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NUTRIENTS REQUIRED FOR DEVELOPING THE FETUS IN DAIRY CATTLE

by

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INTRODUCTION

A cow may use feed for five purposes as follows:-

1. Maintenance
2. Milk production
3. Increasing body weight
4. Growth, if not mature
5. Developing the fetus

Feeding standards have been established experimentally for all of these except fetal development. It is customary for feeders to be more liberal in feeding pregnant animals, probably due to the general belief that developing the fetus is more or less a tax upon the maternal organism. Feeders often say that cows in a lean or moderate state of flesh will drop calves larger and healthier than calves from excessively fat cows. This is thought to be due to the fact that the space for the development of the fetus is restricted

in fat animals or possibly the blood supply is reduced. The author has seen cows so lean at the time of parturition that for several days following, they were too weak to stand, yet the calves were of normal size and healthy. The mother in such cases has drawn upon the materials in the body to supply nutrients for the fetus. The amount required in such cases and in normal cases is hard to determine. In the experiments conducted at this station and reported in this thesis an attempt has been made to measure the nutrients required for fetal development by the changes occuring in the body weight of the mother. The inaccuracy in using body weights as a measure of nutrients used is recognized, yet other than the respiration caloremeter no method seemed more adequate than weighing. It is apparent that these experiments serve to demonstrate only in a practical way the nutrients required to develop the fetus.

The animals in these experiments had been in previous investigations which necessitated that the animals be farrow, also that their maintenance requirements be determined. The plans for these experiments followed and in the case of the two Jersey cows No. 27 and No. 62, each animal during the pregnant period, was given nutrients equal to her maintenance as found when farrow.

No attempt was made to control the weights. The second experiment included the Holstein-Friesian cow, No. 206, the Ayrshire cow No. 304 and the Short Horn cow No. 400. In this trial cow 400 served as a check animal. It was found in the maintenance periods that 304 required 88 per cent as much feed as 400, and 206 required 118 per cent as much as 400.

The plan of the experiment was to hold No. 400 at a uniform weight and to feed the pregnant animals, No. 304 and No. 206, a ration of the same composition and in the same proportion to No. 400 as found necessary during the maintenance period.

The subject of "Nutrients Required for Developing the Fetus in Dairy Cattle" is more readily discussed when the general principles of fetal nutrition are understood. The processes which furnish the fetal membranes with nutrients, the sources of the nutrients, and the changes produced in the maternal organism are of importance and interest in further discussion.

FETAL NUTRITION

Fetal nutrition tho a subject in itself, has many general phases which are of interest and vital importance in the study of pregnant animals.

Howell[1] discusses fetal nutrition in a general way as follows:-

"At the time of fertilization the ovum contains a small amount of nutrients in its cytoplasm. The amount, however, in the mammalian ovum is small and suffices probably only for initial stages of growth. When the ovum becomes implanted in the decidual membrane of the uterus the new material for growth must be absorbed directly from the maternal blood of the uterus. Within a short time, however, the chorionic villi begin to burrow into the uterine membrane at the point of attachment, the decidua serontina, and the placenta gradually forms as a definite organ for the control of fetal nutrition. For the purpose of understanding its general functions it is sufficient to recall that the placenta consists essentially of vascular chorionic papillae from the fetus bathed in large blood-spaces in the decidual membrane of the mother. The fetal blood and maternal

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1. Howell, - Text Book of Physiology.

blood do not come into actual contact; they are separated from each other by the walls of the fetal blood-vessels and the epithelial layers of the chorionic villi, but an active diffusion relation is set up between them. Nutritive material, protein, carbohydrates, fat and oxygen pass from the maternal to the fetal blood, and the waste products of fetal metabolism -- carbon dioxide, nitrogenous wastes, etc.; pass from the fetal to the maternal blood. The nutrition of the fetal tissue is maintained, in fact, in much the same way as if it were an actual part of the maternal organism. That material passes from the maternal blood to the fetus is a necessary inference from the growth of the fetus. The fact has also been demonstrated repeatedly by direct experiment. Madder added to the blood of the mother colors the bones of the embryo.

Salts of various kinds, sugars, drugs, etc., injected into the maternal circulation may afterwards be detected in the fetal blood. But we are far from having data that would justify us in supposing that the exchange between the two bloods is effected by the known physical processes of osmosis, diffusion and filtration. The difficulties in understanding the exchange in this case are the same as in the absorption of nourishment by

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the tissues generally. It is perhaps generally assumed that the chorionic villi play an active part in the process, functioning in fact in much the same way as the intestinal villi. This assumption implies that the epithelial cells of the villi take an active part in the absorption of the material by virtue of processes which cannot be wholly explained, but which without doubt are due to the chemical and physical properties of the substance of which they are composed. This assumption does not mean that the simpler and better understood physical properties of diffusion and osmosis are not also important. The respiratory changes of gases, the diffusion of water, salts, and sugar, may be largely controlled in this way. There are no facts at least which contradict such an assumption. The passage of fats and proteins, however, would seem to require some special activity in the chorionic tissue, which may be connected with the presence of special enzymes. Glycogen occurs in the placenta and in the tissues of the embryo during the period of most active growth. In the latter period of embryonic life, as the liver assumes its functions, the glycogen becomes more localized to this organ and disapears, except for traces, in the skin, lungs and other tissues in which it was present at first in considerable

quantities. It would appear therefore that glycogen (sugar) represents one of the important materials for the growth of the embryo, and that in the beginning at least the tissues have a glycogenetic power. ----- The body fat of the fetus at first is slight in amount, but after the six month begins to increase with some rapidity. The fat forming tissue are in full activity therefore, before birth and function doubtless in the same way as in the adult. ----- In general it is evident that for a long period the maternal organism digests and prepares the food for the embryo, excretes the wastes, regulates the condition of temperature, etc; as it does for a portion of its own substance, but as the fetus approaches term its tissues and organs begin to assume more of an independent activity, as indeed must be the preparation for the sudden change at birth".

To give further weight to Howell's statements regarding the activity of the fetal tissues and organs he sights experiments where the fetal membranes and uterus were unconnected with the central nervous system and the fetus developed normally in weight and size.

METABOLISM IN THE PLACENTA

Marshall[1] has written of the metabolic processes in the placenta as studied in the most part with

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1. Marshall - Physiology of Reproduction.

rabbits, which tho different in some ways (probably) from the metabolic processes in the cow will serve amply enough to represent the ideas which are to be presented.

IRON

In the placenta iron, fat and glycogen are metabolised for fetal use to a certain extent by the decidual cells. Ruminants seem to injest healthy and degenerated erythrocytes. It seems to be an established fact that inorganic iron is metabolized in the placenta. This form of iron can be seen, by the aid of certain stains, in the mesoblast as it approaches the decidua, at the fourteenth day, after which it increases for a short time and then gradually decreases toward the end of the pregnancy period, but at all times some can be found in the decidual cells which lie close to the fetal placenta. The presence of this iron in a large amount in the earlier stages of pregnancy and the gradual decrease during pregnancy, leads Marshall to conclude that the dissappearing of the iron is due to the absorption by the fetus. Organic iron has not been conclusively proven as playing an important part in fetal nutrition, so far as absorption by the fetus goes. Marshall, however, remarks,- "It is possible that organic

iron compounds, not shown by the Haemotoxylin stain, are absorbed and broken up, and latter appear as granules in the mesoderm". The source of this form of iron, according to the author may be haemoglobin or neucleoproteins.

FAT

Fat is found at the tenth day in the viscera, liver, heart and mid-gut, of the rabbit fetus. This is before the allantoic circulation is established, but during the most active time of the vitelline circulation. Marshall gives two ways in which the fat may reach the embryo. Fat may reach the embryo by its vessels during the vitelline circulation and also by the absorption of the trophoblast of fat-droplets contained in the giant cells of the peri-placental folds. Fat is found in the fetal placenta in the trophoblast, especially where it is in close contact with the maternal blood or decidua. In the newborn fetus fat is found chiefly in the subcutaneous tissue, and liver. The amount in these places increasing during the suckling time.

GLYCOGEN

Claude Bernard[1] demonstrated glycogen in the rabbit fetus in 1859. He gave evidence of its increase

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1. Marshall - Physiology of Reproduction.

in the fore part of pregnancy and its decrease in the latter part. This work and that of Godet, Maximow, and Chipman was corroborated by Marshall and Cramer[1]. Glycogen from the decidual cells is absorbed by the trophoblast[1]. This process is shown to be little understood. Marshall[1] states that there is a distinct relationship between the glycogen metabolism and the growth of the fetus, depending on the uses to which glycogen is put. He contributes no anabolic functions to glycogen, but believes it may be closely connected with the possibility of yielding "Bausteine" for building up the main protein of the body.

PROTEIN

In studies of the rabbit it seems to be generally accepted that large molecules of protein materials cannot be diffused and are therefore transformed before being taken up by the fetal ectoderm. Yet Lockhead[1] and Ascoli[1] have shown that haemoglobin and egg albumin pass directly into the fetal membranes. A general assumption from literature on protein metabolism in the placenta is that different species absorb different proteins directly. In some cases one or more kinds, in other cases one or more of the same or different kinds. The same protein may be absorbed direct-

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1. Marshall - Physiology of Reproduction.

ly in one species while in the other transformation takes place before the protein is used by the fetus.

Marshall[1] does not believe the processes of fetal metabolism of protein are comparable with hydrolytic processes which occur in the intestines.

CHANGES IN THE MATERNAL ORGANISM.

The maternal organism becomes pregnant thru the action of hormones, whose nature and identification are yet unknown, yet commonly believed by scientists to be present. After the maternal organism becomes pregnant the waste products of the fetus and nutriment for the fetus are extra demands upon her circulatory system. How much of a strain this adds to the mother is not known, yet it must be considerable. The sources of the nutrients demanded by the fetus is not conclusively shown but some information can be gained by Marshall's[1] discussions on them. He raises the question, "Does the mother deplete her own tissues, or is she content to transfer the unorganized substances, which are absorbed from the blood and not yet fixed as vital constituents of the protoplasm?" In insufficient nutrition the mother certainly gives up organized tissue-products, and even with a plentiful diet, a period is usually observed during which the mother must draw on her own tissue to account for the loss of nitro-

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1. Marshall - Physiology of Reproduction.

gen." He states further that the quality of the ration or food of the mother is directly concerned in the fetal growth, as three out of six rabbits aborted where the diet was rich in carbohydrates during the pregnancy period.

A study of the body weights of the mother in some cases appears to give us some idea of the effect of the fetal growth on the maternal organism. Yet in other cases it seems to be a somewhat unreliable measure. Baumm[1] found that a pregnant woman increased her body weight .650 kilo in the last month of pregnancy, exclusive of fetus and uterine substances. Zacharjewsky[1] found the body weight increased parallel with the fetal growth. Other investigators[1] have found that the mother did not increase her body weight. Marshall[1] explains this by a large variation in the water content of the tissues of the mother.

Normal, subnormal and supernormal absorption of protein is reported as occurring in the mother during pregnancy[1]. Probably this variation can be explained by a possible difference in the quality of proteins fed.

The absorption of carbohydrates during pregnancy seems on the whole decreased. Starch especially is not absorbed so readily in the stomach at this

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1. Marshall - Physiology of Reproduction.

time. Continual feeding of food high in carbohydrates may cause abortion. Bohr[1] believes the fetus is supplied with energy by combustion of carbohydrates.

Ferroni[1] has shown that the absorption of fats is increased in the intestines during pregnancy, and the increased absorption being at its' height during the rapid increase of fat in the subcutaneous tissue of the fetus.

The source of salts or metals is an unsettled problem. It is evident that part at least of the iron is derived from the haemoglobin of the mother, and Charrin[1] has stated that the reserve iron in the spleen of the mother is depleted during pregnancy. Krüger[2] has shown that the iron content of the liver and spleen of bovine foeti is about ten times as much as that in mature animals.

It has been found that calcium, phosphates and sulphates are drawn from the body of the mother, where the ration has an insufficient supply for milk production[3]. It has been estimated in the same investigation that 25 per cent of the total calcium in the body was withdrawn to supply the calcium in the milk. It seems plausable that under like conditions it would be

1. Marshall - Physiology of Reproduction.
2. Hogan - Thesis 1912.
3. Research Bul. No. 5. Wis. Exp. Station.

possible for sufficient salts to be withdrawn from the mother to supply the fetus.

REVIEW OF LITERATURE.

Literature on investigations of like character to those peported in this thesis are not available. However, a comparison of work similar in any respect is interesting and may be of value.

Experiments have been conducted in which rations from restricted sources have been used. It seems to be the concensus of opinion that pigs will not grow and reproduce normally when the ration is products of the corn plant alone. Yet Hart, McCollum, Steenback and Humphrey[1] have shown that heifers will grow and reproduce normally on such a ration.

Experimental data are not available, so far as the author has been able to find, showing whether or not pigs will reproduce normally when fed a ration restricted to products of the wheat plant alone, yet it seems to have been demonstrated that they will grow and fatten readily, when wheat serves as the only grain in the ration[2]. While in the same Wisconsin experiment where the corn plant furnished the ration for a group of heifers, during growth and reproduction, another group was fed a ration restricted to products of the wheat plant. The authors write, "Animals receiving their

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1. Research Bul. 17, Wis. Exp. Sta.,
2. Nebraska Sta., Bul. 75.

nutrients from the wheat plant were unable to perform normally and with vigor all the above physiological processes". In the two years that the above group was fed the wheat ration, all calves dropt by them were either still-births or died in a comparatively short time. The wheat fed animals were then changed to the corn ration and within a year marked improvements in the size of offspring and milk production were noted.

Chittenden writes in his "Nutrition of Man", "Thus of ninety three rats born of meat-fed parents only nineteen were alive at the end of two months, while of ninety-seven young, born of bread-and-milk-fed rats, eighty-two were alive and in apparent health at the end of the same period".

These experiments seem to indicate that reproduction is influenced, to a certain extent at least, by the species, when the ration is from a restricted source. They also indicate that the quality as well as the quantity of feed of the mother may have an influence upon the vigor of the young. The study of the physiological effect of rations, is in its infancy, and where that phase of nutrition has been studied, the results, with present knowledge of protein complex , are difficult to explain.

A study of the chemical composition of a full term bovine fetus was made at this station in 1912[1].

	Full term Fetus Hogan	Fetus 185 days
Water	76.21	84.80
Fat	3.18	2.36
Protein	17.46	10.46
Ash	3.55	1.78
P_2O_5	0.85	0.28

The above comparison as made by Hogan, shows a higher per cent of water and a lower per cent of ash in the fetus of 185 days. This would seem to indicate that a more rapid development takes place in the last three months of uterine growth than in the previous 185 days. It seems plausible then that the demand for nutrients for development in the later stages of fetal growth would be the greater.

Hogan's work shows the new born calf to be about 76 per cent water, thus leaving in a fifty pound calf a comparatively small amount of solids to be obtained from the maternal circulation.

Hogan[1] and Vannatta[2] made analyses of the ash

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1. Hogan - Thesis 1912.
2. Vannatta - Thesis 1911.

of full term bovine foeti. Both foeti were from the same mother and the methods of analysis were very similar. The fetus analyzed by Hogan was some larger than that analyzed by Vannatta but the data are very comparable.

	Bovine Fetal Ash % (Hogan)	Bovine Fetal Ash % (Vannatta)
K_2O	5.716	4.653
Na_2O	5.956	6.226
Cl	2.239	1.949
CO_2	0.749	0.191
SiO_2	0.303	0.639
SO_3	3.114	1.107
MgO	1.750	2.074
P_2O_5	38.462	39.382
Fe_2O_3	0.966	0.983
CaO	41.073	43.113
Total	100.328	100.317
Deduct O =Cl	.516	.440
Total	99.812	99.877

It is readily seen that calcium and phosphorous make up the greater part of the ash of the bovine fetus, yet if we compare the per cent of iron in the ash of the bovine fetus with that in the fat

ox, as reported by Lawes and Gilbert[1] as being 0.41 per cent, we find that the percentage of iron in the new born calf is more than twice as much.

Another striking comparison in regards the iron in the new born calf is made by Krüger, as reported by Hogan,[2] in which he shows the iron content of the liver cells, to be about ten times that of the mature animal.

Why there should be or is such an amount of iron in the new born calf compared with the mature animal seems to be an unsettled question. Hammersten[3] writes, "The feotal liver cells bring an abundance of iron in the world, to be used up, within a certain time, for a purpose not well understood".

As stated before, there is no literature on work parallel with the experiments reported here, and it becomes apparent that the literature on sources of various elements found in the fetus, is lacking as well. However, in an experiment conducted by Hart, McCollum and Humphrey[4] on the role of ash constituents of wheat bran in the metabolism of herbivora, they found that "When calcium or phosphorous were deficient in quantity

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1. Lawes and Gilbert (Phil. Trans.) 1883.
2. Hogan - Thesis 1912.
4. Research Bul. No. 5, Wis. Exp. Station.
3. Hammersten - Physiological Chemistry.

in the food, the skeleton tissues appeared to be ready sources of supply". The author's work is corroborated by the work of two of the same men on pigs[1], from which they conclude "the skeleton tissues can vary its ash content within quite wide limits, there by acting as a source of supply over considerable periods of time for certain ash constituents that may be deficient in quantity in the food".

It seems plausible to expect an animal to draw upon the tissues of the bones to furnish the ash constituents lacking in the ration and needed for fetal development.

Hart, Steenbock and Fuller[2] studied the influence of high lime intake on the skeleton formation in the pig fetus and they conclude, "High calcium rations, had no effect whatever during a single gestation period on the size or calcium content of the skeleton of the fetus. The skeleton is not increased in any dimensions by a wide variation in the amount of calcium fed the mother".

The above statement would seem to indicate that the nutritive membranes of the fetus have a regulative power as to the amount of calcium the fetus

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1. Research Bul. No. 21, Wis. Exp. Station.
2. Research Bul. No. 30, Wis. Exp. Station.

may receive.

In the above experiment different feeds were analyzed for the principle ash constituents. In the table below it is readily seen that the legumes have a high per cent of calcium, and due to this fact Hart, Sttenbock and Fuller conclude that where legumes are fed there is little danger of osteomalacia.

Feed	CaO	P_2O_5	MgO
Corn	.026	.623	.219
Bran	.160	3.040	1.048
Oilmeal	.640	1.860	.770
Alfalfa	4.310	.610	.520
Pea vines	1.887	.412	.412
Silage	.280	.110	.220

In the Royal Zootechnical Institute of Reggio Emilia[1] observations were made on the increase of weight in cows during nine months of gestation. The weights increased up to the end of the eighth month but diminished at the end of the ninth month of gestation. In comparing the weights of the 18 cows

1. International Institute of Ag. Feb. Bul. p. 471.

during the month after calving with the weights when farrow they found 11 out of the 18 increased from 11 to 77 pounds, 2 were stationary and 5 decreased. The author found that 10 cows decreased in weight the first month of gestation.

The same institution reports observations on the weight of the fetus at birth in relation to the live weight of the mother. The figures show that 20 cows (9 Simmenthal, 11 Schwyz) having an average weight of 1326 pounds decreased in weight on an average 167.5 pounds during parturition. This includes, calf, amniotic fluids and afterbirth. The above figures show a reduction of about 14.28 per cent of the live weight of the mother before calving. The loss in weight varied from 110 pounds to 209.4 pounds. The calves averaged 94.5 pounds at birth, or about 7.14 per cent of the mothers' weight after calving.

The review of the above observations reports that the observations would be continued, but does not mention the rations or conditions under which the observations were taken.

Portions of the literature reviewed here may seem ambiguous in their application to the problem at

hand, however, it will be seen later that the theoretical application of the data to be presented depends upon the results of the experiments reported.

FEED AND MANAGEMENT

The experiments which supplied the data for this thesis were planned and directed by Prof. C. H. Eckles. The work of the author as here presented consists in working out and studying this data.

The grain mixture in the rations was the standard grain mixture used at this station. It consists of 4 parts ground corn, 2 parts wheat bran and 1 part oilmeal.

The roughage fed to cows 27 and 62 was corn silage and alfalfa hay. During periods when silage and alfalfa hay were not available green corn and green cowpeas were fed. The proportions of the rations were 4 parts corn silage, 1 part alfalfa hay and 1 part grain mixture.

Cows 206, 304 and 400 received the above ration while on maintenance[1] but during the pregnant periods the corn silage was removed from the ration, because it was found to be difficult to keep a supply on hand at all times. This left the ration in the proportion of 3 parts alfalfa hay and 1 part grain mixture.

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1. Research Bul. No. 7, Mo. Exp. Sta.

All feed was sampled and analyzed by the Agricultural Chemistry Department. When corn silage was fed, a continuous sample was taken by placing a small quantity from each day's feed in a closed glass jar, in which chloroform was present to prevent decomposition. At the end of each 10 days this sample was reduced to the air dry basis and when several of these air dry samples were ready a chemical analysis was made of the composite.

The taking of data in these experiments for the pregnant periods began at the time of breeding and continued until parturition. The records are compiled in ten day periods. The animals were stabled at night and during inclement weather. A dry lot was accessable for exercise. Weights were taken each morning, between seven and eight o'clock, after feeding and before watering.

TABLE I

Data Concerning Cows Used.

Herd No.	Breed	Age Year	Age Mo.	No. Lact. Periods	Av. Yield Milk	Av. Yield Fat
27	Jersey	6	7	6	7,634	399.5
62	Jersey	5	9	4	2,503	122.0
206	Holstein	9	1	6	9,763	308.0
304	Ayrshire	4	11	3	6,582	261.0
400	Shorthorn	8	1	4	4,694	197.0

Table I furnishes general data regarding the animals used.

TABLE II.

Cow	Date bred	Date of Calving	No. of days Pregnant
62	Feb. 27, '09	Nov. 29, '09	276
27	Apr. 11, '09	Jan. 30, '10	294
304	June 21, '12	Apr. 1, '13	284
206	Nov. 2, '12	Aug. 10, '13	281

Table II shows the dates of breeding and parturition together with the number of days each cow was pregnant.

Digestion trials were made on all the animals used while on maintenance (1 and 2), and in the case of cows 206, 304 and 400, the digestion trials were repeated near the end of pregnancy, to determine if pregnancy exerts any appreciable influence upon the digestion coefficients. It was thought that the length of time for these later digestion trials could be shorter than usual, in as much as the animals had been receiving the same ration for a relatively long period of time. The results indicated clearly that the two day period was too short for accurate results. A single additional passage of dung could make the results entirely inaccurate. The data from these trials was discarded for this reason.

As stated before Cows 27 and 62 were given the same amount of nutrients per day during pregnancy as they had previously used for maintenance. After Cow 62 completed her lactation period following the pregnant period, covered by the data included in this study, she was again placed on maintenance. This period of maintenance together with that prior to pregnancy covered the same months as did the pregnant period. The object being to use her maintenance periods

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1. Research Bul. No. 5, Mo. Exp. Sta.,
2. Research Bul. No. 7, Mo. Exp. Sta.,

as a check on her pregnant period.

After observing the results of the experiment conducted with Cows 27 and 62 it was planned to continue the experiment with cows 206, 304 and 400. As stated before Cow 400 was to serve as a check animal. That is Cow 400 was to receive feed, equal to the daily requirement, during her maintenance period, and Cow 304 was to receive 88 per cent of the same amount and Cow 206 was to receive 118 per cent of that amount.

The above three cows received slightly more nutrients during the experiment than they did while on maintenance. This was due probably to the change in the composition of the feeds in the ration.

EXPERIMENT.

Calculating Energy Value -- The method used in calculating the energy value of the feed consumed by the animals in these experiments is explained on pages 128 and 129 of Research Bulletin No. 7, of this Experiment Station.

Per Cent "Amides" -- The per cent amides assumed for the different feeds is the same as reported in the above mentioned bulletin with the exceptions of green cowpeas, which were assumed to be the same as green alfalfa and 'pea and oat hay' which was figured by taking the per cent of amides used for cowpea hay and oat hay, averaging these and using the result as the per cent of amides in pea and oat hay. The hay was equal portions of peas and oats, which makes the above results relatively close to the actual per cent of amides in pea and oat hay.

Digestion Coefficients -- The digestive coefficients were figured from the digestion trials reported in Research Bulletins No. 4 and No. 7 of this Station. The average digestion coefficients used are found in Table 5, which was taken from Jordan's "The Feeding of Animals". The per cent of the aver-

age which each animal's digestion coefficients equalled is found in Table 16.

Determining Weight After Calving -- The weight after calving was determined by taking the average weight of the mother for the ten days prior to parturition; from this the weight of the fetus, about 30 pounds for fluids and 18 to 19 pounds for placenta were deducted. It was found that the weight of placentae and fluids did not vary enough where calves of from 75 to 90 pounds were dropt to make the above method inaccurate. The above method is certainly the most accurate that could have been applied in these experiments.

Experiment I.

Animals Used -- As stated previously the animals used in this experiment were the two Jersey cows Nos. 27 and 62. As stated on page 27 these animals were given the same amount of nutrients per day during gestation as they had previously used for maintenance.

Tables -- Tables 3 and 4 give a record by ten day periods of the feed consumed by each animal.

Tables 6 and 7 give a record by ten day per-

TABLE 3.

POUNDS FEED CONSUMED BY 27 WHILE PREGNANT.

Period No.	Period Ending	Grain	Hay	Silage
	1909			
17	April 17	22.4	22.4	89.6
18	" 27	32.0	32.0	128.0
19	May 7	32.0	32.0	128.0
20	" 17	32.0	32.0	128.0
21	" 27	32.0	32.0	128.0
22	June 6	32.0	32.0	128.0
23	" 16	32.0	32.0	128.0
24	" 26	32.0	32.0	128.0
25	July 6	32.0	32.0	128.0
26	" 16	32.0	32.0	115.2
27	" 26	32.0	32.0	128.0
28	Aug. 5	32.0	32.0	128.0
29	" 15	32.0	32.0	25.6
30	" 25			(1)83.2
30	" 25	32.0	32.0	122.0
31	Sep. 4	32.0	32.0	128.0
32	" 14	32.0	32.0	89.6
				(2)25.6
33	" 24	32.0	32.0	126.2
34	Oct. 4	32.0	41.6	51.2
35	" 14	32.0	80.0	----
36	" 24	32.0	75.2	(3)22.8
37	Nov. 3	32.0	32.0	150.0
38	" 13	32.0	32.0	150.0
39	" 23	32.0	32.0	150.0
40	Dec. 3	32.0	32.0	150.0
41	" 13	32.0	32.0	150.0
42	" 23	32.0	32.0	150.0
	1910			
43	Jan. 2	32.0	32.0	140.0
44	" 12	32.0	32.0	138.75
45	" 22	32.0	32.0	148.75
46	" 29	22.4	22.4	103.25
	Total	940.8	1041.6	3589.75

1. Began feeding green corn
2. " " green cowpea hay
3. " " silage.

TABLE 4.

POUNDS FEED CONSUMED BY 62 WHILE PREGNANT.

Period No.	Period Ending	Grain	Hay	Silage
	1909			
19	Mar. 8	28.0	28.0	112.0
20	" 18	28.0	28.0	112.0
21	" 28	28.0	28.0	112.0
22	Apr. 7	28.0	28.0	112.0
23	" 17	28.0	28.0	112.0
24	" 27	28.0	28.0	112.0
25	May 7	28.0	28.0	112.0
26	" 17	28.0	28.0	112.0
27	" 27	28.0	28.0	112.0
28	June 6	28.0	28.0	109.5
29	" 16	28.0	28.0	112.0
30	" 26	28.0	28.0	112.0
31	July 6	28.0	28.0	112.0
32	" 16	28.0	28.0	100.8
33	" 26	28.0	28.0	112.0
34	Aug. 5	28.0	28.0	112.0
35	" 15	28.0	28.0	22.4
				(1)76.8:
36	" 25	28.0	28.0	112.0
37	Sept. 4	28.0	28.0	112.0
38	" 14	28.0	28.0	78.4
				(2)22.4
39	" 24	28.0	28.0	113.8
40	Oct. 4	28.0	36.4	44.8
41	" 14	28.0	70.0	0----
42	" 24	28.0	67.2	(3)21.3
43	Nov. 3	28.0	28.0	150.0
44	" 13	28.0	28.0	135.75
45	" 23	28.0	28.0	150.0
46	" 29	16.8	16.8	90.0
Total		772.8	862.4	2907.95

1. Began feeding green corn
2. " " gowpea hay
3. " " Silage.

TABLE 5

AVERAGE DIGESTION COEFFICIENTS.

Feed	Protein	Crude Fibre	N. Free Extract	Fat
Corn	67.9	58.0	94.6	92.1
Bran	77.8	28.6	69.4	68.0
Oilmeal	88.8	57.0	77.6	88.6
Alfalfa	72.0	46.0	69.2	51.0
Corn Silage	49.3	66.7	68.6	80.0
Green Corn	54.0	51.0	75.0	78.0
Green Alfalfa	74.0	43.0	72.0	39.0
Green Clover	66.0	49.0	71.0	61.0
Green Cowpeas	76.0	60.0	80.0	59.0
Green Oats	77.0	31.0	77.0	89.0

TABLE 6.

COW 27

No. of Period	Nutrients Digested Daily			Therm Value	Av. Period Wt.
	Protein	Carbohy-drates	Fat		
17	.765	5.721	.227	6.620	895.7
18	.765	5.721	.227	6.620	902.1
19	.767	5.727	.205	6.571	907.2
20	.768	5.729	.196	6.550	908.6
21	.768	5.729	.196	6.550	911.1
22	.768	5.729	.196	6.550	921.2
23	.768	5.729	.196	6.550	923.5
24	.768	5.729	.196	6.550	923.6
25	.768	5.729	.196	6.550	923.2
26	.747	5.506	.190	6.303	919.9
27	.760	5.746	.196	6.560	935.4
28	.760	5.746	.196	6.560	940.1
29	.725	5.444	.179	6.146	944.7
30	.775	5.601	.176	6.313	948.1
31	.781	5.714	.177	6.425	962.3
32	.804	5.480	.173	6.233	971.5
33	.962	5.754	.173	6.688	991.2
34	.877	4.668	.154	5.467	1038.1
35	1.143	5.214	.158	6.005	1020.0
36	1.114	5.373	.162	6.163	1049.8
37	.800	5.634	.153	6.316	1067.0
38	.800	5.634	.153	6.316	1071.0
39	.800	5.634	.153	6.316	1048.5
40	.800	5.634	.153	6.316	1030.2
41	.800	5.634	.153	6.316	1041.5
42	.800	5.634	.153	6.316	1058.0
43	.791	5.478	.151	6.158	1055.7
44	.790	5.459	.150	6.137	1057.5
45	.799	5.614	.153	6.296	1055.5
46	.760	4.903	.141	5.575	1067.6

TABLE 7.

COW 62

No. of Period	Nutrients Digested Daily[1] Protein	Carbohy-drates	Fat	Therm Value	Av. Period Weight
19	.666	4.839	.203	5.653	917.1
20	.666	4.839	.203	5.653	925.0
21	.666	4.839	.203	5.653	923.7
22	.666	4.839	.203	5.653	921.1
23	.666	4.839	.203	5.653	924.4
24	.666	4.839	.203	5.653	918.4
25	.668	4.843	.183	5.607	924.5
26	.669	4.845	.176	5.594	929.2
27	.669	4.845	.176	5.594	935.9
28	.666	4.800	.175	5.546	936.4
29	.669	4.845	.176	5.594	937.9
30	.669	4.845	.176	5.594	943.7
31	.669	4.845	.176	5.594	943.4
32	.652	4.656	.171	5.384	944.5
33	.662	4.858	.176	5.599	953.9
34	.662	4.858	.176	5.599	955.1
35	.646	4.776	.163	5.451	953.7
36	.680	4.828	.160	5.483	952.7
37	.680	4.828	.160	5.483	960.3
38	.702	4.636	.156	5.313	958.8
39	.847	4.930	.158	5.727	973.6
40	.765	3.946	.139	4.649	989.8
41	.994	4.396	.142	5.127	985.1
42	.984	4.607	.145	5.332	1000.1
43	.714	5.027	.144	5.666	1019.5
44	.702	4.815	.140	5.448	996.0
45	.714	5.027	.144	5.666	992.2
46	.711	5.030	.145	5.667	980.0

TABLE 8.

COW 62

WHILE FARROW

Period Ending	Nutrients Digested Daily			Therm Value	Av. Weight
	Protein	Carbohydrates	Fat		
1911					
Apr. 27	.890	5.627	.273	6.865	897
May 7	.890	5.627	.273	6.865	897
" 17	.869	5.507	.266	6.709	902
" 27	.943	5.008	.272	6.146	881
June 6	1.101	4.876	.305	6.118	885
" 16	1.176	4.769	.319	6.217	887
" 26	1.303	5.216	.360	6.858	901
July 6	1.259	4.999	.354	6.611	910
" 16	1.300	5.167	.371	6.857	910
" 26	.972	4.355	.268	5.538	893
Aug. 5	.973	4.371	.265	5.547	895
" 15	1.024	4.506	.282	5.753	909
" 25	.942	4.231	.259	5.388	909
Sept. 4	.918	4.177	.252	5.313	904
" 14	.906	5.447	.274	6.526	905
" 24	.756	5.076	.267	6.045	908
Oct. 4	.756	5.076	.267	6.045	907
" 14	.756	5.076	.267	6.045	917
" 24	.756	5.076	.267	6.045	904
Nov. 3	.782	5.247	.275	6.241	907
" 13	.756	5.076	.267	6.045	910
" 23	.756	5.076	.267	6.045	914
Dec. 3	.756	5.076	.267	6.045	922

iods of the daily digestible nutrients, energy value and weights of the animals while on this experiment.

Table 8 gives a record by ten day periods of the daily digestible nutrients, energy value and weights of Cow 62 for her maintenance periods which cover the same months as the last 23 periods of her gestation period.

<u>Condition of animals</u> -- To ascertain what condition Cows 27 and 62 maintained during the experiment one only needs to study Table 19, in which is shown that Cow 27 gained 48 pounds and Cow 62 lost 17 pounds. These weights show that the animals were in normal condition at the close of the experiment and nothing indicative of the reverse was noted thruout the experiment.

<u>Weight after Calving</u> -- Table 19 gives the weight of the animals after calving. It is reasonable to expect a variation of from 15 to 30 pounds to fall within the limits of experimental error. This was shown to be a fact in the case of Cow No. 62. This animal was weighed at different intervals during parturition and all feces, fluids, placenta and the

calf were weighed and credited to the weight after calving. It was found that an amount equal to over 50 per cent of the weight of the calf could not be accounted for. In view of this fact and what we know of variations in body weight in comparatively short periods of time, it seems that an error of from 15 to 30 pounds on a thousand pound animal might easily be made on an animal during parturition. Granting this, we find that these two animals have performed strikingly similar in this experiment. When we consider the weight of the calves Cow 27 has gained more than Cow 62.

Comparison of Nutrients During Gestation and Maintenance -- In Table 18 a comparison is made of the average daily digestible nutrients and energy value during gestation and while on maintenance. From these data it is seen that both animals have produced the foeti and maintained normal weights on less feed than they used for maintenance when farrow.

This does not necessarily mean that the growth of the fetus exerts no tax upon the maternal organism. It might rather indicate that the animal used her feed more economically during pregnancy, or it might indicate that the physiological strain upon the

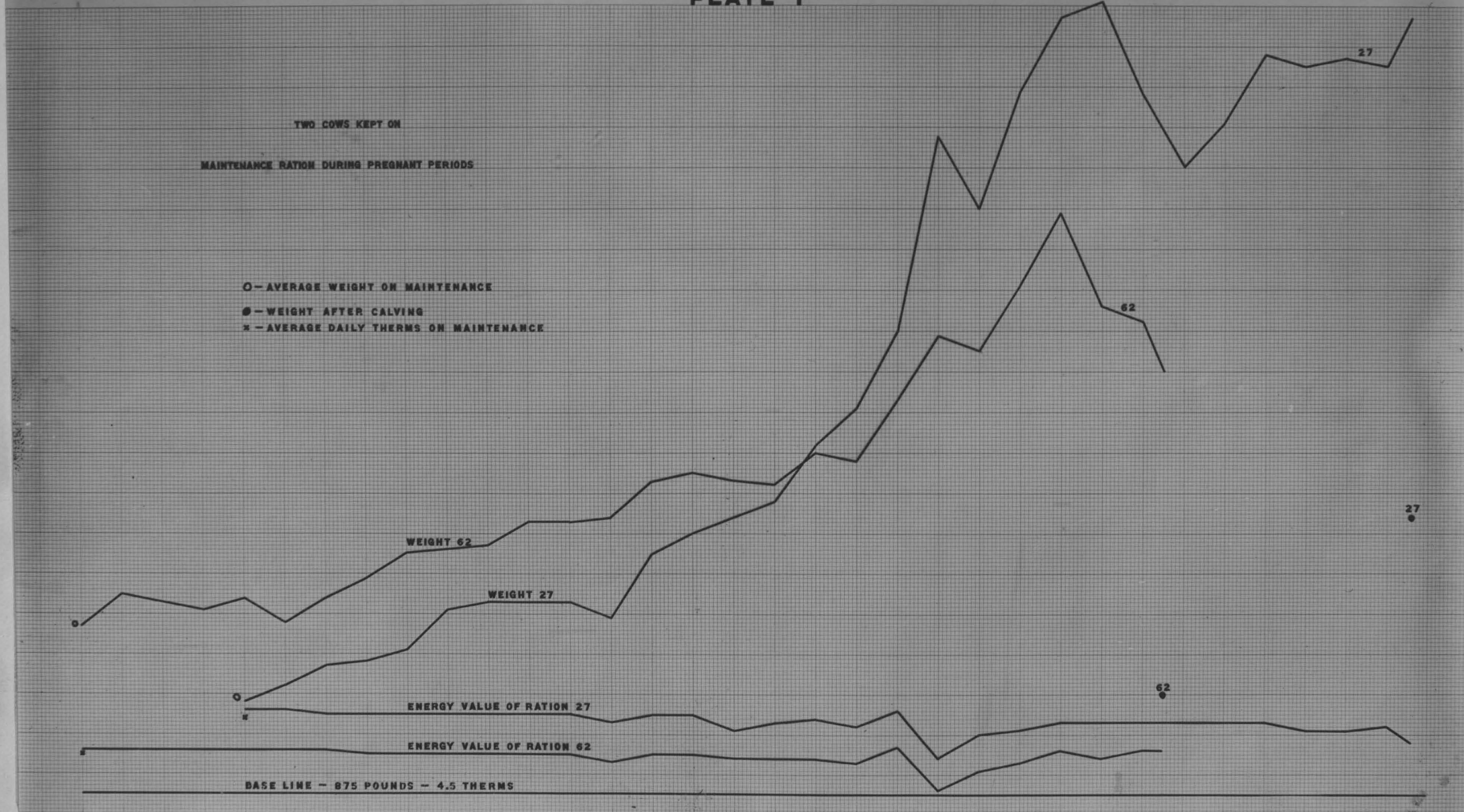
mother cannot be measured by changes in her body weight. Yet it might be that pregnancy causes the animal to function abnormally under these conditions.

As stated before it was planned to determine whether or not the feed was used more economically during pregnancy, but due to factors already mentioned the data could not be used.

Plate I which is plotted from the last two columns of Tables 6 and 7 shows that Cows 27 and 62 made gradual gains in body weight up to the latter part of the eighth month, after which there was a tendency to loose weight. From this plate can be seen that the therm curves did not raise with the weight curves. This when taken into account with other facts already presented shows that these two animals did not require extra feed for developing the feoti.

Maintenance and Gestation Requirement For The Same Months of the Year -- It was thought that the season of the year might have some influence upon the results obtained in Experiment I. As previously stated, Cow 62 was fed a maintenance ration following her lactation period at the close of this experiment.

PLATE 1


TWO COWS KEPT ON
MAINTENANCE RATION DURING PREGNANT PERIODS
O — AVERAGE WEIGHT ON MAINTENANCE
● — WEIGHT AFTER CALVING
x — AVERAGE DAILY THERMS ON MAINTENANCE
27
62
WEIGHT 62
WEIGHT 27
27
62
ENERGY VALUE OF RATION 27
ENERGY VALUE OF RATION 62
BASE LINE — 875 POUNDS — 4.5 THERMS

This maintenance period together with the one prior to gestation covered the same months of her gestation period.

Plate 2, plotted from the last two columns of Table 8 and the last two columns of Table 7 from the 24th period to the 46th shows strikingly the facts regarding the above hypothesis.

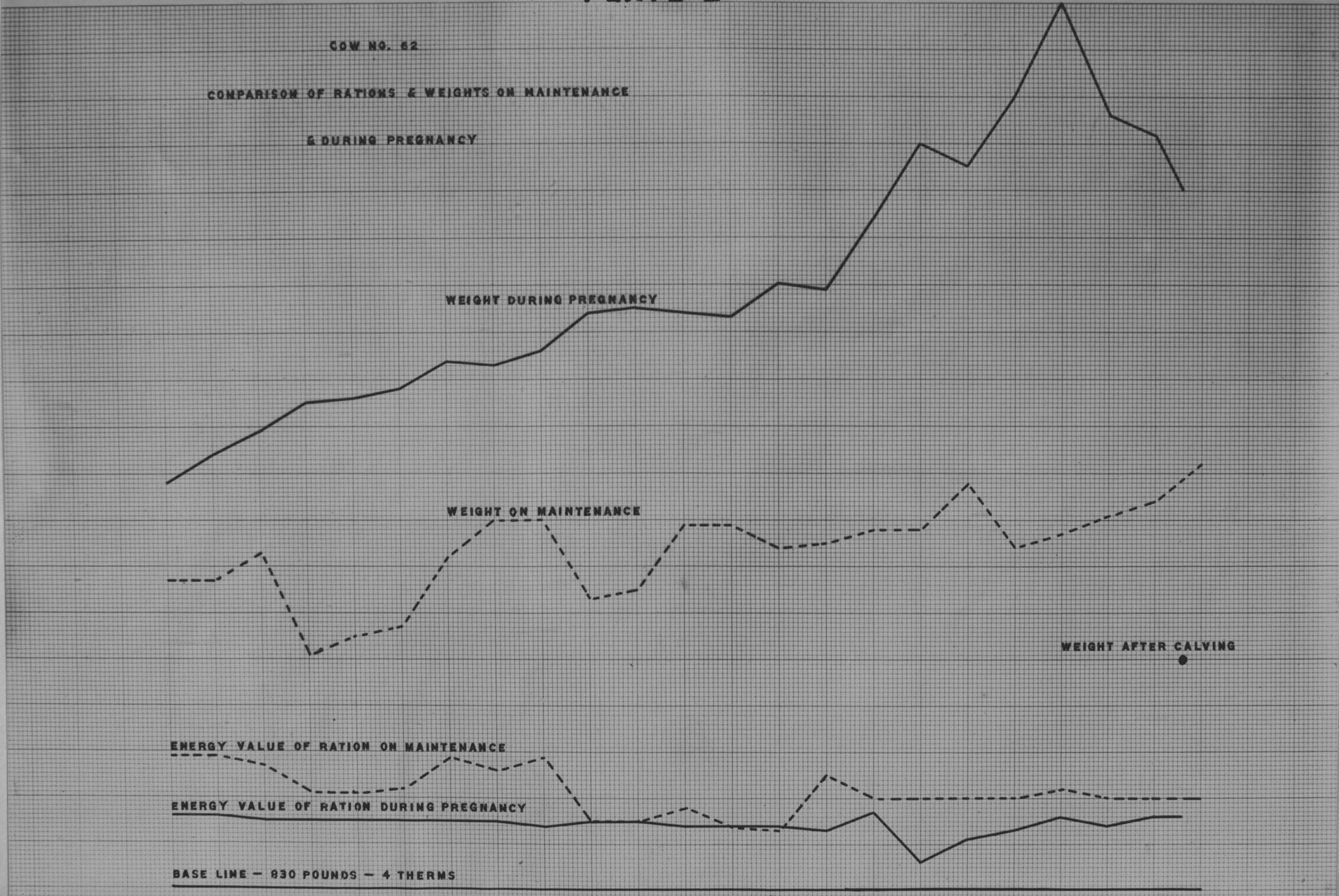
The broken lines representing the body weights and energy value of the feed while on maintenance fall between the solid lines representing the body weights and energy value of the feed while pregnant. This graphical presentation of the data is strengthened by the data of Table 9 which shows the total nutrients, energy values and average weights of the two periods.

TABLE 9.

Condition	Protein	Carbohydrates	Fat	Therms	Average Weight
Farrow	225.40	1149.62	65.37	1418.67	903.6
Pregnant	161.76	1096.41	37.02	1341.03	999.3

It is readily seen that Cow 62 received less digestible nutrients and maintained a higher average

PLATE 2


COW NO. 62
COMPARISON OF RATIONS & WEIGHTS ON MAINTENANCE
& DURING PREGNANCY
WEIGHT DURING PREGNANCY
WEIGHT ON MAINTENANCE
WEIGHT AFTER CALVING
ENERGY VALUE OF RATION ON MAINTENANCE
ENERGY VALUE OF RATION DURING PREGNANCY
BASE LINE — 830 POUNDS — 4 THERMS

weight during gestation than she did while on maintenance. She received .337 therms daily less while pregnant than when farrow and on maintenance. It is a well known fact that an animal will maintain a certain weight on less feed after being on maintenance for awhile. This factor does not enter into our problems as reported in this thesis because it was considered before the work was started and the maintenance data was not used until the animal was adjusted to conditions. Taking everything into consideration, the data on Cow 62 shows conclusively that it required no extra feed nor loss in weight to produce the fetus.

As stated before, there is no attempt made to prove that changes in the weight of the maternal organism represent the tax upon the mother in a physiological way. Yet these data show that if the maintenance requirement of the mother was accurately determined, and it is believed that such is the case, the growth of the fetus was not made by an extra amount of feed being fed the mother during gestation.

Experiment II.

Animals Used -- The animals used in this experiment were the Holstein Cow 206, The Ayrshire Cow 304, and the Dairy Shorthorn Cow 400. As stated on page 28 of this thesis, after observing the results of the foregoing experiment it was planned to continue the experiment with the above named animals. Cow 400 was to serve as a check animal. That is, she was to receive feed equal to her maintenance requirement and be held at a uniform weight, Cow 304 was to receive 88 per cent of the amount of feed given Cow 400 and Cow 206 was to receive 118 per cent of the same amount.

As previously stated these three animals received slightly more nutrients during this experiment than while on maintenance. This was probably due to changes in the composition of the feed.

Tables -- Tables 10, 11, and 12 give a record of the feed consumed by ten day periods of these three animals.

Tables 13, 14 and 15 give a record by ten day periods of the daily digestible nutrients, energy values and weights of these three animals.

TABLE 10.

POUNDS OF FEED CONSUMED BY 206 WHILE PREGNANT.

Period No.	Period Ending	Grain	Hay
	1912		
14	Nov. 7	22.0	66.0
15	" 17	44.0	132.0
16	" 27	44.0	132.0
17	Dec. 7	44.0	132.0
18	" 17	44.0	132.0
19	" 27	43.0	129.0
	1913		
20	Jan. 6	42.0	126.0
21	" 16	40.2	120.6
22	" 26	39.8	119.4
23	Feb. 5	38.0	114.0
24	" 15	38.0	114.0
25	" 25	38.0	114.0
26	Mar 7	38.0	114.0
27	" 17	38.0	114.0
28	" 27	38.0	114.0
29	Apr. 6	38.0	114.0
30	" 16	38.0	114.0
31	" 26	38.0	114.0
32	May 6	38.0	114.0
33	" 16	39.2	117.6
34	" 26	40.0	120.0
35	June 5	40.0	120.0
36	" 15	40.0	120.0
37	" 25	40.0	120.0
38	July 5	40.5	121.5
39	" 15	41.0	123.0
40	" 25	30.8	85.2
41	Aug. 4	48.4	145.2
42	" 10	25.4	83.3
Total		1128.3	3384.8

TABLE 11.

POUNDS FEED CONSUMED BY 304 WHILE PREGNANT.

No. of Period	Period Ending	Grain	Hay
	1912		
1	June 30	33.6	100.8
2	July 10	34.0	102.0
3	" 20	34.0	102.0
4	" 30	34.8	104.4
5	Aug. 9	35.0	105.0
6	" 19	35.0	105.0
7	" 29	35.0	105.0
8	Sept 8	35.0	105.0
9	" 18	34.8	104.4
10	" 28	34.0	102.0
11	Oct. 8	34.0	102.0
12	" 18	33.2	99.6
13	" 28	32.7	98.1
14	Nov. 7	32.0	96.0
15	" 17	32.0	96.0
16	" 27	32.0	96.0
17	Dec. 7	32.0	96.0
18	" 17	32.0	96.0
19	" 27	31.9	94.5
	1913		
20	Jan 6	32.0	94.5
21	" 16	30.2	90.6
22	" 26	29.8	89.4
23	Feb. 5	28.0	84.0
24	" 15	28.0	84.0
25	" 25	28.0	84.0
26	Mar. 7	28.0	84.0
27	" 17	28.0	84.5
28	" 27	28.0	84.0
29	" 31	11.2	33.6
Total		908.2	2722.4

TABLE 12.

POUNDS FEED CONSUMED BY 400 ON MAINTENANCE.

Period No.	Period Ending		Grain	Hay
	1912			
1	June	30	41.0	123.0
2	July	10	40.1	120.3
3	"	20	40.0	120.0
4	"	30	40.0	120.0
5	Aug.	9	39.2	117.3
6	"	19	39.0	117.0
7	"	29	39.0	117.0
8	Sept.	8	39.0	117.0
9	"	18	39.0	117.0
10	"	28	39.0	117.0
11	Oct.	8	39.0	117.0
12	"	18	38.2	114.0
13	"	28	37.7	113.1
14	Nov.	7	37.0	111.0
15	"	17	37.0	111.0
16	"	27	37.0	111.0
17	Dec.	7	37.0	111.0
18	"	17	37.0	111.0
19	"	27	36.0	108.0
	1913			
20	Jan.	6	35.0	105.3
21	"	16	34.1	102.3
22	"	26	33.8	101.4
23	Feb.	5	32.0	95.9
24	"	15	32.0	95.9
25	"	25	32.0	96.0
26	Mar	7	32.0	96.0
27	"	17	32.0	96.0
28	"	27	32.0	96.0
29	Apr.	6	32.0	96.0
30	"	16	32.0	96.0
31	"	26	32.0	96.0
32	May	6	32.2	96.6
33	"	16	34.0	102.0
34	"	26	34.0	102.0
35	June	5	34.0	102.0
36	"	15	34.0	102.0
37	"	25	34.0	102.0
38	July	5	35.0	105.0
39	"	15	36.0	108.0
40	"	25	36.0	108.0
41	Aug.	4	36.0	108.0
42	"	14	36.0	108.0
Total			1503.3	4509.7

TABLE 13.

COW 206

No. of Period	Nutrients Digested Daily: Protein	Carbohy-drates	Fat	Therm Value	Av. Weight
14	1.742	9.047	.238	9.620	1327
15	1.742	9.055	.238	91668	1341
16	1.742	9.055	.238	9.668	1350
17	1.742	9.055	.238	9.668	1360
18	1.742	9.055	.238	9.668	1370
19	1.702	8.842	.232	9.421	1373
20	1.463	8.637	.227	9.205	1379
21	1.592	8.266	.218	8.809	1367
22	1.576	8.183	.216	8.719	1363
23	1.504	7.811	.206	8.322	1366
24	1.504	7.811	.206	8.322	1365
25	1.504	7.811	.206	8.322	1353
26	1.504	7.811	.206	8.322	1357
27	1.504	7.811	.206	8.322	1366
28	1.504	7.811	.206	8.322	1364
29	1.504	7.811	.206	8.322	1351
30	1.504	7.811	.206	8.322	1364
31	1.504	7.811	.206	8.322	1399
32	1.344	8.066	.196	8.310	1388
33	1.387	8.325	.203	8.577	1396
34	1.415	8.493	.207	8.747	1399
35	1.415	8.493	.207	8.747	1413
36	1.415	8.493	.207	8.747	1415
37	1.415	8.487	.210	8.748	1412
38	1.431	8.541	.245	8.888	1415
39	1.449	8.650	.248	9.001	1420
40	1.030	6.133	.184	6.376	1398
41	1.710	10.208	.293	10.620	1397
42	1.590	9.689	.260	9.826	1400

TABLE 14.

COW 304

No. of Period	Nutrients Digested Daily: Protein	Carbohydrates	Fat	Therm Value	Av. Period Weight
1	1.323	6.529	.330	7.509	962
2	1.339	6.603	.334	7.594	987
3	1.339	6.603	.334	7.594	987
4	1.371	6.770	.341	7.784	1002
5	1.379	6.827	.343	7.846	994
6	1.379	6.827	.343	7.846	1007
7	1.379	6.827	.343	7.846	1012
8	1.401	6.897	.284	7.750	1012
9	1.423	6.963	.195	7.566	983
10	1.391	6.775	.191	7.363	992
11	1.391	6.775	.191	7.363	1006
12	1.358	6.641	.186	7.219	1019
13	1.338	6.541	.173	7.082	1028
14	1.306	6.400	.180	6.952	1013
15	1.306	6.400	.180	6.952	1026
16	1.306	6.400	.180	6.952	1033
17	1.306	6.400	.180	6.952	1047
18	1.306	6.400	.180	6.952	1066
19	1.292	6.330	.179	6.884	1063
20	1.293	6.337	.179	6.893	1080
21	1.235	6.041	.170	6.565	1086
22	1.220	5.962	.167	6.481	1097
23	1.146	5.603	.156	6.186	1099
24	1.146	5.603	.156	6.186	1092
25	1.146	5.603	.156	6.186	1088
26	1.146	5.603	.156	6.186	1090
27	1.151	5.626	.157	6.109	1090
28	1.146	5.603	.156	6.186	1089
29	1.146	5.603	.156	6.186	1080

TABLE 15.

COW 400

No. of Period	Nutrients Digested Daily: Protein	Nutrients Digested Daily: Carbohydrates	Nutrients Digested Daily: Fat	THerm Value	Av. Weight
1	1.532	7.848	.386	8.934	1119.4
2	1.498	7.675	.378	8.737	1142
3	1.494	7.660	.376	8.718	1127
4	1.494	7.667	.375	8.727	1136
5	1.463	7.518	.368	8.555	1141
6	1.457	7.493	.366	8.523	1137
7	1.457	7.493	.366	8.523	1138
8	1.480	7.571	.303	8.421	1135
9	1.513	7.689	.209	8.269	1126
10	1.513	7.689	.209	8.269	1132
11	1.513	7.689	.209	8.269	1155
12	1.482	7.530	.205	8.100	1151
13	1.463	7.440	.204	8.006	1161
14	1.435	7.292	.199	7.842	1146
15	1.435	7.292	.199	7.842	1142
16	1.435	7.292	.199	7.842	1150
17	1.435	7.292	.199	7.842	1157
18	1.435	7.292	.199	7.842	1168
19	1.397	7.090	.194	7.635	1171
20	1.362	6.915	.190	7.442	1172
21	1.323	6.720	.183	7.229	1163
22	1.311	6.664	.182	7.170	1175
23	1.241	6.304	.172	6.783	1174
24	1.241	6.304	.172	6.783	1169
25	1.242	6.308	.172	6.787	1159
26	1.242	6.308	.172	6.787	1148
27	1.242	6.308	.172	6.787	1154
28	1.242	6.308	.172	6.787	1149
29	1.242	6.308	.172	6.787	1147
30	1.242	6.308	.172	6.787	1148
31	1.242	6.308	.172	6.787	1144
32	1.117	6.552	.165	6.749	1140
33	1.179	6.918	.174	7.195	1132
34	1.179	6.918	.174	7.195	1135
35	1.179	6.918	.174	7.195	1134
36	1.179	6.918	.174	7.195	1130
37	1.179	6.913	.177	7.197	1132
38	1.213	7.074	.211	7.425	1127
39	1.247	7.275	.217	7.645	1133
40	1.247	7.275	.217	7.645	1136
41	1.247	7.275	.217	7.645	1144
42	1.247	7.275	.217	7.645	1145

TABLE 16.

PER CENT OF AVERAGE COEFFICIENTS

Cow	Protein	Crude Fibre	N. Free Extract	Fat
27	96.1	104.9	110.0	93.7
62	95.4	96.5	107.4	96.3
206	96.4	148.0	105.7	114.0
304	99.6	138.6	104.7	117.8
400	94.5	137.3	102.9	113.1

TABLE 17.

TOTAL DIGESTIBLE NUTRIENTS CONSUMED.

Cow	Protein	Carbohydrates	Extract	Energy Value
27	238.34	1638.60	51.72	1858.78
62	195.06	1338.36	47.17	1523.68
304	367.19	1801.30	61.82	1994.16
206	426.73	2346.84	61.74	2471.90
400	563.16	2968.86	93.63	3205.43

Condition of Animals -- These three animals like those of Experiment I seemed to be in normal condition at all times with the exception of Cow 206 during one period, in which she went off feed. The coat of hair was slightly rough, but this is common in all maintenance work.

Weight After Calving -- In Table 19 it is evident that these two animals appear to have lost in weight. These figures will be discussed more in detail in the following pages.

Comparison of Nutrients During Gestation and Maintenance -- Cow 304 -- In Table 18 it is readily seen that when we make allowance for experimental error in weight after calving, Cow 304 has duplicated the results of Experiment I. This fact is more evident when we study the comparison in Table 19, in which we see that Cow 304 has lost but 14 pounds, received but little feed above her maintenance ration and has dropt an 82.5 pound calf. When we study Plate 4, which is plotted from the last two columns of Table 14 and the last two columns of Table 15 from the first twenty-nine periods, it is seen that the therm curves gradually decline.until at the close of the experiment they are below the average maintenance requirement.

TABLE 18

DAILY DIGESTIBLE NUTRIENTS AND ENERGY VALUE.

Cow	Period	Protein	Carbohydrates	Fat	Energy Value
27	Maintenance	.818	5.830	.315	6.385
	Gestation	.811	5.570	.176	6.322
62	Maintenance	.734	5.020	.272	5.487
	Gestation	.707	4.850	.171	5.521
206	Maintenance	1.217	7.796	.299	8.586
	Gestation	1.518	8.316	.219	8.796
304	Maintenance	.925	5.645	.228	6.266
	Gestation	1.292	6.278	.217	6.948
400	Maintenance I	.990	6.306	.243	6.926
	Maintenance 2	1.340	7.068	.222	7.631

TABLE 19.

Cow No.	Average Weight on Maintenance	Wt. when Bred	Weight after Calving	Dif. After Calving	Wt. of Calf
27	897	896	944	+48	75.0
62	917	917	900	-17	48.5
304	984	962	948	-14	82.5
206	1291	1327	1256	-71	95.0
400	1128	1119	1145	+26	----

PLATE 3

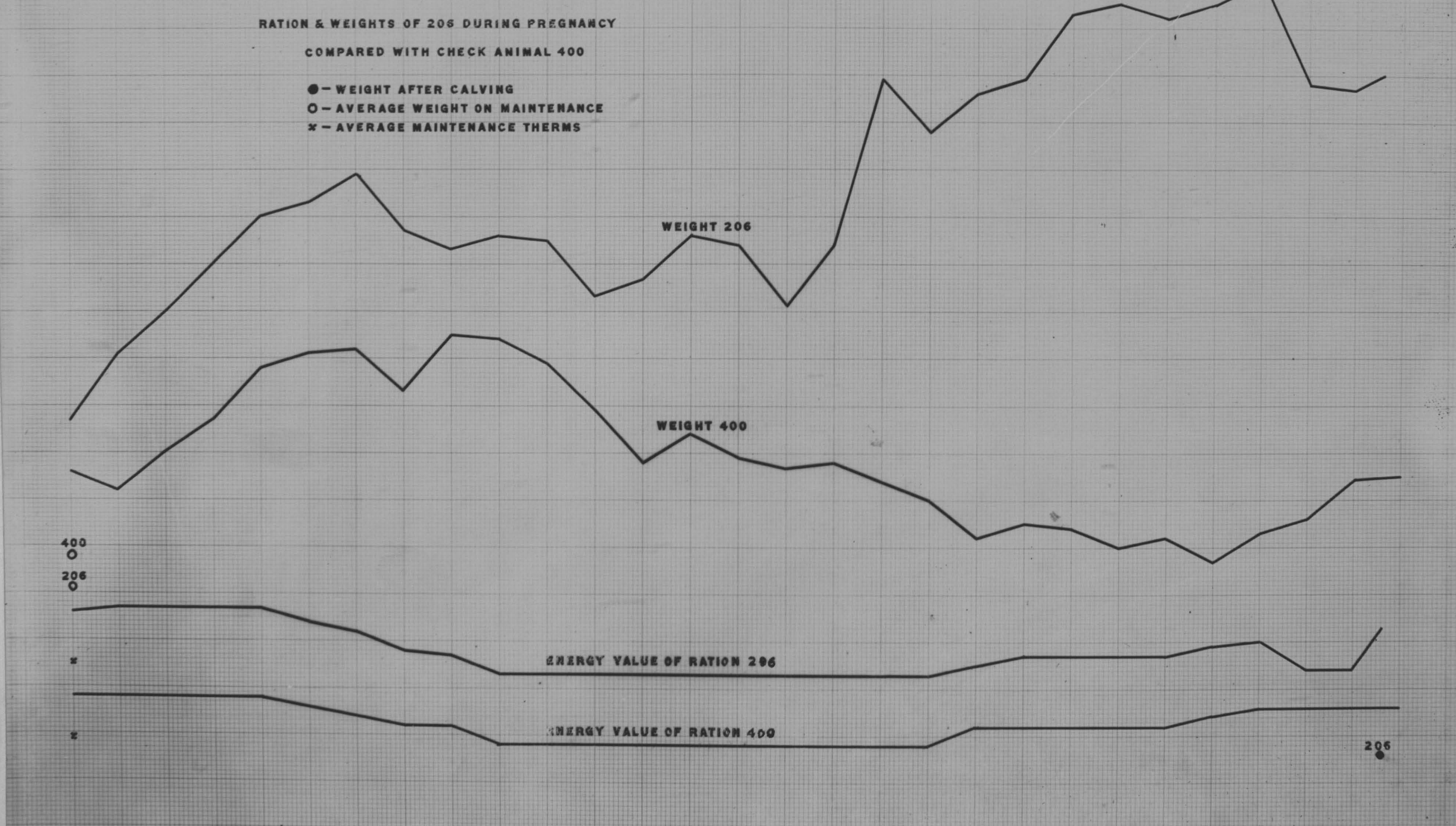
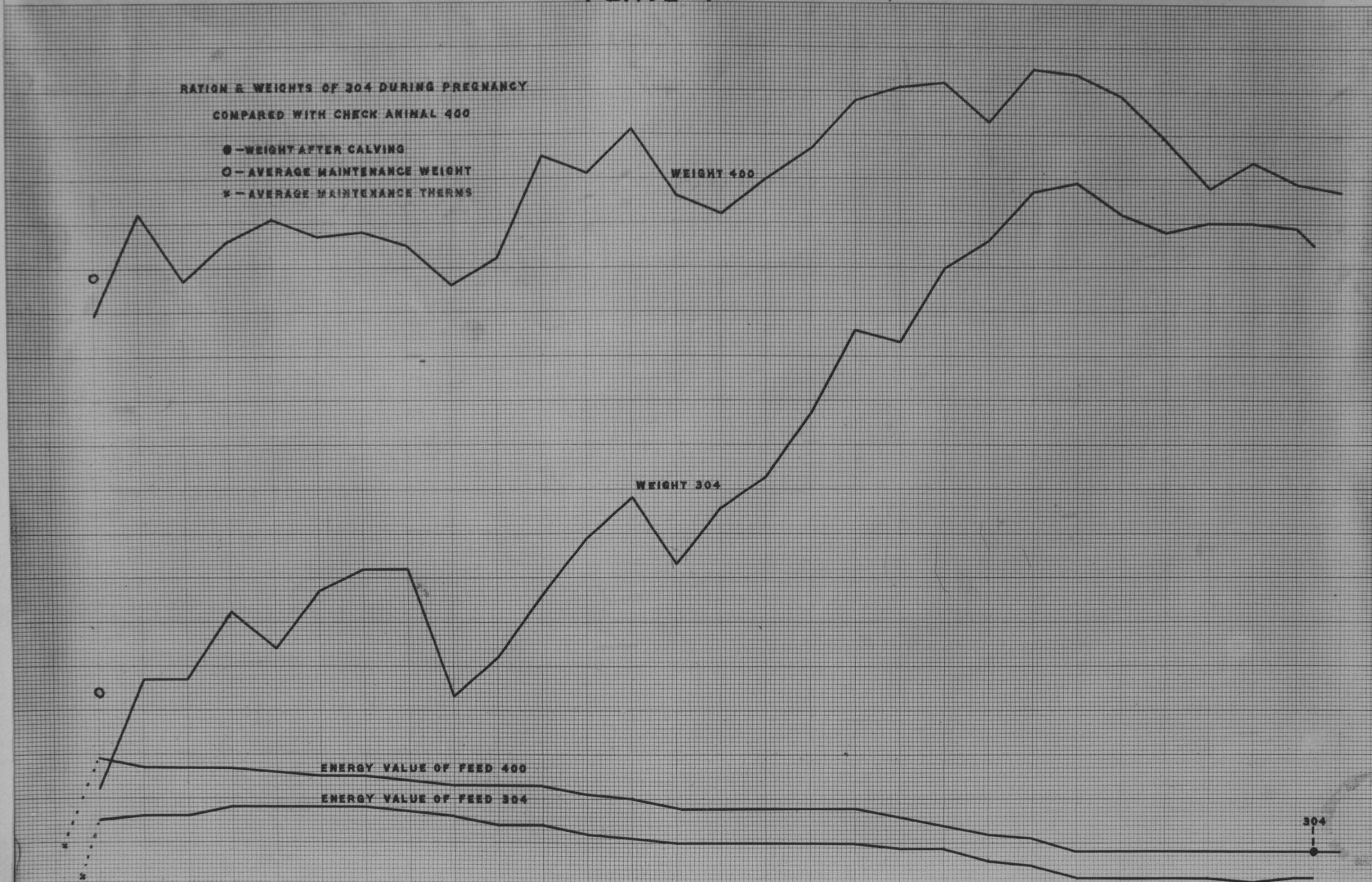

RATION & WEIGHTS OF 206 DURING PREGNANCY
COMPARED WITH CHECK ANIMAL 400
● – WEIGHT AFTER CALVING
O – AVERAGE WEIGHT ON MAINTENANCE
x – AVERAGE MAINTENANCE THERMS
WEIGHT 206
WEIGHT 400
400
206
ENERGY VALUE OF RATION 206
ENERGY VALUE OF RATION 400
206

PLATE 4


RATION & WEIGHTS OF 304 DURING PREGNANCY
COMPARED WITH CHECK ANIMAL 400
● —WEIGHT AFTER CALVING
O — AVERAGE MAINTENANCE WEIGHT
x — AVERAGE MAINTENANCE THERMS
WEIGHT 400
WEIGHT 304
ENERGY VALUE OF FEED 400
ENERGY VALUE OF FEED 304
304

Yet the weight curve of Cow 304 gradually increases until the eighth month. It is true that the weight curve of the check animal increases slightly yet this increase in weight does not account for the 128 pounds which Cow 304 has gained. When all factors are taken into consideration it remains conclusive that Cow 304 has duplicated the findings of Experiment I.

Cow 206 -- It might be said that an experiment without an exception to the general results is a condition devoutly to be wished, yet it is the exception that proves the rule.

The data of Cow 206 might at first seem in variance to that of the other three cows. But we have factors entering into this case that were not in the others. A study of Table 18 shows that Cow 206 has received but .21 of a therm daily more during gestation than while on maintenance. Table 19 shows that she produced a 95 pound calf and weighed 71 pounds less than when she was bred. But it also shows that she was only 35 pounds lighter than her normal body weight. Bearing in mind these facts we find in Table 13, during period 40 that she received very little feed. She was off feed at this time. This condition

came at a time when it seems normal during pregnancy for an animal to loose weight. In the two periods following 40 she was given an extra amount of feed to make up what she refused in period 40. This tends to misrepresent her gestation period, in that she was physiologically taxed at a time when it would show the most and her feed was raised too late to readjust her body before calving. Plate 3 shows this clearly. It also shows that the ration was decreased about the middle of gestation a little too low causing her to lose weight for a time of at least 40 days. Taking the above factors into consideration we probably have in this case similar results as shown in the other three cases.

Experiment II when summed up as a whole shows practically the same results as Experiment I.

Table 20 gives the per cent of the dams weight which the calf equals. The average for the four animals is 7.43 per cent. Eckles in his "Dairy Cattle and Milk Production" gives an average for the different breeds of 6.94 per cent. In the French investigations reported on page 21 the per cent of fetus to dam is 7.14. These figures show that on

the average the calves dropt by the four cows in this investigation were above normal size.

Table 21 shows the per cent of weight which the mother is reduced by parturition. The average for the four cows is 10.58 per cent, which is about 4 per cent less than the observations of the Royal Zootechnical Institute. This difference is probably due to the difference in the size of the animals. The Simmenthal and Schwyz cattle are larger than our American breeds and drop larger calves.

TABLE 20

WEIGHT OF FETUS TO WEIGHT OF DAM

Cow	Weight after Calving	Weight of Fetus	% of mother's Weight
27	944	75.0	7.94
62	900	48.5	5.03
304	948	82.5	8.70
206	1256	95.0	7.56
Total:	4048	301.0	----
Av.	1012	75.25	7.43

TABLE 21.

PER CENT WEIGHT LOST IN PARTURITION.

Cow	Av. Wt. last 10 da. of Gestation	Reduced by Parturition	% mothers' weight before Calving
27	1067.6	123.6	11.57
62	980.0	80.0	8.16
304	1080.0	132.0	12.22
206	1400.0	144.0	12.85
Total:	4527.6	479.6	-----
Av.	1131.9	119.9	10.58

COMPARISON WITH MOTHER'S MILK.

An interesting comparison can be made between the fetus and the mothers milk. Using Hogan's[1] figures for the composition of the fetus and comparing them with the composition of average milk, as seen in the following table, there is little similarity other than the per cent of fat.

	New Born Calf	Cows Milk
Water	76.21	87.17
Fat	3.18	3.69
Protein	17.46	3.55
Ash	3.55	.71
P_2O_5	.85	.215

There is the greatest variation in the per cent of ash. The fetus having just five times as much as the milk.

It is interesting to calculate the amount of milk which a cow would have to produce to furnish the solids found in calves of average weights. Eckles[2] gives the average weight of calves for the different breeds as follows:-

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1. Hogan - Thesis 1912, University of Missouri.
2. Eckles - Dairy Cattle and Milk Production.

Jersey	53	pounds
Ayrshire	64	"
Holstein	89	"
Dairy Short Horn . . .	76	"

The following table gives the amount of milk of average composition, required to furnish the solids in feoti of average weights.

TABLE 22.

Breed	Average Weight Calf	Pounds Milk Required to Furnish			
		Ash	Protein	P_2O_5	Fat
Jersey	53	264.9	260.6	209.3	45.6
Ayrshire	64	320.0	314.7	253.0	55.4
Short Horn	76	380.0	373.4	300.4	65.4
Holstein	89	444.9	437.7	351.6	76.6

A study of the above table shows ash, protein and P_2O_5 to be the solids requiring the most milk to furnish quantities equal to that found in the average weight feoti.

It is to be understood in this comparison, and those that follow, that no attempt is made to use milk production as a measure for fetal development. It is

used to show the small amount of solids in the fetus.

TABLE 23.

Breed	Weight of Calf	Pounds Milk Daily Required To Furnish			
		Ash	Protein	P_2O_5	Fat
Jersey	53	.93	.92	.73	.16
Ayrshire	64	1.12	1.10	.81	.19
Short Horn	76	1.33	1.31	1.05	.22
Holstein	89	1.56	1.50	1.23	.26

Table 23 shows the pounds of average milk required daily in a normal gestation period to furnish the constituents in calves of average weights. This table shows that if milk production were a measure for fetal development, it would not be much of a tax upon the maternal organs. Another fact brought out in a comparison of this kind is that we are trying to measure a factor which is too small to be considered in its relation to body weight of the mother. Because in the case of Cow 62, her body weight varied more than 50 per cent of the fetus' weight before and after parturition. That is, she was weighed before calving and all excrete, fluids and the calf were weighed, and

after parturition she weighed thrity some pounds more than could be accounted for.

A comparison of average weight feoti and average milk is no more interesting than a comparison of actual conditions, in which the weight of the fetus is compared with the amount of milk required to furnish the solids in the fetus, when the milk composition used is that of the mother's milk. Fortunately the milk of the animals used in this investigation was analyzed.[1] There were no P_2O_5 determinations made on the milk of these animals, but in the comparison in Table 22 the relation between protein and P_2O_5 is close enough so that it is probably accounted for when the protein is.

Table 24 gives the percentage composition of each cow's milk.

TABLE 24.

Constituents	Per Cent Composition of Milk From Cow			
	27	62	206	304
Water	85.18	85.43	88.72	87.80
Protein	3.98	3.99	2.95	3.28
Fat	5.51	5.31	3.40	3.85
Ash	.73	.75	.75	.73
Milk Sugar	4.60	4.52	4.18	4.34

1. Research Bul. No. 7, Mo. Exp. Sta.,

The above table shows a relatively low per cent of protein in the milk of Cows 206 and 304. This when taken with a high per cent of ash will change the large amount of milk required to furnish the ash, as in Table 22, to a correspondingly large amount to furnish the protein.

TABLE 25.

Cow No.	Weight of Calf	Pounds Mother's Milk Required to Furnish		
		Ash	Protein	Fat
27	75	364.3	328.8	43.2
62	48.5	229.3	212.2	29.0
206	95	449.3	562.0	88.8
304	82.5	401.3	439.0	68.0

Table 25 shows the amount of the mother's milk required to furnish the various constituents in the fetus. The amount required daily for the gestation periods (actual number of days) is given in Table 26.

TABLE 26.

Cow No.	Weight of Calf	Pounds Milk Required Daily		
		Ash	Protein	Fat
27	75	1.23	1.11	.11
62	48.5	.83	.76	.10
206	95	1.52	2.00	.31
304	82.5	1.41	1.54	.23

Tables 25 and 26 show as do 22 and 23 that it requires a very small amount of milk to furnish the constituents in the fetal body.

The ash requirement in these comparisons in most cases seemed to be the most important. In making a comparison of fetal ash and milk ash, we can determine whether or not the amounts of milk above will furnish the various constituents of the ash.

Table 27 gives in the last two columns the figures used for the comparison of the ash of the fetus and milk.

TABLE 27

Constituents	Fetus Ash Vannatta	Fetus Ash Hogan	Fetus Ash Average	Milk Ash Fleishman
K_2O	4.653	5.716	5.184	25.64
Na_2O	6.226	5.956	6.091	12.45
P_2O_5	39.382	38.462	38.922	21.24
Fe_2O_3	0.983	0.966	0.974	.34
CaO	43.113	41.073	42.093	24.58
Cl	1.949	2.239	2.094	16.34
Co_2	0.191	0.749	0.470	
$Si O_2$	0.639	0.303	0.471	
SO_3	1.107	3.114	2.110	
MgO	2.074	1.750	1.912	3.09
Sum	100.317	100.328	100.322	103.68
Deduct O=Cl	0.440	0.516	0.478	3.68
Total	99.877	99.812	99.844	100.00

Table 28 gives the grams of the various constituents in each fetus.

TABLE 28.

Constituents	Ash in Fetus of Cow (Grams)			
	27	62	206	304
K_2O	62.476	40.400	71.360	68.722
Na_2O	73.407	47.468	83.846	80.746
P_2O_5	469.080	303.330	535.784	515.977
Fe_2O_3	11.738	7.590	13.407	12.912
CaO	507.296	328.042	579.435	558.014
Cl	25.236	16.319	28.825	27.759
Co_2	5.664	3.662	6.469	6.230
$Si\ O_2$	5.676	3.670	6.483	6.243
SO_3	25.429	16.443	29.045	27.971
MgO	23.043	14.900	26.319	25.346
Sum	1209.045	781.828	1380.973	1329.920
Deduct 0 = Cl	5.760	3.725	6.579	6.336
Total	1203.285	778.099	1374.394	1323.584

If the ash constituents found in the fetus were supplied in the form of milk ash, the Fe_2O_3 would be the constituent which would determine the amount of milk ash that would be required. When the necessary amount of Fe_2O_3 was supplied there would be an excess of the other constituents. For example 3454.9 grams of milk ash are required to furnish the 11.74 grams of Fe_2O_3 found in the 75 pound fetus of cow 27. If the Fe_2O_3 was not considered it would require 2073.0 grams of milk ash or 40 % less.

Table 29 gives the amount of milk ash which would be required to supply all the ash constituents for each fetus, the amount in each case being determined by the Fe_2O_3 requirement.

TABLE 29.

Cow	Weight of fetus Lbs.	Grams Milk ash required
27	75.0	3454.9
62	48.5	2234.9
206	95.0	3949.9
304	82.5	3800.0

Table 30 gives the amount of milk (Total and daily) required to furnish the ash of the different feoti.

TABLE 30.

Cow	Total Milk Ash Grams	Total Milk Pounds	Milk Required Daily Pounds
27	3454.96	1044.7	3.5
62	2234.97	657.8	2.3
206	3949.99	1162.6	4.1
304	3800.00	1149.1	4.0

It has been shown on the previous page that Fe_2O_3 is the constituent which requires the greatest amount of milk to furnish an amount equal to that found in the fetus. From calculations made it was found that the mother has about the same amount of iron in her blood as the fetus has in its' entire body. Charin (P. 13 of this Thesis) gives us reason to believe that the fetus may obtain this iron from the reserve iron of the mother's body. Using Lawes and Gilbert's figures in a thousand pound animal there is close to 75 grams of iron. It seems plausible then that without

considering the iron we would more nearly represent the amount of milk required to furnish the ash constituents of the fetus. When iron is not considered we find the amount of milk required to furnish the ash constituents of the fetus is reduced 40 per cent. Applying this to the figures in the last column of Table 30 we get a daily milk requirement as follows.

Cow	Milk required to furnish ash other than Fe.
27	2.1
62	1.4
206	2.46
304	2.40

The above figures show again that it requires very little milk to represent the total constituents in the fetus.

To determine whether or not the feoti in the experiments reported in this thesis had to draw upon the mother for calcium, phosphorous and magnesium the composition of the different feeds as reported in Research Bul. 30, Wisconsin Experiment Station were applied to the feed of several of the animals.

In the case of Cow 206 it was found that she was - receiving .52 pound CaO, .13 P_2O_5 and .08 MgO. The relation of the other animals to these amounts is in the same proportion as their feed is to that of Cow 206. In all cases it was found that there was an abundance of these constituents in the ration.

Eckles[1] reports the therm value of the milk from the cows used in this study. Table 31 gives the thermal value of the milk of each animal required to furnish equal amounts of constituents found in the feoti of the animal.

TABLE 31.

Cow	Weight of Calf	Total Milk Required	Therm Value
27	75.0	364.3	142.8
62	48.5	229.3	87.8
206	95.0	562.0	155.4
304	82.5	439.0	133.5

The Above table shows that .552 therms daily represents the energy value of the milk requir-

1. Eckles - Research Bul. No. 7, Mo. Exp. Sta.,

ed to furnish the total constituents in a 95 pound fetus.

It might be interesting to compare the energy value of the milk required to furnish the total constituents in the fetus with the energy value of the fat and protein in the fetus.

Table 32 is calculated from Hogan's figures on weight and composition of the various parts of the fetus.

TABLE 32.

Parts of Fetus	% Fat	% Protein	% Part is of body weight
Blood	.190	8.900	5.3
Liver	1.074	14.031	5.0
Nervous System	7.333	10.425	1.0
Internal Organs	5.790	13.744	10.3
Excreta	8.417	17.369	.9
Hide	1.190	31.688	12.4
Skeleton	2.437	18.016	24.0
Flesh	4.416	16.888	40.9

Stohmann' gives the following figures as the Calorific value of fat and protein when oxidized outside of the body.

	Calories per grain
Animal Tissue Fat	9.50
Protein	5.71

Table 33 gives the weights of the various parts of the 95 pound fetus of Cow 206 and the grams of fat and protein in each part, together with the energy value of the fat and protein.

TABLE 33.

Parts of Fetus	Weight of parts Lbs.	Fat Grams	Protein Grams
Blood	5.03	4.0	202
Liver	4.75	23.0	302
Nervous System	.95	31.0	45
Internal Organs	9.78	256.0	609
Excreta	.85	32.0	66
Hide	11.78	63.0	1691
Skeleton,	22.80	252.0	1860
Flesh	38.85	777.0	2972
Total	94.79	1438.0	7747
Energy Value Therms		13.661	34.087

1. Hammersten - Physiological Chemistry Page 625.

The above table shows the total therm value of a 95 pound fetus (fat and protein) to be 47.74 therms. This represents about eight days maintenance therms for a thousand pound cow. It must not be overlooked, however, that this is stored energy in the form of fat and protein in the fetus. Henry[1] reports figures which show that it takes approximately 4.3 therms above maintenance for each pound of fat and each pound of protein stored in the body. Applying these figures to the amount of fat and protein in the 95 pound fetus we get 67.16 therms. Which represents the amount above maintenance that an animal would have to receive to put 1438 grams fat and 7747 grams protein on the body, or the amount which is found in the body of a 95 pound fetus. This represents the maintenance for a thousand pound cow for about ten days. Of course the fat and protein of the calf does not represent energy for other physiological processes, but if the energy required to produce the fetus was five times the above amount it would still remain a somewhat insignificant amount when we take into consideration the length of time covered by a normal gestation period.

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1. Henry - Feeds and Feeding.

To sum up the comparisons and data herein presented it seems that we are trying to measure a factor so small that live weights and weight of feed are not sufficiently accurate for the purpose.

SUMMARY.

Average Results -- To represent what the four animals did on the average the following table is given.

No. of Cow	Total Daily Maintenance Therms	Average	Total Daily Gestation Therms	Average
27				
62				
206				
304	26.724	6.681	27.587	6.896

The above figures show that .215 therms more daily were received by the animals during gestation than on maintenance. Returning to the case of Cow 206, had she not been off feed in period 40 she might have performed normally thru the last four periods, on the amount of feed received in period 38 (Table 13). Granting this the results are at once changed from a + .215 therms daily more for gestation, to a -.085 therms daily. Thus it seems conclusive that when

everything is taken into consideration these four animals practically produced the fetus and maintained their weight on the same amount of feed which they used for maintenance.

The results of this thesis would apply only in cases where the ration fed has a normal amount of ash and other nutrients. We can not say what the results would be in feeding a limited amount of ash, tho in extreme cases, especially with immature animals, the probabilities are that abnormalities would appear. The results that would be obtained from feeding certain proteins or an excess of carbohydrates can not be determined by these two experiments. Yet when the two experiments are considered on the whole, it is conclusive that the feoti were developed on maintenance rations and at the same time the mothers maintained normal weight. In the case of Cow 62 it is conclusive that she developed a 48.5 pound fetus and maintained normal weight on .337 therms less per day than she used for maintenance when farrow.

It might be mentioned again that there is no attempt made to prove that 'changes in body weight' re-

present the tax upon the maternal organism, because the tax if there is any is too small to be observed by the changes in the maternal appearance, and in any case the nutrients required to develop a 100 pound fetus would probably be little more than the daily variation in body weight of a thousand pound cow.

CONCLUSIONS.

1. The study of nutrients required for developing the fetus is a physiological question and must be investigated from that standpoint.

2. There is a gradual increase in the mother's weight, from the time of breeding to the latter part of the eighth month.

3. Nutrients required to develop the fetus in dairy cows and the tax on the maternal organism are too small to be measured by changes in the mother's weight.

4. For cases of practical feeding, when an animal is in a thrify condition and is receiving a maintenance ration, there is little danger of having an insufficient amount of nutrients for fetal development.

This thesis is never to leave this room.
Neither is it to be checked out overnight.