.73	.77	.99	.48	.67	.69	.77	.89	1.2
Value of a, Lbs.		170	125	94	110	87	86	68	71	59	32	200	96	94	77	56	21
Value of a, Kgs.		252	196	154	181	148	150	120	126	109	70	292	163	162	142	113	53
Body Weight		Predicted Resting Heat Production Cal./Day															
Kgs.	Lbs.																
1.8	4	(340)	(276)	(225)	(264)	(220)	(227)	(185)	(195)	(172)	(126)	(389)	(243)	(245)	(224)	(192)	(111)
2.7	6	416	(347)	(291)	(340)	289	(301)	(247)	263	235	(189)	473	(319)	(324)	(306)	(276)	(180)
3.6	8	481	409	348	(408)	350	(369)	(304)	324	293	251	530	(387)	(395)	(382)	357	255
4.5	10	537	464	401	(469)	407	(431)	357	381	348	313	604	(659)	(460)	453	435	333
5.4	12	589	515	450	526	460	(490)	407	436	400	375	659	(507)	(522)	522	511	414
6.4	14	636	562	496	580	510	545	455	488	450	436	710	(563)	581	588	586	498
7.2	16	680	607	539	631	557	594	501	537	499	498	757	615	637	651	660	585
8.2	18	721	649	580	679	603	650	545	586	546	560	801	666	691	713	734	674
9.1	20	760	689	620	726	647	700	588	632	593	621	842	715	743	773	806	765
11.3	25	850	783	714	836	752	819	690	744	704	775	938	829	866	918	982	999
13.6	30	931	869	801	938	849	930	787	850	810	928	1023	938	982	1057	1156	1244
15.9	35	1006	948	883	1033	942	1036	880	952	912	1081	1102	1039	1039	1190	1326	(1497)
18.1	40	1075	1024	960	1124	1030	1138	968	1049	1010	1234	1175	1137	1198	1319	1493	(1757)
20.4	45	1140	1094	1034	1210	1115	1235	1054	1143	1106	(1386)	1243	1230	1300	1444	1658	(2023)
22.7	50	1230	1162	1105	1294	1196	1330	1137	1235	1200	(1538)	1308	1320	1398	1566	1821	(2296)
27.2	60	1316	1290	1240	1451	1352	1511	1297	1411	1381	(1843)	1427	1492	1585	1802	2142	(2848)
31.8	70	1422	1408	1366	1599	1499	1683	1449	1578	1555	(2146)	1537	1654	1763	2029	(2456)	(3438)
36.3	80	1521	1520	1486	1739	1639	1848	1595	1740	1723	(2450)	1639	1809	1933	(2249)	(2767)	(4036)
40.8	90	(1613)	1625	1600	1873	1773	2006	1736	(1896)	1886	(2947)	1734	1957	2097	(2462)	(3072)	(4647)
45.4	100	(1700)	1725	1710	(2002)	1903	2160	1873	(2048)	2046	(3056)	1824	2100	2255	(2670)	(3374)	(5275)
49.9	110	(1783)	1822	(1816)	(2126)	2029	(2309)	2006	(2195)	2202	(3358)	(1909)	(2239)	(2408)	(2873)	(3673)	(5914)
54.4	120	(1862)	1914	(1919)	(2245)	2151	(2454)	(2136)	(2339)	2301	(3660)	(1991)	(2374)	(2557)	(3073)	(3969)	(6564)
59.0	130	(1938)	(2004)	(2018)	(2362)	(2269)	(2595)	(2262)	(2480)	(2504)	(3962)	(2069)	(2504)	(2602)	(3267)	(4262)	(7226)
63.5	140	(2011)	(2090)	(2114)	(2474)	(2385)	(2734)	(2386)	(2618)	(2651)	(4263)	(2143)	(2632)	(2844)	(3459)	(4552)	(7898)
68.0	150	(2082)	(2174)	(2208)	(2584)	(2497)	(2869)	(2508)	(2754)	(2796)	(4564)	(2216)	(2756)	(2983)	(3648)	(4841)	(8580)
70.0	154	(2111)	(2207)	(2245)	(2627)	(2542)	(2923)	(2556)	(2807)	(2853)	(4685)	(2244)	(2805)	(3037)	(3723)	(4956)	(8855)

TABLE 5.—SECTION 2

Goat No.		Angora Females 18	Angora Females 15	Angora Females 19	Angora Females 17	Angora Males 16	Angora Males 14	Av. Toggenburg females	Av. Toggenburg males	Av. Angora females	Av. Angora males	Av. all data
Month of Birth		Feb.	Feb.	Feb.	Feb.	Feb.	Feb.					
No. measurements		58	48	51	53	60	57					
Mos. observed		13	8	13	13	13	13					
Value of n		.51	.53	.53	.57	.54	.67	.663	.710	.504	.596	.642
Value of a, Lbs.		130	143	120	110	140	91	88.8	88.5	140	120	98.6
Value of a, Kgs.		195	220	180	170	215	155	150	155	209	192	164
Body Weight		Predicted Resting Heat Production Cal./Day										
Kgs.	Lbs.											
1.8	4	264	298	250	242	296	230	(223)	(237)	282	274	240
2.7	6	324	370	310	306	368	302	291	316	345	349	312
3.6	8	375	430	361	360	430	367	353	387	399	414	375
4.5	10	421	485	407	409	485	426	409	454	447	473	432
5.4	12	462	534	448	453	536	481	461	517	490	528	486
6.4	14	499	579	486	495	582	533	511	576	529	579	537
7.2	16	535	622	522	534	626	583	558	634	566	626	585
8.2	18	568	662	555	571	667	631	604	689	601	672	631
9.1	20	599	700	587	607	706	677	647	742	634	716	675
11.3	25	671	787	661	689	796	786	750	870	709	817	779
13.6	30	737	867	728	764	878	889	847	990	777	911	875
15.9	35	797	941	790	835	955	985	938	1105	840	999	967
18.1	40	853	1010	848	901	1026	1017	1025	1215	899	1082	1053
20.4	45	906	(1075)	902	963	1093	1166	1108	1320	954	1160	1136
22.7	50	956	(1137)	(954)	1023	1158	1251	1188	1423	1005	1235	1215
27.2	60	(1049)	(1252)	(1051)	(1135)	1277	1414	1341	1620	(1102)	1377	1366
31.8	70	(1135)	(1359)	(1141)	(1239)	1388	1567	1485	1807	(1191)	1510	1508
36.3	80	(1215)	(1458)	(1224)	(1337)	(1492)	(1714)	1623	1987	(1274)	(1635)	1643
40.8	90	(1290)	(1552)	(1303)	(1430)	(1590)	(1855)	1754	2160	(1352)	(1753)	1772
45.4	100	(1361)	(1642)	(1378)	(1518)	(1683)	(1991)	1881	2328	(1426)	(1867)	1896
49.9	110	(1429)	(1727)	(1449)	(1603)	(1772)	(2122)	2004	(2491)	(1496)	(1977)	2016
54.4	120	(1494)	(1808)	(1518)	(1685)	(1857)	(2250)	2123	(2649)	(1575)	(2082)	2132
59.0	130	(1556)	(1887)	(1583)	(1763)	(1939)	(2373)	(2238)	(2804)	(1627)	(2183)	(2244)
63.5	140	(1616)	(1962)	(1647)	(1840)	(2018)	(2494)	(2351)	(2955)	(1689)	(2282)	(2353)
68.0	150	(1674)	(2035)	(1707)	(1913)	(2095)	(2612)	(2462)	(3104)	(1749)	(2378)	(2460)
70.0	154	(1696)	(2064)	(1732)	(1942)	(2125)	(2658)	(2504)	(3162)	(1773)	(2415)	(2502)

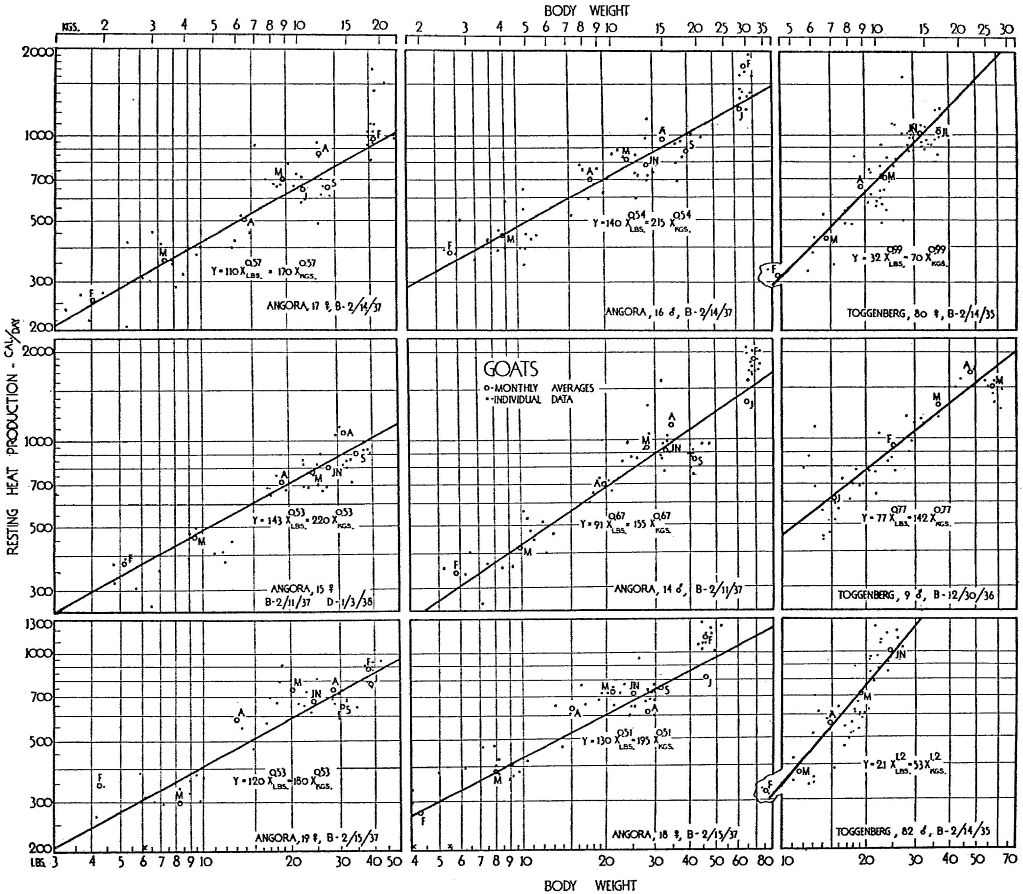


Fig. 16.—Continuation of Fig. 14.

TABLE 5a.—VALUES OF n CLASSIFIED BY MONTH OF BIRTH.

Born in February			Born December			Born July			Born March		
Goat	n	Mos.	Goat	n	Mos.	Goat	n	Mos.	Goat	n	Mos.
12 T♂	.48	8	10 T♀	.63	13	92 T♀	.70	16	86 T♀	.63	21
13 T♀	.50	12	6 T♂	.67	14	91 T♀	.80	17	90 T♀	.67	21
18 A♀	.51	13	8 T♂	.69	14	93 T♀	.82	15			
15 A♀	.53	8	7 T♀	.70	14						
19 A♀	.53	13	9 T♂	.77	5						
16 A♂	.54	13	11 T♂	.89	4						
75 T♀	.57	22									
17 A♀	.57	13									
14 A♂	.67	13									
80 T♀	.99	6									
82 T♂	1.2	5									

The situation is represented graphically in Fig. 17. The *resting* metabolism curves of the *growing* goats from Figs. 13, 14, 15, 16 are brought together on this one chart. The average *basal* metabolism curve of *mature* animals of *different species* previously published[11] is also shown in Fig. 17.

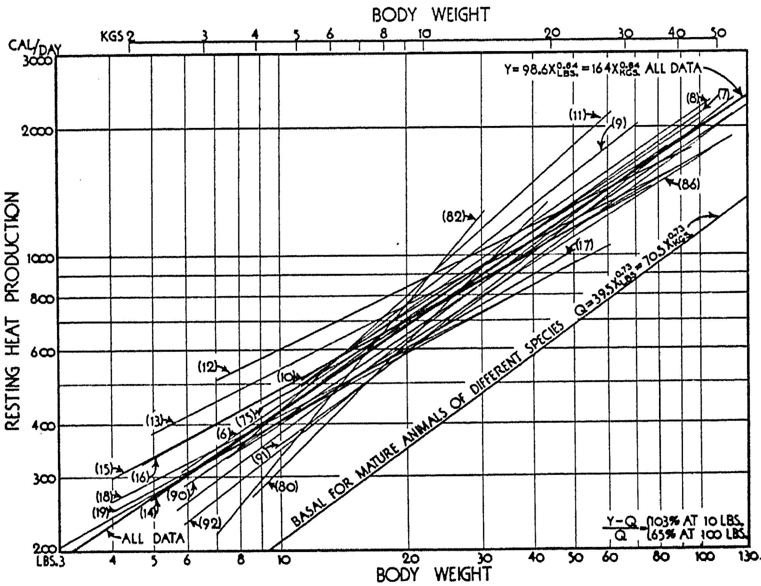


Fig. 17.—Comparison of the individual resting metabolism curves of the growing goats given in Figs. 14, 15, and 16 with the *basal* metabolism curve of *mature* animals of *different species* given in Missouri Res. Bul. 220.

The equation of the average curve of *basal* metabolism of *mature* animals of *different species* is (in the kilogram scale)

$$Q = 70.5\ X^{0.73} \qquad \text{(A)}$$

The average equation of the data for the resting metabolism of the *growing* goat is

$$Y = 164\ X^{0.64} \qquad \text{(B)}$$

There is not only considerable difference in the value of the exponent (0.64 vs 0.73) in equation (A) and (B) but also in the coefficient (164 vs 70.5). The difference in coefficients (164 vs 70.5) is explained in part by the difference in slope: as indicated by the curves in Fig. 17, the lower the slope the higher the coefficient. Another part (20% to 30%) of the difference in the value of the coefficient is due to the fact that the "resting metabolism" of the goats includes about 30% of the heat increment of feeding. The remainder of the difference may be the expression of an age and growth effect: growing animals have a higher metabolism than mature.

A comparison of the average goat curve and the basal curve of mature animals of different species in Fig. 17 indicates that at 10 pounds, the difference between the basal and goat curve divided by the basal curve (see equations (A) and (B)) is 103%; at 100 lbs., it is 65%.

A comparison between the average *resting* metabolism of our *growing* goats, and the *basal* metabolism values of mature goats compiled in Benedict's monumental last monograph[24] reveals still greater differences. If it were not for Benedict's great authority in metabolism investigations we should feel that his basal metabolism values for goats given in Fig. 9, page 81, and Table 4, page 176 (basal metabolism of 36 Kg. doe 800 Cal. per day) of his monograph are too low. At any rate, our attempts to secure basal metabolism values yielded higher results, as indicated by our Figs. 10, 11, and 12.

In a way our Fig. 17 substantiates Benedict's conclusion[24] made in another connection as follows: "our analysis of the basal metabolism data so carefully and objectively selected makes it evident that for warm-blooded animals no unifying principle in metabolism has thus far been found to exist" (p. 178, 1938). The only regularity shown in our Fig. 17, is irregularity. However, the fault may be with our methods. As previously noted, the month of birth has a profound influence on the value of the slope, and therefore on the coefficient. A part of the influence of month of birth is due to the fact that our animals were measured not in a thermoneutral laboratory but in a goat barn the temperature of which was nearly the same as outdoors with all the seasonal fluctuations. Sex is another factor: males tend to have a higher slope than females. State of health appears to be a third factor. The animals that died early (see Table 5) had a higher slope. The apparently higher slope of the short-lived animals has another explanation: The curve relating metabolism to body weight

[24]Benedict, F. G., Vital Energetics. A study in comparative basal metabolism. Carnegie Institution of Washington, Publication 503, July, 1938. See also Ritzman, E. G., Washburn, L. E., and Benedict, F. G., The basal metabolism of the goat. New Hampshire Agr. Exp. Sta. Tech. Bul. 66, 1936.

of growing goats is not strictly logarithmic. As shown in Figs. 14, 15, and 16, the distribution of the metabolism data on the log-log grid is not strictly linear, but it tends to rise and decline with increasing body weight. This accords with the expectations from Dubois'[25] age standard for metabolism per unit area in man. It is entirely possible that the metabolism in the goat, as in man, rises and declines with increasing weight or age when referred to unit area, or to a fractional power of weight. If such is the case then the slope would be expected to be steeper in young animals than in older.

VIII. DISCUSSION AND SUMMARY.

This bulletin presents a study of growing and lactating goats with a comparison of the productive performances (growth and milk production) of goats and cattle.

The study includes: (1) growth in weight; (2) time changes in milk production with the advance of the period of lactation; (3) gross energetic efficiency of milk production; (4) annual variations in growth and metabolism, in relation to annual variations in breeding frequency; (5) decline in respiratory exchange including methane production with advancing fast; and (6) the relation between heat production ("resting metabolism") and body weight during growth.

1. Goats appear to approach mature body weight, or what is the same appear to decline in growth rate, 2 to 2½ times as rapidly as cows. The female goats under observation declined in growth rate at the instantaneous rates of from 12% to 17% per month; a male declined at 8.8% per month; a castrated male at 11% per month. Dairy cows declined at about 5% per month. Goats therefore matured (with respect to growth in weight) from $\frac{8.8}{5} = 1.7$ to $\frac{17}{5} = 3.4$ times as rapidly as cows previously investigated. The female goats declined in growth rate from $\frac{12}{8.8}$ to $\frac{17}{8.8} = 1.4$ to 2 times as rapidly as the male goat. Equivalence charts and tables are presented indicating the equivalent growth ages of the individual goats and cows.

2. From the above observations on the relative rates of decline in growth in goats and cows one is led to expect that the decline of milk

[25]Dubois, E. F., Metabolism in Health and Disease. Philadelphia, 1936.

production with the advance of the stage of lactation should be about twice as great in dairy goats as in dairy cows. However, the data were too variable for quantitative conclusions at this time, although there is no doubt that on the average the milk production declines more rapidly in goats than in cows, as demonstrated by an analytic chart in the text.

3. The gross energetic efficiency of milk production, that is the ratio of milk-energy produced to TDN energy consumed, is of the same order in goats as in cows and in rats, and this in spite of the fact that *per unit body weight* goats produce more milk than cows, and rats produce more than goats. True that the smaller the animal the more milk-energy it produces per unit body weight, but the smaller the animal the greater also its heat production (metabolism) and consequently the greater its maintenance cost per unit body weight, and it appears that maintenance cost and milk production change at the same relative rates with changing body weight. The net result is that energetic efficiency of milk production tends to be independent of body weight, and apparently even of species, provided that the inherited dairy "impulse" is the same in animals under consideration, as it is in dairy cattle, dairy goats, and rats. Dairy cattle and beef cattle, on the other hand, although of the same species and body weight are not comparable because of different lactation inheritance. The central idea is that body size *as such* (other conditions remaining the same) may not influence energetic efficiency of milk production (although it may influence profit).

4. There is a statistically significant annual metabolic rhythm in goats, with the maximum in early spring. It happens that early spring is the season of lowest breeding frequency and maximum birth frequency. The possible association between the metabolic and breeding curves is discussed in the text. Sheep and humans appear to have similar annual metabolic rhythms. There appears to be an annual growth in young goats timed in the same way as the annual metabolism rhythm.

5. Data are presented on the decline of heat production and fermentation gases (methane) with the advance of time after feeding. The resting heat production (heat production about 12 hours after feeding) is of the order of 30% above the basal level. Methane production declines rapidly with advance of time after feeding so that it becomes relatively insignificant within 24 hours after feeding.

6. During active growth (prior to the first lactation period) the heat production increases with about $\frac{2}{3}$ power of body weight.

Summarizing, this bulletin presents a study of the goat—its growth, lactation, energetic efficiency, metabolism—in a comparative manner, carrying out the comparison principally with the dairy cow, but also comparing its energetic efficiency of milk production with the rat, and its annual metabolic rhythm with that of man and sheep.

Appendix

(See following pages)

TABLE 6.—GROWTH IN WEIGHT OF THE SANDBURG GOATS. (SEE FIG. 20 FOR "GROWTH STANDARDS.")

		Females																									Males		Castrated Males		
	Av. Weight pounds Females	Rachel	Jean	Katinka	Angelica	Cherikha	Sonya	Julie	Natasha	Carmela	Victoria	Ginia	Cosette	Colette	Susanna	Elena	Karina	Evangeline	Brenda	Sheila	Bianca	Little Jean	Meg	Valerie	Coronado	Katushka	Pokagon	Conquistador	Boniface	Uri	Moni
Month of Birth		Feb.	Feb.	Feb.	Feb.	Mar.	Apr.	May	Mar.	Apr.	Feb.	Mar.	Mar.	Mar.	Mar.	Mar.	Apr.	May	Mar.	May	May	June	June	July	May	Apr.	Feb.	Mar.	Apr.	Apr.	Feb.
Age—Days		Body Weight, pounds																													
Birth	7.5	10	8	7	9	...	5	7	...	8	8	...	6	6	9	8	7	7	...	9	7	4	8	...	8	6	10	8	9	5	8
Birth—8	9.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	10	6	10	...	...	...	...	...	...	...	...
—15	12.0	...	...	...	...	...	11	...	...	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	14	12	...
—21	16.5	...	...	...	...	...	...	...	...	17	...	...	...	...	...	...	...	15	...	18	13	...	...	...	18	...	...	...	21	...	...
—24	17.3	...	...	...	...	...	15	...	...	...	...	...	...	...	...	...	17	...	...	23	17	...	...	...	...	16	...	...	...	16	...
—31	21.0	...	...	...	21	...	...	...	...	21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21	...	...	20
—38	22.4	...	...	18	23	...	17	...	...	26	...	...	...	...	...	...	...	21	...	27	20	22	25	...	23	...	...	...	...	...	...
—45	23.4	...	...	20	...	...	21	...	...	30	...	...	...	...	...	...	24	...	...	...	...	...	...	...	...	22	...	...	...	...	...
—59	27.6	...	...	...	...	...	25	...	21	...	...	...	...	...	34	33	...	...	...	...	...	...	...	24	...	...	...	...	...	...	...
—65	29.6	...	...	...	...	...	...	...	21	...	...	...	...	34	...	...	...	...	24	...	...	33	36	...	...	...	...	39	...	...	...
—71	34.5	...	...	...	38	...	...	...	25	...	...	...	34	...	...	...	...	33	23	44	39	...	...	...	39	...	...	41	...	...	36
—81	40.8	...	...	36	42	...	...	...	...	47	...	53	44	40	42	40	38	...	28	...	...	...	...	...	...	37	...	50	45	...	40
—92	43.5	...	...	39	45	...	39	...	28	...	...	58	...	...	...	...	...	...	33	...	...	...	...	37	...	...	48	...	...	40	...
—97		...	...	41	49	...	...	...	...	...	...	62	...	...	...	...	...	42	...	...	...	45	47	...	...	...	...	...	...	...	...
—107	51.6	...	...	47	52	...	...	...	...	...	...	...	...	...	55	54	50	...	...	55	51	...	...	...	...	50	54	...	...	...	...
—117		...	...	50	...	...	51	...	40	63	...	...	58	52	...	...	...	...	...	...	...	...	...	45	...	...	...	67	64	51	...

—14[illegible]	[illegible]	...	[illegible]	62	64	[illegible]	...	...	[illegible]	...	...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	...	...	[illegible]	[illegible]	...	...	...	[illegible]	...	...	[illegible]	...	...	68
—159		...	...	...	...	54	63	...	52	67	...	79	...	...	...	...	74	59	57	...	...	64	67	...	62	...	...	...	81	61	...
—174	71.1	...	...	76	...	...	...	50	...	...	68	...	79	69	75	70	...	...	...	82	71	...	...	...	...	...	82	79	...	...	69
—189	71.6	...	...	...	76	...	66	54	61	80	...	86	...	...	...	79	81	66	67	82	76	...	...	61	67	...	...	...	89	66	...
—199	76.9	73	72	...	...	70	68	57	...	87	...	...	87	77	82	...	...	...	...	92	81	...	...	...	...	...	...	...	...	...	...
—214	77.8	...	...	81	87	...	71	56	67	90	85	91	...	...	...	...	...	...	73	93	77	...	...	62	...	...	92	...	...	...	77
—229	79.4	...	...	...	...	80	73	57	73	89	...	...	93	80	85	81	...	...	75	94	82	71	78	...	...	...	...	...	106	72	...
—247	83.7	80	78	88	93	87	72	...	77	90	89	99	...	...	...	...	...	...	83	...	...	...	...	68	...	...	98	...	119	72	78
—261	83.8	86	80	88	95	97	...	...	75	...	95	...	...	...	...	...	83	70	82	...	...	74	80	...	...	...	103	...	...	...	...
—275	84.6	85	83	92	97	98	...	61	81	...	100	...	...	...	...	...	...	...	82	...	...	...	...	67	...	...	100	...	...	...	...
—289	90.2	92	86	89	95	95	...	...	...	98	100	...	...	...	...	...	82	72	...	104	92	78	89	...	...	...	...	...	127	...	...
—307	88.7	85	86	94	96	...	76	67	...	...	98	...	94	81	89	81	...	...	...	110	98	81	94	...	...	...	...	...	...	...	...
—322	92.8	86	88	...	...	...	76	73	...	103	...	103	...	...	94	93	98	75	...	119	105	...	...	...	...	...	...	...	134	...	...
—349	97.4	...	...	...	102	107	82	81	84	...	115	111	102	88	106	104	108	79	94	...	...	...	...	...	...	...	115	...	143	...	...
—359	99.4	...	...	105	...	...	91	...	88	...	...	...	113	100	...	...	...	...	...	...	...	...	...	...	...	...	116	...	...	...	...
—370	109.4	95	94	...	...	107	...	88	93	...	...	121	...	...	...	112	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
—380		...	...	110	111	118	...	88	...	...	118	...	119	106	111	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
—399	110.9	101	97	117	120	...	98	93	101	...	125	125	...	...	...	...	...	...	...	...	...	...	...	...	...	...	132	...	161	...	...
—415		109	102	...	...	130	97	...	...	...	136	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
—431		...	...	...	...	...	96	96	110	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
—447	105.6	...	...	...	...	...	...	...	110	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	165	...	...
—458		...	...	109	115	...	95	...	114	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	145	...	...	...	...
—476	109.1	111	...	107	...	...	98	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	166	...	...
—500		104	...	...	...	134	...	100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	174	...	...
—531	115.8	114	...	...	...	136	104	106	116	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	156	...	173	...	...
—563		...	...	...	...	143	101	110	112	112	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	176	...	...
—606	117.4	109	123	109	...	143	104	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	153	...	...	...	...
—639		109	129	118	116	148	104	107	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	149	...	169	...	...
—667	119.9	112	127	...	...	...	110	116	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	167	...	...
—692		...	...	...	109	141	122	121	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	183	...	...
—720	134.0	115	126	124	116	155	128	121	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	185	...	...
—740		...	135	146	132	176	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	174	...	...	...	...
—780	136.7	139	144	106	138	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	174	...	...	...	...
—790		145	148	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 7.—GROWTH IN WEIGHT OF THE METABOLISM (MISSOURI) GOATS. (SEE FIG. 20 FOR "GROWTH STANDARDS.")

	Toggenburg																Angora					
	Females										Males						Females				Males	
Goat No. ...	86	90	91	75	92	93	7	10	13	80	6	8	12	9	11	82	17	18	19	15	14	16
	Body Weight,* Pounds																					
Age, Days																						
Birth	8	6	10	...	6	6	...	...	6	...	...	...	7	...	...	...	...	...	...	...	...	...
10	10	7	11	9	9	7	...	...	8	9	...	12	10	11	7	8	4	5	5	...	...	...
20	13	8	12	10	11[f]	8[f]	14	13	12	12	17	17	15	15	11	10	6	7	7	7	8	8
30	14	9	13	12	12	10	18	17	16	13	22	21	22	19	14	11	8	9	9	10	10	9
40	15	10	14[s]	14	14	11	22	21	20	16	27	25	25	23	17	13	11	11	11	13	14	12
50	16	11	15	15	16	12[s]	26	26	24	18	32	31	30	27	22	14	12	13	13	15	16	15
60	17	12	17	16	18	13	30	28	26	19	36	...	33	...	27	15	14	15	15	18	19	17
70	18[f]	13	18	17	...	15	33	...	28	21	41	41	37	...	31	16	16	17	16	20	20	19
80	18	15	20	18	22	16	35	...	33	22	46	45	42	39	36	17	19	21	19	23	26	23
90	19	17	22	20	24	18	38	41	36	23	49	49	46	43	39	18	21	23	21	25	28	25
100	20	20	23	21	25	20	40	43	38	24	52	53	48	44	42	20	22	23	23	27	31	26
110	21	23	24	24	27	21	42	46	42	28	54	56	53[f]	49	44	24	24	24	24	28	33	27
120	23	27	25	26	30	23	43	46	43	30	58	59	54	56	47[d]	27[d]	25	27	25	29	34	29
135	26[f]	31	26	31	32	25	44	49	46	35	63	63	54	70[f]	...	...	...[f]	...[f]	...[f]	...	...	...[f]
150	29	33[f]	28	34	33	26	46	55	49	...[d]	66[f]	65[f]	...	62	...	...	27	31	29	32[f]	39[f]	34
165	32	35	29	37	34	...	44	59	50	...	67	67	...	...[d]	...	...	28	32	30	32	43	35
180	34	38	30	42[f]	37	28	52[f]	63[f]	52	...	68[f]	...[f]	...	...	...	...	29	32	30	33	42	34
195	37	42	32	45	38	30	54	...	54	...	...	...	65	...	...	...	30	31	30	35	41	34
210	39	43	35	48	42	33	56	...	54	...	...	...	64	...	...	...	30	32[s]	32	36	43	39
225	40	44	40	51	47	39	58	72	53	...	72	77	68	...	...	...	29	...	33	37	43	40
240	42	46	[illegible]	53	...	...	58	[illegible]	53	...	72	77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46

270	44	50	52	57	59	51	61	[illegible]	54	...	74	86	[illegible]	...	...	...	31	37	34	40	[illegible]	[illegible]
285	45	51	55	59	62	52	...	76	54	...	74	80	70	...	...	...	...	...	...	...	...	...
300	46	53	59	61	65	54	67	77	54	...	75	77	71	...	...	...	32	40	35	43	49	50
315	47	55	63	62	67	56	73	84	54	...	78	77	71	...	...	...	32	41	35	...	51	53
330	48	58	67	62	70	53	78	92	...	...	83	...	72	...	...	...	35	...	34	...[d]	...	...
345	50	62	69	62	72	60	79	93	...	...	85	86	74	...	...	...	36	43	35	...	62	61
360	53	...	71	63	73	63	81	93	59	...	87	87	77	...	...	...	38	45	36	...	66	65
390	62	77	74	70	76[f]	70	91	85	61	...	90	92	87	...	...	...	42	51	43	...	72	71
420	69	81	80	77	82	71[f]	100[b]	83	...	...	94	94	...	...	...	...	...	...	...	...	...	...
450	73[f]	88	88	83	95	...[d]	...	...[b]	...	...	...	...	...	...	...	...	...	...	...	...	...	...
480	76	93	97	87	101	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
510	81	98	110[b]	92[f]	114	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
540	86	103	75	97[f]	...[b]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
570	92	103	80	101	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
600	96	110	82	110	86	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
630	100	115	83	120	100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
660	101[b]	115	86	131	...[b]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
690	90	...	87	139[b]	85	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
720	86	105	...	103	...[d]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
780	113	90	80[s]	110	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
840	100	...	...	...[d]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
900	95	80	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
960	92	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1080	90	100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[f] Fast; [s] Sick; [b] Birth; [d] Died.
*Above body weights were read from smooth curves through the individual data.

TABLE 8.—DAILY PRODUCTION OF THE SANDBURG GOATS.

SECTION 1

Ten-Month O.A.R. record (lbs.) of Carlotta, 48960, began at 3 yrs., 8 mos., 14 days: 2626 lbs. milk, 97.7 lbs. fat. Purebred Toggenburg. October 23, when owner away, became indisposed (plant poisoning ?) recovered through December and January and normal last test week. Born July 12, 1933. Av. Weight 135 lbs.

	Mar. 1937	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	....	10.5	14.3	10.5	13.6	13.1	9.4	8.3	2.9	3.4	3.1
2	....	10.9	15.3	12.2	12.7	11.0	9.9	8.1 135 lbs.	2.4	3.3	3.0
3	....	11.4	15.1	12.1	13.0	12.3	9.7	6.9	1.6 127 lbs.	2.9	3.2
4	....	11.7	14.7	11.8	13.6	12.0	9.0	8.2	1.3	2.8	3.2
5	....	11.3	14.0	11.6	12.7	10.8	8.1 135 lbs.	8.2	1.9	3.5	3.5
6	....	11.0	14.7	11.3	13.8	12.5	9.1	8.2	2.9	3.8	3.5
7	....	10.6	13.3	13.1	12.4	11.1	10.1	7.4	1.4	3.6	3.9
8	....	11.7	14.6	13.5	11.0	10.2	10.2	7.4	0.9 Bred	3.5	3.7
9	....	10.5	12.6	13.4	11.8	10.9	9.1	7.1	2.0	3.3	4.0
10	....	11.6 140 lbs.	13.1	12.3	11.1	10.5	9.8	7.4	2.0	3.0	3.6
11	....	11.0	13.4	12.5	12.0	10.9	7.9	7.7	2.2	3.3	3.6
12	....	10.5	14.2	11.9	11.9	11.0	9.5	7.4	2.6	3.1	3.9 135 lbs.
13	....	11.4	13.8	14.6	12.3	11.1	9.0	5.8	1.5	3.2	4.0
14	....	11.5	12.7	13.9	12.9	10.4	7.9	6.5	1.6	2.6	4.0
15	....	12.6	12.7	11.7	12.0	9.4	7.4	7.8	2.7	2.7	3.8
16	....	11.4	12.9	13.1 146 lbs.	10.4	10.6	6.0	7.2	1.8	2.6	3.8
17	....	12.4	12.6	14.4	11.5	8.8	6.4	8.1	2.0	2.7	4.1
18	.... 136 lbs.	12.5	12.7	13.7	10.3	9.7	6.5	6.6	2.2	2.7	3.8
19	.... Kidded	14.5	12.2	14.0	11.9	8.9	9.1	7.2	2.1	3.0	3.6
20	....	14.4	9.8	13.6	11.0	9.1	9.2	6.9	2.7	3.2	3.7
21	....	13.5	11.7	13.3	11.8	9.7	8.3	6.0	2.4	3.1	3.9
22	....	13.5	9.6	14.0	11.6	9.4	8.0	6.6	2.7	3.0	4.0
23	....	15.4	12.5 129 lbs.	13.9	11.3	9.5	8.0	5.1	2.8	3.1	4.4
24	....	13.7	12.1	12.3	12.0	10.0	9.5	3.9 (ill, off	2.5	3.2	3.9
25	....	14.2	11.7	13.0	11.3	9.1	9.9	3.7 feed)	2.9	3.3	4.0
26	8.8	14.1	12.5	11.9	12.2	9.5	9.6	2.8	3.5	3.0	....
27	9.0 132 lbs.	14.2	13.5	13.6	12.7	9.7	7.9	3.7	3.3	3.2	....
28	11.6	14.6	12.7	14.6	13.0	9.5	9.0	3.0	3.3	3.0	....
29	8.9	13.8	12.2	12.9	11.2	9.2	8.4	4.5	3.6	2.5	....
30	10.7	14.0	13.3	12.6	11.4	9.1	7.7	3.2	3.2	2.6	....
31	10.5	....	12.4	....	10.8	9.9	....	3.1	....	3.3	....
Milk Lbs.	59.5	373.4	402.9	387.3	371.1	318.9	259.6	194.0	70.9	95.5	93.2
Fat %	....	3.284	3.639	2.956	3.275	3.762	3.629	5.8	6.233	4.543	4.045

TABLE 8.—SECTION 2

Ten-Month O.A.R. record (lbs.) of Leona, 49014, began at 6 yrs., 1 mo., 23 days: 2868 lbs. milk, 101.9 lbs. fat. Sire pure-bred Toggenburg 36216; dam, ¾ Saanen Grade. Born March 1, 1931. Av. Weight 149 lbs.

	Apr. 1937	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	....	9.7	12.7	12.7	11.3	11.7	9.8	9.4	5.1	6.1	5.9
2	....	11.4	11.5	13.2	10.2	12.0	8.7	9.0	6.5	6.3	6.3
3	....	9.3	12.2	12.3	12.0	11.4	8.4	9.0	7.0	6.6	6.6
4	....	9.9	11.5	13.7	11.3	10.8	8.8	9.1	6.5	6.4	6.8
5	....	11.0	12.1	11.0	9.8	10.6 148 lbs.	10.1	8.5	7.2	5.8	6.6
6	....	10.8	12.0	12.3	11.5	11.7	10.5	9.4	7.7	5.7	6.6
7	....	11.1	12.7	12.7	11.0	10.5	9.9	8.7	5.8 Bred	6.3	7.0
8	....	10.9	12.9	11.7	10.6	10.2	9.7	8.3	5.7	6.2	6.5
9	....	10.8	12.7	12.0	11.4	11.3	8.2	7.4	5.5	6.5	6.4 149 lbs.
10	....	10.5	12.9	11.6	11.2	11.8	9.3	7.2	5.7	6.5	6.5
11	....	11.3	12.0	11.1	10.8	10.3	10.4	6.4	6.4	6.7	6.6
12	....	12.3	11.5	9.0	10.2	11.1	10.3	7.9	6.9	6.7 141 lbs.	6.4
13	....	11.3	12.8	5.9	9.7	11.3	9.3	6.9	6.9	6.7	6.2
14	....	11.7	13.3	9.8	10.6	10.6	10.6	7.0	6.8	6.7	6.2
15	....	12.0	11.5	11.1	10.8	12.2	10.5	7.8	6.6	7.0	6.2
16	....	12.7	11.9 162 lbs.	10.8	11.4	12.0	9.7	6.4	6.8	6.3	6.4
17	....	11.8	13.0	10.3	10.0	10.7	11.5	7.0	6.9	7.0	6.6
18	.... Kidded	12.2	13.1	9.9	10.1	9.0	10.4	7.8	6.9	6.7	6.3
19	....	10.9	12.7	10.7	9.6	8.8	11.0	7.5	6.8	6.8	6.2
20	....	11.2	13.5	11.0	11.3	10.5	10.5	7.4	6.9	7.0	5.5
21	....	12.9	12.5	13.0	12.2	8.6	9.5	7.8	6.9	6.6	4.8
22	....	12.1	12.0	11.1	11.6	9.3	9.7	7.1	6.5	6.7	4.7
23	....	12.7 144 lbs.	13.5	9.5	9.8	7.6	9.2	7.0	6.7	6.7	5.0
24	9.4	13.0	12.1	11.6	11.1	6.3	8.7	7.4	7.2	6.2	....
25	8.6	13.2	13.7	11.6	10.7	9.1	9.3	7.6	7.3	6.9	....
26	10.1	13.0	10.7	11.4	10.6	9.6	8.9	8.1	6.3	6.9	....
27	10.4	14.0	12.7	10.1	9.1	7.2	9.7	6.9	7.3	6.7	.... (151
28	10.6	13.5	13.9	11.1	9.3	9.0	9.3	6.7	6.7	5.7	.... lbs.
29	10.3	12.3	13.1	11.2	10.6	8.9	10.3	7.2	6.9	5.6	.... Mar.
30	11.4	13.3	12.1	11.1	12.2	9.4	9.6	5.9	5.9	6.4	.... 7)
31	....	13.0	....	11.2	10.3	....	9.0	....	4.9	6.4	....
Milk Lbs.	70.8	365.8	374.8	345.7	330.3	303.5	300.8	229.8	203.2	200.8	142.3
Fat %	....	3.611	3.358	3.153	3.358	4.123	2.894	4.258	3.632	3.777	3.937

TABLE 8.—SECTION 3

Ten-Month O.A.R. record (lbs.) of Felicia, 48968, began at 5 yrs., 11 mos., 11 days: 2545 lbs. milk, 99.1 lbs. fat. Purebred Toggenburg. Born March 27, 1931. Av. Weight 123 lbs.

	Mar. 1937	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	.... Kidded	9.4	10.6	10.9	11.3	11.1	9.2	8.3	6.6	4.0	2.2
2	.... 118 lbs.	9.0	11.3	10.4	10.6	9.9	9.7	8.2 124 lbs.	6.3	4.1	3.1
3	....	9.6	10.5	10.9	10.8	11.3	9.6	7.7	5.5 117 lbs.	4.0	3.0
4	....	9.3	10.9	10.6	11.7	11.1	9.3	8.1	5.7	3.6	3.0
5	....	8.9	10.4	10.6	10.7	9.5	8.4 125 lbs.	8.6	5.3	4.0	2.2
6	....	9.0	10.6	10.9	11.6	12.1	8.5	8.0	5.5	4.1	2.5
7	....	8.8	11.2	10.2	11.0	10.8	9.8	7.4	5.9	4.0	2.3
8	7.1	9.3	11.0	10.8	10.7	10.5	9.0	7.5	5.7	4.0	.... 120 lbs.
9	7.4	9.2	10.6	10.7	11.0	11.0	8.2	7.2	6.6	3.9	....
10	6.8	8.8 129 lbs.	10.9	10.5	10.2	10.5	9.4	7.1	5.5	3.5	....
11	8.7	9.0	11.3	10.9	11.2	9.9	7.8	8.5	5.6	3.7	....
12	7.0	9.0	11.3	10.9	11.1	10.2	9.9	7.6 Bred	5.5	3.6	....
13	7.1	9.9	10.8	12.2	9.7	10.2	9.3	6.4	5.4	3.8	....
14	7.7	8.9	11.3	11.7	10.4	9.7	7.7	8.0	5.1	3.8	....
15	8.2	10.0	11.1	10.5	10.4	10.3	9.0	8.3	5.7	3.8	....
16	7.5	10.0	12.1	10.9 142 lbs.	9.1	10.1	8.6	7.4	5.4	2.4	....
17	8.1	9.2	11.2	11.9	10.6	9.7	8.2	8.4	5.5	1.9	....
18	7.5	9.4	10.4	10.7	8.8	10.9	7.5	7.3	5.1	2.6	....
19	9.1 120 lbs.	9.2	10.2	11.3	10.2	10.0	9.1	7.7	4.4	2.6	....
20	7.6	9.4	11.0	11.3	10.8	9.9	8.6	7.3	4.9	3.1	....
21	7.8	10.0	9.5	11.1	10.3	9.5	7.1	6.3	4.5	3.3	....
22	8.1	8.9	7.8	11.3	10.8	9.3	6.7	7.2	4.4	3.2	....
23	8.1	10.1 118 lbs.	9.5	11.1	9.8	9.7	9.2	6.2	4.5	3.2	....
24	8.5	9.9	9.7	10.9	11.7	10.0	8.8	5.8	4.5	3.2	....
25	8.7	9.6	9.6	11.6	10.8	10.0	9.1	6.3	4.4	3.1	....
26	8.8	10.2	10.4	10.4	11.1	10.4	9.4	6.8	4.7	2.9	....
27	8.3 117 lbs.	10.2	11.5	10.8	10.1	9.8	7.6	6.3	4.1	3.2	....
28	10.4	10.3	10.4	11.8	10.9	9.0	8.0	5.9	4.0	3.0	....
29	8.2	10.6	10.7	11.0	10.8	9.2	8.2	6.6	3.9	2.7	....
30	9.5	10.8	10.6	10.9	11.1	9.4	7.6	6.2	4.3	2.8	....
31	9.4	....	10.1	....	10.7	9.4	....	6.0	....	3.0	....
Milk Lbs.	195.6	285.9	328.5	330.3	330.0	314.4	258.5	224.6	154.5	104.1	18.3
Fat %	4.997	4.458	3.322	3.351	3.555	3.864	3.434	4.058	5.447	4.003	....

TABLE 8.—SECTION 4

Ten-Month O.A.R. record (lbs.) of Sophie, 48969, began at 5 yrs., 11 mos., 21 days: 2189 lbs. milk, 60.2 lbs. fat. Sire purebred Toggenburg, 36216; dam, unregistered Swiss-Nubian cross-bred. Born April 10, 1931. Av. Weight 151 lbs.

	Mar. 1937	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	....	8.2	9.9	10.2	10.4	8.8	6.5	7.0	4.9	4.4	3.2
2	....	8.2	10.8	9.9	10.0	7.3	7.3	6.3 149 lbs.	4.8	4.7	2.7
3	....	8.0	9.5	10.4	10.8	9.6	6.6	6.2	6.0 147 lbs.	4.6	3.0
4	....	7.7	10.6	9.6	10.6	9.4	6.2	6.1	4.7	4.0	2.9
5	....	8.2	10.3	9.6	9.7	8.3	6.2 147 lbs.	6.5	4.8	4.3	2.8
6	....	8.3	10.7	10.5	10.5	10.9	6.5	5.7	4.8	4.2	2.8
7	....	8.5	10.3	9.5	9.2	9.0	7.5	5.1	4.9	3.7	2.9
8	....	8.3	10.6	10.2	9.7	8.4	7.2	5.5	4.9	4.1	3.2
9	....	8.2	10.0	10.2	10.3	9.0	7.2	5.8	4.4 Bred	3.9	3.0
10	....	8.0 157 lbs.	10.3	10.3	9.8	8.7	8.3	6.4	4.4	3.7	3.1
11	....	8.4	10.3	10.4	10.4	8.8	7.4	6.4	4.5	3.8	3.3
12	....	8.5	10.0	9.1	9.8	8.9	7.8	5.5	5.1	3.8	3.2 139 lbs.
13	....	8.8	11.1	11.3	10.6	8.6	7.9	5.6	4.9	4.8	3.0
14	...	8.2	10.0	10.2	10.2	9.0	6.9	5.5	3.7	3.1	3.2
15	....	9.3	10.1	9.2	9.3	7.4	7.7	5.2	4.5	3.2	3.9
16	....	9.4	10.9	9.5 170 lbs.	8.6	7.0	7.1	5.4	4.5	3.2	3.5
17	....	9.2	10.3	10.9	10.6	7.7	6.6	6.3	4.8	3.6	3.6
18	....	9.3	9.9	10.0	9.2	7.4	6.2	4.8	4.7	3.7	3.8
19	....	9.6	9.9	9.7	10.0	6.0	6.8	5.3	4.1	3.2	3.4
20	....	10.0	9.5	10.0	9.6	5.6	5.6	5.6	4.3	3.4	3.7
21	....	9.9	11.4	8.9	9.9	7.1	6.3	5.3	4.5	3.4	3.7
22	....	10.2	10.4	11.3	10.5	7.8	7.0	6.2	4.7	3.1	3.9
23	....	11.1	10.8 148 lbs.	11.9	9.5	7.9	8.3	5.5	4.4	3.2	3.8
24	....	10.6	11.2	10.1	9.8	7.8	7.4	5.2	4.3	3.1	3.4
25	.... Kidded	9.4	11.1	10.0	9.2	7.8	7.6	5.3	4.4	2.4	3.9
26	....	9.9	10.4	10.5	9.6	8.5	7.0	5.3	4.8	2.8	3.8
27	....	9.7	10.7	10.2	9.3	7.9	5.6	4.8	4.3	3.8	3.8
28	....	9.7	9.5	10.6	10.0	8.1	6.6	5.2	4.0	3.4	3.9
29	....	10.4	10.6	9.9	9.1	8.2	7.0	5.5	4.4	3.0	3.7
30	....	10.1	10.7	10.2	8.4	8.6	6.4	5.0	4.6	2.7	3.7
31	....	....	10.0	....	7.8	6.4	....	4.9	....	4.5	....
Milk Lbs.	....	270.3	322.7	304.3	302.4	251.9	208.7	174.4	148.1	112.8	101.8
Fat %	....	4.166	3.798	3.480	3.571	3.849	3.931	4.909	5.528	5.158	4.894

TABLE 8.—SECTION 5

Ten-Month O.A.R. record (lbs.) of Rachel, 50378, began at 1 yr., 3 mos., 16 days: 1721 lbs. milk, 60.7 lbs. fat. Purebred Toggenburg. Born February 1, 1936. Av. Weight 115 lbs.

	May 1937	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1	....	8.7	9.2	9.5	7.2	6.0	5.7	4.0	3.2	2.8	1.7
2	....	8.7	9.2	7.8	7.4	6.1 109 lbs.	5.5	3.7	3.8	2.8	1.6
3	....	8.8	8.9	7.7	8.2	6.2	4.9 113 lbs.	3.7	3.7	3.0	1.6
4	....	8.5	8.3	8.4	7.8	6.3	5.2	3.6	3.6	2.8	1.4
5	....	8.3	8.9	7.3	6.5 109 lbs.	6.9	5.3	4.0	3.8	2.8	1.3
6	....	9.1	8.5	9.1	6.9	6.7	5.2	4.2	3.6	2.9	....
7	....	8.4	8.4	8.0	7.3	6.2	5.3	4.0	3.8	3.1	.... 139 lbs.
8	.... Kidded	8.7	9.2	8.1	6.8	6.4	5.3	4.2	4.0	2.9	....
9	....	8.0	8.2	8.5	6.4	6.0	4.6	3.9	4.0	3.1	....
10	....	8.6	7.8	7.8	6.8	6.4	4.6	3.8	3.7	2.8	....
11	....	8.8	8.2	8.1	5.9	6.5	5.3	3.9	3.6	2.7	....
12	....	8.7	8.0	8.6	8.0	6.0	5.4	4.3	3.5 115 lbs.	2.6	....
13	....	9.6	7.4	8.2	7.0	5.5	4.9	3.8	3.4	2.5	....
14	....	9.4	7.3	7.8	6.9	6.4	4.5	3.4	3.6	2.7	....
15	....	8.3	8.3	8.0	7.0	6.9	5.2	3.0	3.5	2.4	....
16	....	8.8 114 lbs.	7.0	8.6	6.9	6.0	5.3	3.2	3.5	2.4	....
17	7.3	9.0	7.7	8.4	6.8	6.3	5.0	4.0	3.3	2.4	....
18	6.9	9.0	7.4	8.6	6.6	5.5	5.1	3.7	3.1	2.5	....
19	7.2	8.5	8.5	8.4	7.5	6.3	4.3	3.5	3.2	2.5	....
20	7.3	9.8	8.1	7.8	6.8	6.1	4.8	3.7	2.9	2.5	....
21	7.9	9.4	7.8	8.0	6.7	5.8	4.4	3.4	2.9	2.4	....
22	7.9	8.3	8.2	7.3	6.9	6.5	4.6	3.4	2.8	2.4	....
23	8.3 105 lbs.	8.9	7.5	8.3	7.5	6.5	4.3	3.7	2.8	2.2	....
24	7.9	8.5	8.3	8.3	6.6	5.5	3.9	3.4	2.5	1.6	....
25	9.4	9.0	6.7	7.9	6.3	5.1	4.5	3.1	2.9	1.6	....
26	8.6	7.6	8.5	8.3	6.0	5.2	5.2	3.2	3.2	1.7	....
27	9.1	9.2	8.0	7.6	5.2	5.8	4.4	3.7	3.0	1.9	....
28	8.5	9.1	9.1	7.1	5.8	5.1	3.3	3.5	2.7	1.9	....
29	8.5	9.0	8.7	8.4	6.2	5.3	3.9 Bred	3.3	2.9	....	....
30	9.4	9.0	9.2	7.9	6.8	5.5	3.5	3.4	3.0	....	....
31	8.7	....	8.2	7.8	....	5.2	....	3.7	2.9	....	....
Milk Lbs.	122.9	263.7	254.7	251.6	204.7	186.2	143.4	113.4	102.4	69.9	7.6
Fat %	4.421	3.332	3.341	2.833	3.135	3.563	4.050	4.060	4.000	4.276	....

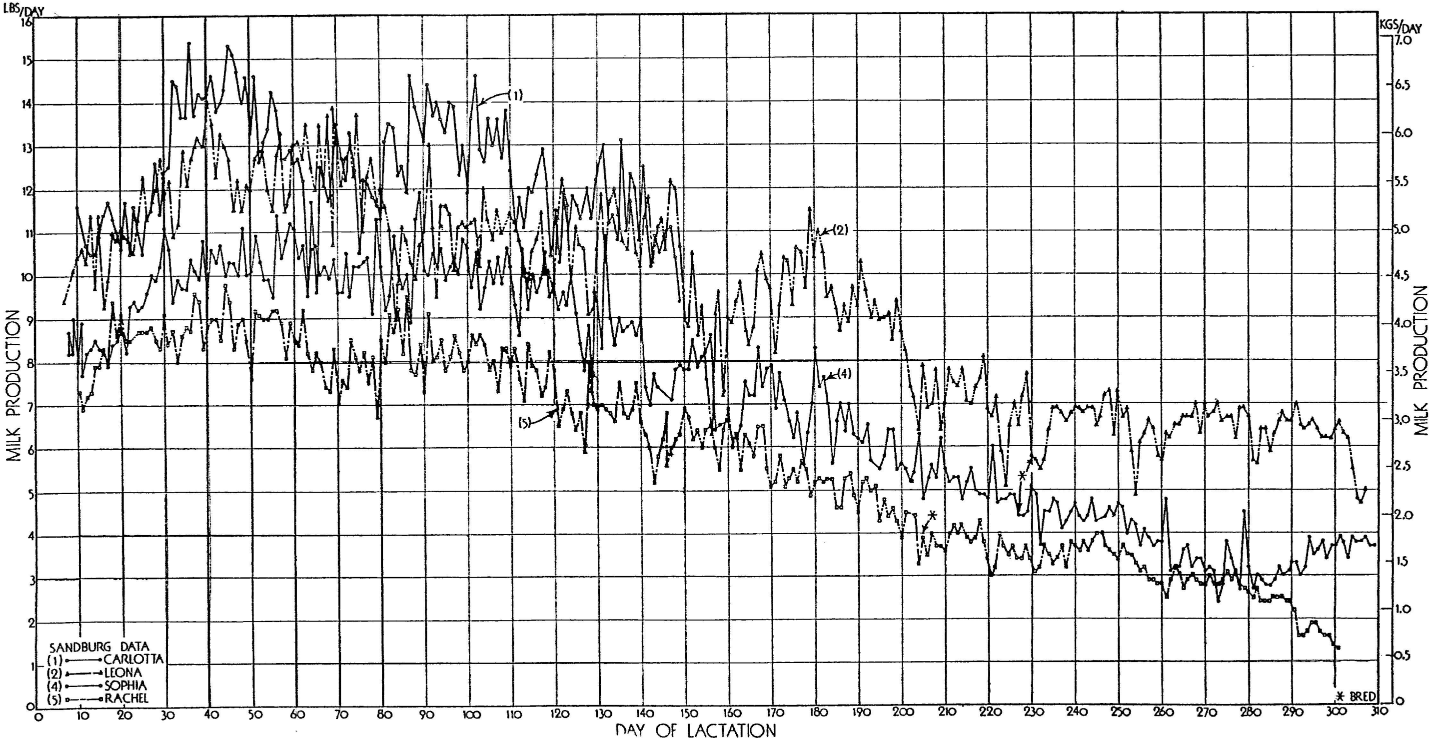


Fig. 18.—The course of daily milk production in four of the Sandburg goats. Carlotta's record was abbreviated because of her illness.

TABLE 9.—MILK AND FAT PRODUCTION IN GOATS.

SECTION 1

Sandburg Data

	Cloverleaf		Leona		Felicia		Sophia		Rachel	
	Av. Weight 135 lbs.		Av. Weight 149 lbs.		Av. Weight 123 lbs.		Av. Weight 151 lbs.		Av. Weight 115 lbs.	
Lacta-tion Week	lbs./day Milk	% Fat	lbs./day Milk	% Fat	lbs./day Milk	% Fat	lbs./day Milk	% Fat	lbs. /day Milk	% Fat
1	...	....	...	....	...		...		...	
2	10.3		10.2		7.4		8.2		7.3	4.421
3	11.2		10.6		8.0	4.997	8.3		8.5	
4	11.4		11.4		8.7		9.5	4.166	8.8	
5	13.7	3.284	12.0	3.611	9.2		10.1		8.6	
6	14.1		13.1		9.0		10.2		9.0	3.332
7	14.5		12.3		9.5		10.3		8.9	
8	13.5		12.4		9.6	4.458	10.3	3.798	8.9	
9	12.1	3.639	12.6	3.358	10.6		10.7		8.6	
10	12.1		12.6		10.7		10.2		7.7	
11	12.1		12.9		11.3		10.0		7.9	3.341
12	12.5		12.1		9.9	3.322	10.0	3.480	8.4	
13	13.3	2.956	9.7		10.4		10.4		8.3	
14	13.4		11.0	3.153	10.6		10.2		8.2	
15	13.1		11.1		10.9		10.2		8.2	
16	12.6		11.0		11.2	3.351	10.1		8.0	2.833
17	11.8		10.6		11.0		9.6		7.7	
18	11.3	3.275	10.8	3.358	11.2		9.7	3.571	6.9	
19	12.0		10.3		10.9		8.6		6.9	
20	11.8		11.3		10.0		9.0		6.9	3.135
21	10.8		10.9		10.6	3.555	8.0		6.0	
22	9.6		11.0		10.8		7.1	3.849	6.4	
23	9.6	3.762	8.6	4.123	10.7		7.7		6.4	
24	9.5		8.9		10.3		6.8		6.2	
25	9.3		9.4		9.9	3.864	7.6		6.1	3.563
26	7.7		10.0		9.7		6.4	3.931	5.5	
27	8.4	3.629	10.3	2.894	9.3		7.1		5.4	
28	8.7		9.4		8.9		6.3		5.1	
29	7.8		9.1		8.5		5.8		4.9	4.050
30	7.1		7.5		8.4	3.434	5.4		4.5*	
31	6.9		7.3	4.258	7.9		5.4	4.909	3.8	
32	3.8	5.8	7.4		7.7		5.2		4.0	
33	2.3*		6.4		7.8*		4.7*		3.7	
34	2.0		6.3*		6.8	4.058	4.6		3.5	4.060
35	2.0		6.8		6.3		4.4	5.528	3.4	
36	2.8	6.233	6.9		5.8		4.4		3.6	
37	3.3		6.3	3.632	5.6		4.2		3.7	
38	3.4		6.2		5.1	5.447	3.8		3.2	4.000
39	2.9		6.7		4.9		3.4		2.8	
40	3.0		6.7		4.0		3.1	5.158	2.9	
41	3.0	4.543	6.4	3.777	3.8		3.1		2.9	
42	3.3		6.4		3.0		3.1		2.5	4.276
43	3.8		6.6		3.1		3.5		2.2	
44	3.8		6.3	3.937	2.9	4.003	3.7	4.894	1.7	
45	4.1	4.045	5.0		2.6		2.2		1.3	

*Bred during that lactation week.

TABLE 9.—SECTION 2

Asdell Data

Lactation Week	Goat 13 Av. Weight 93 lbs. lbs./day Milk	Goat 13 % Fat	Goat 6 Av. Weight 113 lbs. lbs./day Milk	Goat 6 % Fat	Goat 46 Av. Weight 86 lbs. lbs./day Milk	Goat 46 % Fat	Goat 40 Av. Weight 87 lbs. lbs./day Milk	Goat 40 % Fat	Goat 44 Av. Weight 78 lbs. lbs./day Milk	Goat 44 % Fat	Goat 16 Av. Weight 111 lbs. lbs./day Milk	Goat 16 % Fat	Goat 41 Av. Weight 100 lbs. lbs./day Milk	Goat 41 % Fat
1	4.8	6.1	6.9	5.4	5.2	6.9	5.3	5.6	4.5	5.3	7.1	5.6	6.3	6.2
2	5.4	5.2	8.0	5.1	6.1	5.5	6.7	5.0	5.9	4.5	7.5	4.3	6.7	5.5
3	5.9	5.4	9.0	4.5	6.5	5.4	7.0	5.2	6.7	4.4	8.1	4.0	7.1	4.9
4	5.8	5.4	8.5	4.6	7.1	5.0	7.2	4.9	7.3	4.1	7.9	4.0	7.1	4.6
5	5.6	5.2	8.7	4.0	7.5	4.4	7.0	4.7	7.4	3.8	8.2	3.7	6.7	5.0
6	5.7	4.8	8.0	4.4	7.5	4.4	7.1	4.9	7.2	4.0	7.5	3.6	6.3	5.2
7	5.4	5.0	8.4	4.4	7.3	4.1	6.6	4.8	6.8	4.4	7.2	3.5	5.7	5.2
8	5.5	4.5	8.5	4.1	7.7	4.1	6.8	4.6	7.0	3.7	7.1	3.6	5.0	5.1
9	5.4	4.7	8.0	4.0	7.6	4.2	7.0	4.5	7.2	3.5	6.8	3.6	4.9	4.8
10	5.5	4.6	6.9	4.2	7.5	3.7	6.6	4.5	6.1	3.4	6.1	3.7	4.9	4.6
11	5.2	4.9	7.3	3.8	7.2	3.8	6.1	4.4	5.0	3.5	5.8	3.5	5.0	4.6
12	4.9	5.0	7.1	3.6	7.0	3.7	5.6	4.4	5.4	3.4	5.3	3.0		
13	4.2	5.1	6.5	3.8	6.6	3.5	5.5	4.2	5.2	3.6				
14	4.5	5.0	5.9	3.8	6.3	3.6	5.4	4.0	5.2	3.6				
15	4.5	4.8	4.6	3.7	6.0	3.7	5.2	4.2	5.0	3.7				
16	4.3	5.0	4.9	4.0	6.0	3.7	5.3	4.1	4.9	3.5				
17	4.6	4.7	5.1	3.4	6.1	3.7	5.4	4.0	5.0	3.4				
18	4.4	4.5	4.7	3.2	6.1	3.3	5.2	4.0						
19	4.2	4.2	4.6	3.3	6.0	3.3	5.3	3.9						
20	4.0	4.5	4.9	2.9	6.0	3.5	5.5	3.8						
21	3.9	4.5	5.1	3.4	5.9	3.6	5.5	3.8						
22	3.8	4.7	4.8	3.3	5.6	3.6	5.6	3.8						
23	3.6	4.5	...	...	5.5	3.0	5.5	3.1						
24	...	...	...	...	...	...	5.1	3.7						
25	...	...	...	...	...	...	5.0	3.9						

TABLE 10.—GROSS EFFICIENCY OF MILK PRODUCTION COMPUTED FROM ASDELL'S GOAT DATA.

SECTION 1

Lactation Week	Goat 13 Body Weight lbs.	Goat 13 Daily TDN Consumption lbs.	Goat 13 Daily TDN Consumption Cals.	Goat 13 Daily (FCM) Milk Production lbs.	Goat 13 Daily (FCM) Milk Production Cals.	Goat 13 Gross Efficiency %	Goat 6 Body Weight lbs.	Goat 6 Daily TDN Consumption lbs.	Goat 6 Daily TDN Consumption Cals.	Goat 6 Daily (FCM) Milk Production lbs.	Goat 6 Daily (FCM) Milk Production Cals.	Goat 6 Gross Efficiency %
1	88.4	3.37	6113	6.35	2159	35.3	110.9	3.24	5877	8.41	2859	48.6
2	86.7	3.54	6422	6.40	2176	33.9	114.4	4.30	7800	9.37	3186	40.8
3	89.3	3.67	6657	7.13	2424	36.4	118.0	5.42	9832	9.63	3274	33.3
4	91.7	3.94	7147	6.97	2370	33.2	116.9	4.50	8163	9.33	3172	38.9
5	91.5	3.79	6875	6.68	2271	33.0	115.8	4.86	8816	8.73	2968	33.7
6	91.0	3.15	5714	6.42	2183	38.2	115.5	3.95	7165	8.42	2863	40.0
7	92.6	3.29	5968	6.22	2115	35.4	115.3	4.65	8435	8.84	3006	35.6
8	94.2	3.30	5986	5.88	1999	33.4	114.4	5.01	9088	8.66	2944	32.4
9	94.6	3.21	5823	6.02	2047	35.2	113.6	4.94	8961	8.05	2737	30.5
10	94.8	3.44	6240	6.02	2047	32.8	114.4	3.74	6784	7.08	2407	35.5
11	93.9	2.88	5224	5.84	1986	38.0	115.5	4.10	7437	7.05	2397	32.2
12	93.3	2.91	5279	5.62	1911	36.2	116.6	4.25	7710	6.76	2298	29.8
13	92.6	2.73	4952	4.86	1652	33.4	114.7	4.10	7437	6.27	2132	28.7
14	93.7	2.94	5333	5.21	1771	33.2	112.5	3.48	6313	5.75	1955	31.0
15	94.6	2.99	5424	5.01	1703	31.4	112.2	2.73	4952	4.37	1486	30.0
16	95.3	3.05	5533	4.89	1663	30.1	112.0	3.71	6730	4.94	1680	25.0
17	95.7	3.09	5605	5.09	1731	30.9	111.6	3.93	7129	4.61	1567	22.0
18	95.0	2.89	5242	4.71	1601	30 5	111.1	2.82	5115	4.19	1425	27.9
19	94.4	2.76	5007	4.40	1496	29.9	109.8	2.90	5261	4.07	1384	26.3
20	94.6	2.75	4989	4.33	1472	29.5	108.5	2.96	5369	4.12	1401	26.1
21	94.8	2.71	4916	4.16	1414	28.8	110.0	2.95	5351	4.64	1578	29.5
22	94.8	2.77	5025	4.14	1408	28.0	112.0	3.01	5460	4.27	1452	26.6
23	94.8	2.61	4735	3.84	1306	27.6	....	...	....	...	....	...
24	...	...	....	...	....	...	....	...	....	...	....	...
Aver.	93.1	3.12	5660	5.49	1866	32.8	113.4	3.89	7056	6.71	2281	32.0

TABLE 10.—SECTION 2

Lactation Week	Goat 46 Body Weight lbs.	Goat 46 Daily TDN Consumption lbs.	Goat 46 Daily TDN Consumption Cals.	Goat 46 Daily (FCM) Milk Production lbs.	Goat 46 Daily (FCM) Milk Production Cals.	Goat 46 Gross Efficiency %	Goat 40 Body Weight lbs.	Goat 40 Daily TDN Consumption lbs.	Goat 40 Daily TDN Consumption Cals.	Goat 40 Daily (FCM) Milk Production lbs.	Goat 40 Daily (FCM) Milk Production Cals.	Goat 40 Gross Efficiency %
1	75.9	2.89	5242	7.42	2523	48.1	84.4	3.25	5896	6.62	2251	38.2
2	77.6	3.80	6893	7.42	2523	36.6	84.7	3.62	6567	7.72	2625	40.0
3	79.2	3.78	6857	7.86	2672	39.0	84.9	3.75	6802	8.22	2795	41.1
4	81.1	3.78	6857	8.09	2751	40.1	85.6	3.91	7093	8.17	2778	39.2
5	82.9	3.87	7020	8.05	2737	39.0	86.4	3.59	6512	7.61	2587	39.7
6	83.3	3.74	6784	7.87	2676	39.4	85.6	3.70	6712	8.09	2751	41.0
7	83.6	3.53	6403	7.43	2526	39.5	84.7	3.55	6440	7.50	2550	39.6
8	82.7	3.89	7056	7.78	2645	37.5	85.3	3.71	6730	7.41	2519	37.4
9	81.6	4.00	7256	7.86	2672	36.8	86.2	3.95	7165	7.47	2540	35.5
10	81.8	3.44	6240	7.15	2431	39.0	85.6	3.65	6612	7.08	2407	36.4
11	82.2	3.36	6095	6.96	2366	38.8	84.9	3.24	5877	6.43	2186	37.2
12	82.7	3.41	6186	6.66	2264	36.6	84.5	3.25	5896	5.94	2020	34.3
13	82.5	3.38	6131	6.13	2084	34.0	85.1	3.35	6077	5.63	1914	31.5
14	82.0	3.60	6530	5.98	2033	31.1	86.0	3.30	5986	5.44	1850	30.9
15	82.5	3.35	6077	5.78	1965	32.3	87.8	3.46	6276	5.41	1839	29.3
16	82.9	3.32	6022	5.77	1962	32.6	89.7	3.40	6168	5.41	1839	29.8
17	82.9	2.97	5388	5.84	1986	36.9	89.5	3.45	6258	5.40	1836	29.3
18	83.1	2.77	5025	5.50	1870	37.2	89.3	3.21	5823	5.15	1751	30.1
19	82.9	2.51	4553	5.41	1839	40.4	90.4	3.16	5732	5.20	1768	30.8
20	82.9	2.56	4644	5.52	1877	40.4	91.5	3.28	5950	5.32	1809	30.4
21	82.9	2.46	4462	5.56	1890	45.4	91.1	3.30	5986	5.34	1816	30.3
22	83.1	2.56	4644	5.29	1799	38.7	90.8	3.25	5896	5.42	1843	31.3
23	85.1	2.39	4335	4.71	1601	36.9	91.9	3.41	6186	4.78	1625	26.3
24	...	...	....	...	....	...	89.7	3.05	5533	4.94	1680	30.4
Aver.	85.6	3.28	5950	6.61	2247	38.1	87.3	3.45	6258	6.32	2149	34.2

TABLE 10.—SECTION 3

Lactation Week	Goat 44 Body Weight lbs.	Goat 44 Daily TDN Consumption lbs.	Goat 44 Daily TDN Consumption Cals.	Goat 44 Daily (FCM) Milk Production lbs.	Goat 44 Daily (FCM) Milk Production Cals.	Goat 44 Gross Efficiency %	Goat 16 Body Weight lbs.	Goat 16 Daily TDN Consumption lbs.	Goat 16 Daily TDN Consumption Cals.	Goat 16 Daily (FCM) Milk Production lbs.	Goat 16 Daily (FCM) Milk Production Cals.	Goat 16 Gross Efficiency %
1	71.0	1.60	2902	5.41	1839	63.4	110.0	3.19	5787	9.38	3189	55.1
2	73.4	2.50	4535	6.32	2149	47.4	110.7	3.07	5570	7.86	2672	48.0
3	75.9	3.19	5787	7.11	2417	41.8	111.4	3.52	6385	8.04	2734	42.8
4	78.1	3.56	6458	7.37	2506	38.8	111.6	3.61	6549	7.83	2662	40.6
5	75.0	3.67	6657	7.28	2475	37.2	111.8	3.70	6712	7.87	2676	39.9
6	71.9	3.69	6694	7.16	2434	36.4	111.1	3.30	5986	7.07	2404	40.2
7	76.3	3.56	6458	7.23	2458	38.1	110.5	3.27	5932	6.63	2254	38.0
8	80.9	3.55	6440	6.72	2285	35.5	110.9	3.22	5841	6.68	2271	38.9
9	82.0	3.24	5877	6.71	2281	38.8	111.6	3.28	5950	6.46	2196	36.9
10	83.1	2.83	5134	5.50	1870	36.4	110.5	2.95	5351	5.85	1989	37.2
11	82.5	2.45	4444	4.62	1571	35.4	109.6	2.83	5134	5.41	1839	35.8
12	81.8	2.61	4735	4.87	1656	35.0	107.6	2.56	4644	4.50	1530	32.9
13	80.0	2.61	4735	4.91	1669	35.2	....	...	....	...	....	...
14	78.5	2.65	4807	4.90	1666	34.7	....	...	....	...	....	...
15	77.4	2.54	4608	4.76	1618	35.1	....	...	....	...	....	...
16	78.9	2.71	4916	4.57	1554	31.6	....	...	....	...	....	...
17	78.7	2.71	4916	4.54	1544	31.4	....	...	....	...	....	...
Aver.	78.0	2.92	5302	5.88	1999	38.4	110.6	3.21	5822	6.96	2366	40.5

TABLE 10.—SECTION 4

Lacta-tion Week	Goat 41 Body Weight lbs.	Goat 41 Daily TDN Consumption lbs.	Goat 41 Daily TDN Consumption Cals.	Goat 41 Daily (FCM) Milk Production lbs.	Goat 41 Daily (FCM) Milk Production Cals.	Goat 41 Gross Efficiency %	Average of Goats 13, 6, 46, 40, 44, 16, and 41 Body Weight lbs.	Average Daily TDN Consumption lbs.	Average Daily TDN Consumption Cals.	Average Daily (FCM) Milk Production lbs.	Average Daily (FCM) Milk Production Cals.	Average Gross Efficiency %
1	99.9	3.56	6458	8.38	2849	44.1	91.5	3.01	5460	7.42	2523	46.2
2	99.9	3.85	6984	8.21	2791	40.0	92.5	3.53	6403	7.61	2587	40.4
3	99.4	4.04	7329	8.06	2740	37.4	94.0	3.91	7093	8.01	2723	38.4
4	99.0	4.00	7256	7.79	2649	36.5	94.9	3.90	7075	7.93	2696	38.1
5	101.2	3.91	7094	7.73	2628	37.0	94.9	3.91	7093	7.71	2621	37.0
6	103.4	4.05	7348	7.43	2526	34.4	94.5	36.5	6621	7.49	2547	38.5
7	101.2	4.07	7383	6.70	2278	30.9	94.9	3.70	6712	7.22	2455	36.6
8	99.0	3.35	6077	5.78	1965	32.3	95.3	3.72	6748	6.99	2377	35.2
9	98.3	3.47	6295	5.47	1860	29.5	95.4	3.73	6766	6.86	2332	34.5
10	98.6	3.51	6367	5.39	1833	28.8	95.5	3.37	6113	6.30	2142	35.0
11	101.7	3.62	6567	5.49	1867	28.4	95.8	3.21	5823	5.97	2030	34.9
12	....	...	....	...	....	...	94.4	3.17	5750	5.72	1945	33.8
13	....	...	....	...	....	...	91.0	3.23	5859	5.56	1890	32.3
14	....	...	....	...	....	...	90.5	3.19	5787	5.46	1856	32.1
15	....	...	....	...	....	...	90.9	3.01	5460	5.07	1724	31.6
16	....	...	....	...	....	...	91.8	3.24	5877	5.12	1741	29.6
17	....	...	....	...	....	...	91.7	3.23	5859	5.10	1734	29.6
18	....	...	....	...	....	...	94.6	2.92	5297	4.89	1663	31.4
19	....	...	....	...	....	...	94.4	2.83	5134	4.77	1622	31.6
20	....	...	....	...	....	...	94.4	2.89	5242	4.82	1639	31.3
21	....	...	....	...	....	...	94.7	2.86	5188	4.92	1673	32.2
22	....	...	....	...	....	...	95.2	2.90	5261	4.78	1625	30.9
23	....	...	....	...	....	...	90.6	2.80	5079	4.44	1510	29.7
24	....	...	....	...	....	...	....	...	....	...	....	...
Aver.	100.1	3.77	8831	6.95	2363	34.1	....	...	....	...	....	...

TABLE 10.—SECTION 5

Lactation Week	Non-lactating Goat 42 Body Weight lbs.	Daily TDN Consumption lbs.	Daily TDN Consumption Cals.	Estimated "net* efficiency" of milk production of goats 46 & 40: *46*	*40*
1	80.9	0.97	1760	72.5	54.4
2	82.2	1.07	1941	50.9	56.7
3	82.5	1.05	1905	54.0	57.1
4	83.1	1.06	1923	55.7	53.7
5	82.9	1.08	1959	54.1	55.6
6	83.3	1.08	1959	55.5	57.9
7	84.9	1.07	1941	56.6	56.7
8	85.1	1.07	1941	51.7	52.6
9	85.3	1.08	1959	50.4	48.8
10	86.4	1.08	1959	56.8	50.6
11	86.0	1.07	1941	57.0	55.5
12	85.8	.80	1451	47.8	45.4
13	84.0	.81	1469	44.7	41.5
14	83.6	.80	1451	40.0	40.8

*The "net efficiency" of milk production in Goat 46 (and 40) was obtained by dividing the milk Calories she produced by the TDN Calories she consumed less TDN Cal. used for maintenance by dry Goat 42 of about the same body weight. That is,

$$\text{Net efficiency of milk production of Goat 46 (or 40)} = \frac{\text{Milk Cal. produced by 46 (or 40)}}{\text{TDN Cal. consumed by 46 (or 40)} - \text{TDN Cal. consumed by 42}}$$

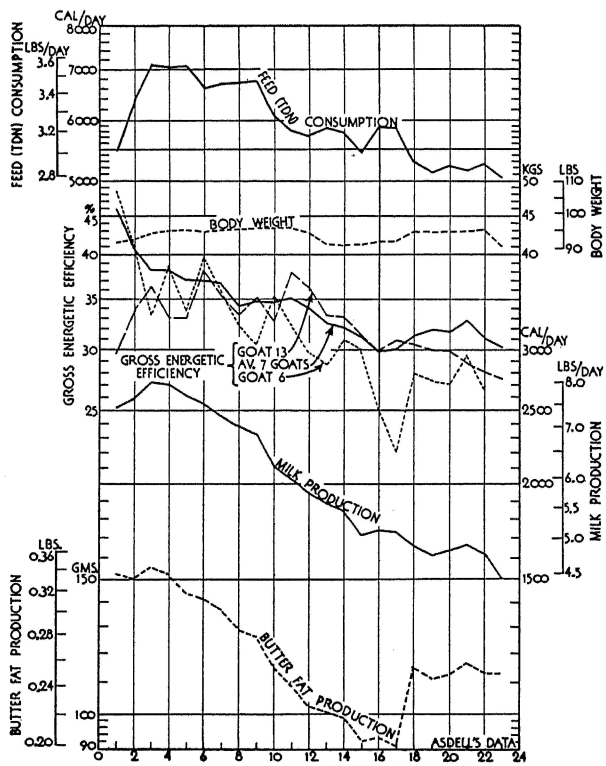


Fig. 19.—Asdell's data (supplementing Table 10) plotted on an arithlog grid to represent the relative courses of gross energetic efficiency of milk production, feed consumption (1 lb. TDN = 1800 Cal.) and butter-fat production in goats with advancing stage of lactation.

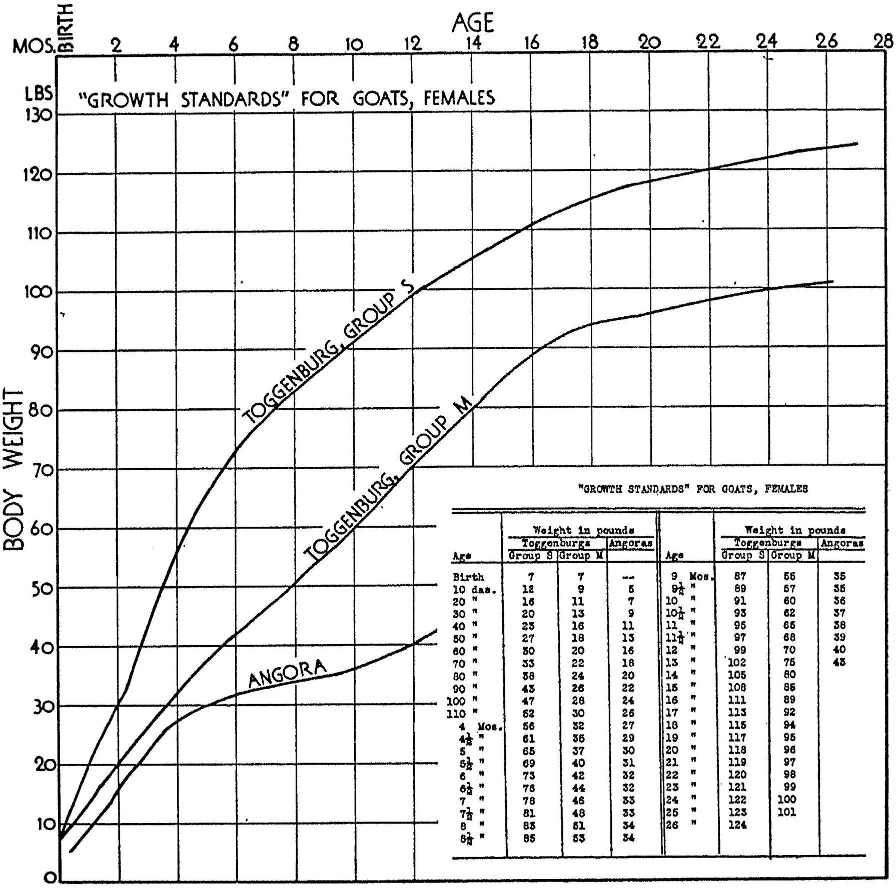
TABLE 11A.—COMPUTED FROM GIVEN FORMULAS "RESTING" HEAT PRODUCTION IN GROWING GOATS. (16 Toggenburg; 6 Angoras)

(Pound Scale)

Body Wt. Lbs.	All Data $Y = 98.6\ X^{.642}$				All Males $Y = 97.5\ X^{.676}$				All Females $Y = 96.8\ X^{.638}$			
	Cal./Animal Day	Cal./lb./Day	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$	Cal./Animal Day	Cal./lb./Day	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$	Cal./Animal Day	Cal./lb./Day	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$
3	200	67	94	96	205	68	96	99	195	65	92	94
4	240	60	87	95	249	62	90	99	235	59	85	93
5	277	55	86	95	289	58	89	99	270	54	83	92
6	312	52	84	94	327	54	88	99	304	51	82	92
7	344	49	83	94	363	52	88	99	335	48	81	91
8	375	47	82	94	398	50	87	99	365	46	80	91
9	404	45	81	93	431	48	87	100	393	44	79	91
10	432	43	80	93	462	46	86	100	421	42	78	91
12	486	41	79	93	523	44	85	100	473	39	77	90
14	537	38	78	92	580	41	84	100	521	37	76	90
16	585	37	77	92	635	40	84	100	568	36	75	89
18	631	35	76	92	688	38	83	100	612	34	74	89
20	675	34	76	92	739	37	83	100	655	33	74	89
25	779	31	74	91	859	34	82	100	755	30	72	88
30	875	29	73	91	971	33	81	100	848	28	71	88
35	967	28	72	90	1078	31	80	101	936	27	70	87
40	1053	25	71	90	1180	30	80	101	1019	26	69	87
45	1136	25	71	90	1278	28	79	101	1098	24	68	87
50	1215	24	70	89	1372	27	79	101	1175	24	68	86
60	1366	23	69	89	1552	26	78	101	1320	22	66	86
70	1508	22	68	89	1723	25	78	101	1456	21	66	86
80	1643	21	67	88	1885	24	77	101	1586	20	65	85
90	1772	20	66	88	2041	23	76	101	1709	19	64	85
100	1896	19	66	88	2192	22	76	102	1828	18	64	85
110	2016	18	65	88	2338	21	76	102	1943	18	63	85
120	2132	18	65	87	2480	21	75	102	2054	17	62	84
130	2244	17	64	87	2618	20	75	102	2160	17	62	84

TABLE 11B.—COMPUTED FROM GIVEN FORMULAS "RESTING" HEAT PRODUCTION FOR GROWING GOATS.

	All Data $Y = 168\ X^{.642}$				(Kg. Scale) All Males $Y = 166\ X^{.676}$				All Females $Y = 160\ X^{.638}$			
Body Wt. Kgs.	Cal./Animal Day	Cal./Kg.	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$	Cal./Animal Day	Cal./Kg.	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$	Cal./Animal Day	Cal./Kg.	Cal./Day (Body Wt.)$^{.73}$	Cal./Day (Body Wt.)$^{2/3}$
2	262	131	154	165	265	132	156	167	249	124	146	157
4	409	102	146	162	424	106	151	168	387	97	138	154
6	531	88	144	161	557	93	151	169	502	84	136	152
8	638	80	139	159	677	85	147	169	603	75	131	151
10	736	74	136	158	787	79	146	169	695	70	129	150
12	828	69	136	158	890	74	146	170	781	65	128	149
14	914	65	133	157	988	71	143	170	862	62	125	149
16	996	62	131	157	1082	68	142	170	938	59	123	148
18	1074	60	131	156	1171	65	143	170	1011	54	123	147
20	1149	57	131	156	1258	63	143	171	1082	54	123	147
22	1222	56	127	155	1342	61	140	171	1150	52	120	146
24	1292	54	127	155	1423	59	140	171	1215	51	119	146
26	1360	52	126	155	1502	58	139	171	1279	49	118	146
28	1427	51	125	155	1579	56	138	171	1341	48	118	145
30	1491	50	124	154	1654	55	138	171	1401	47	117	145
35	1647	47	123	154	1836	52	137	171	1546	44	115	144
40	1794	45	121	153	2010	50	136	172	1683	42	114	144
45	1935	43	120	153	2176	48	135	172	1815	40	113	143
50	2071	41	119	152	2337	47	134	172	1941	39	112	143
55	2201	40	118	152	2492	45	134	172	2063	38	111	142
60	2328	39	116	152	2644	44	132	172	2181	36	109	142
65	2450	38	116	151	2790	43	132	172	2295	35	109	142
70	2570	37	116	151	2934	42	132	172	2406	34	108	141



"GROWTH STANDARDS" FOR GOATS, FEMALES

Age	Weight in pounds		
	Toggenburgs		Angoras
	Group S	Group M	
Birth	7	7	--
10 das.	12	9	5
20 "	16	11	7
30 "	20	13	9
40 "	23	16	11
50 "	27	18	13
60 "	30	20	16
70 "	33	22	18
80 "	38	24	20
90 "	43	26	22
100 "	47	28	24
110 "	52	30	26
4 Mos.	56	32	27
4½ "	61	35	29
5 "	65	37	30
5½ "	69	40	31
6 "	73	42	32
6½ "	76	44	32
7 "	78	46	33
7½ "	81	48	33
8 "	83	51	34
8½ "	85	53	34

Age	Weight in pounds		
	Toggenburgs		Angoras
	Group S	Group M	
9 Mos.	87	55	35
9½ "	89	57	35
10 "	91	60	36
10½ "	93	62	37
11 "	95	65	38
11½ "	97	68	39
12 "	99	70	40
13 "	102	75	43
14 "	105	80	
15 "	108	85	
16 "	111	89	
17 "	113	92	
18 "	115	94	
19 "	117	95	
20 "	118	96	
21 "	119	97	
22 "	120	98	
23 "	121	99	
24 "	122	100	
25 "	123	101	
26 "	124		

Fig. 20.—"Growth Standards" for three groups of female goats, as read from smoothed curves.

TABLE 12.—RELATION BETWEEN WEIGHTS OF KIDS AND MOTHERS.

(Arranged in Order of Declining % Ratio $\frac{\text{Wt. Kids}}{\text{Wt. Mother}}$.)

Goat	Weight of mother after Kidding*	No. Kids	Total weight of Kids Lbs.	Percent total weight of Kids to weight of mother	Age of mother Yrs.
Creamy	138	5	27.3	20	6
Gloria	124	4	24.8	20	4
Katinka	115	3	22.1	19	2
Carlotta	135	3	22.0	16	4
Jean	123	3	18.0	15	2
Caroline	120	3	17.5	15	3
Betty	124	2	18.0	15	2
Susanna	105	2	15.8	15	2
Colette	100	3	13.8	14	1
Rachel	125	3	17.0	14	2
Sonya	105	2	14.8	14	2
Felicia	125	2	16.3	13	7
Sonie	122	2	15.8	13	2
Cosette	101	2	13.3	13	1
Gladiolus	135	2	17.0	13	6
Glory	120	2	15.8	13	2
Cherikha	160	3	19.0	12	2
Leona	145	3	18.0	12	7
Rey Sunshine	141	2	17.0	12	4
Angelica	120	2	14.5	12	2
Meggi	115	2	13.0	11	8
Shirley	115	2	11.8	10	7
Ginevra	120	2	12.3	10	2
Pride	125	2	11.3	9	4
Sally	100	1	7.5	8	2
Elena	102	1	8.3	8	1
Karina	125	1	10.0	8	1
Diane	90	1	5.0	6	2
Ginia	130	1	8.0	6	2

*Weights of mothers were partly estimated. Mothers were weighed at various times after kidding. These data were plotted against time, and the most "reasonable" weights were estimated from the time curves.