



## For Reference

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NOT TO BE TAKEN FROM THIS ROOM

THE INFLUENCE OF ULTRA-VIOLET LIGHT  
AND VITAMIN D ON THE GROWTH OF FALL  
FARROWED PIGS.

by

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April, 1928.

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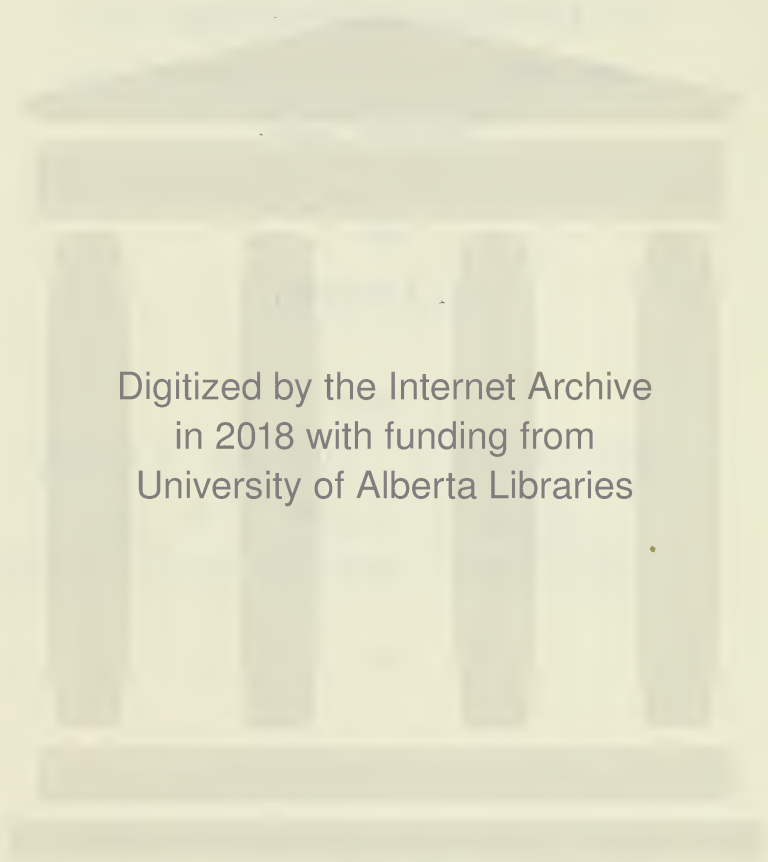
by

M. Syrotuck.

A Thesis

Submitted to the University of Alberta  
in Partial Fulfilment of the Require-  
ments for the Degree of Master of Science.

Edmonton, Alberta,  
April, 1928.



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Acknowledgements.

Especial thanks are accorded to Assistant Professor R.D. Sinclair, of the University of Alberta, for the plan and outline of this thesis, for his valued co-operation in analysis of results and his helpful interest throughout; to Assistant Professor J.E. Bowstead and Professor J.P. Sackville, of the University of Alberta, for helpful suggestions.



THE INFLUENCE OF ULTRA-VIOLET LIGHT  
AND VITAMIN D ON THE GROWTH OF  
FALL FARROWED PIGS.

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INTRODUCTION.

Livestock production of the present day varies from that of some years ago. Increase in human population has necessitated a heavy increase in the livestock population in order that the demand for meat for human consumption may be fully met. This rapid increase in the livestock population of all countries and the demand for meat products of superior quality has given rise to what may be regarded at the present time as an intensive system of livestock production. The present tendency is to remove farm animals from natural conditions of feed and environment, and force them to rapid growth and early maturity by means of scientific feeding and handling.

This general development, which may in a broad sense be regarded as depriving animals of their natural mode of living, has given rise to nutritional problems which were not current when farm animals were permitted to develop naturally. This early maturity in the present day livestock production is a matter of prime importance. Economy of production and the quality of the product are to a large extent dependent upon the meat producing animal being converted into an edible form at as early an age as possible. Early maturity suggests that all of the animal requirements from the nutritional standpoint must be met if physiological disturbances are to be avoided.





Any disturbance in nutrition will occasion slow and costly gains and, in addition, well marked symptoms of deranged physiology may be evidenced.

In addition to the nutritional factors, carbohydrates, proteins and fat, which have been well understood for many years, it is now well recognized that farm animals require an adequate supply of mineral matter in their daily ration. The quantity of mineral matter supplied in the ration may be a limiting factor to normal growth. Research work in animal nutrition conducted during recent years has shown that a deficiency of mineral matter in the ration, or an irregularity in connection with the factors favoring the utilization of mineral in the body, may give rise to serious nutritional disorders. For example, a lack of calcium and phosphorus in the ration, or a deficiency in connection with such factors as ultra-violet light and vitamin D which favor the assimilation of these elements, may not only cause what is termed by the practical man "unthriftiness", but disorders commonly referred to as "stiffness", "paralysis" and "rickets".

That such deficiency problems have a practical significance in Alberta is indicated by the number of unthrifty pigs which reach the markets throughout the country, and the number which may be seen on farms where pigs are more or less closely confined. Farmers ask from time to time, "What causes stiffness in pigs during the winter months, and what may be done to overcome the difficulty?" In connection with winter pig feeding experiments at the University of Alberta, cases



of stiffness have been encountered. It has been noted that winter grown pigs closely housed have been more subject to stiffness than those allowed free access to sunlight. This correlation as between stiffness and sunlight has suggested a study of factors influencing the utilization of the main elements essential for bone growth. Accordingly, an experiment was planned and conducted at the University of Alberta during the past winter with the object of determining the influence of exposure to sunlight and effect of feeding vitamin D through the medium of cod liver oil on the utilization of calcium and phosphorus and prevention of abnormalities which might be classified under the general term "stiffness". The treatise which follows is based on this piece of investigational work, but, before entering into a review of this special problem, some space will be given to a brief historical treatment of these nutritional factors, namely, ultra-violet rays and vitamin D, together with a resumé of experimental findings relative to their application to livestock production.





## REVIEW OF LITERATURE.

In view of frequent usage of the term "ultra-violet rays" in connection with the discussion which follows, it would seem well at the outset to consider the relation between these rays and others in the light spectrum.

Light is divided into three divisions of radiation - infra red, or heat rays, visible light and ultra-violet or chemical rays. Infra red and ultra-violet rays are invisible. Light rays are usually expressed in Angstrom units, although the term micromillimeter is also used. An Angstrom unit ( $\overset{\circ}{\text{A}}$ ) has a wavelength of  $10^{-8}$  centimeters, and a micromillimeter ( $\mu\mu$ ) a wavelength of  $10^{-7}$  centimeters. Red light of the solar spectrum has a range of 7700 to 6200  $\overset{\circ}{\text{A}}$ , with an average frequency of 375 per second. Violet light has a range from 4300 to 3900  $\overset{\circ}{\text{A}}$ , with an average frequency of 750 per second. Ultra-violet means beyond the violet and according to this indicates all wavelengths from 0 to 4000  $\overset{\circ}{\text{A}}$  Angstrom units.

Ultra-violet rays have two separate actions on living beings, and are exerted by rays from regions of different wavelengths. The lethal effect is characterized by the death of the cell on which it is exerted; hence the bactericidal action of ultra-violet light. This effect is exhibited by rays of wavelengths shorter than 2900  $\overset{\circ}{\text{A}}$ . Ellis and Wells (1) give the bactericidal action as confined to the middle ultra-violet between wavelength 3970 and 2100  $\overset{\circ}{\text{A}}$ . The other sort of effect is termed stimulative or biologic since stimulation of biologic processes is its commonest expression. This action of the



ultra-violet is exerted from the limit of the visible light (3900 Å) to about 2900 Å. The ultra-violet component of solar radiation at the earth's surface is practically identical with the region which is possessed of stimulative action and which is not endowed with lethal power. In other words, living beings on the face of the earth have at least partially adapted themselves to exposure to rays of wavelengths not shorter than 2900 Å.

#### Sources of Ultra-Violet Light.

There are two sources of ultra-violet rays - natural and artificial. The natural source is that great body of incandescence, the sun.

Ellis and Wells (2) give the following as artificial sources:

1. Lamps burning fluids in oxygen as carbon-disulphide, the so-called chemical lamps, or other devices of similar character. These are of very restricted application.
2. High tension disrupted electric spark discharge between metal electrodes - for example, iron, nickel, cobalt, copper, tungsten, zinc, magnesium, aluminum and cadmium. These form the basis of simple apparatus useful in producing fluorescent effects.
3. Establishment of an arc between electrodes of solid metal such as iron or carbon, usually without exhaustion of air.
4. Mercury vapor arcs, especially those created "in vacuo".

For an intense study of ultra-violet rays, and their application to livestock production, the quartz mercury vapor





lamp is used. At a number of experiment stations in the United States this form of irradiation is used for scientific and practical purposes. The lamp emits rays of the stimulative region of the ultra-violet.

#### Sunlight as a Source of Ultra-Violet Rays.

Sunlight is the most powerful form of irradiation known; only one twenty-billionth part is intercepted by the earth, and six-tenths of this amount passes through the earth's atmosphere. As stated, the ultra-violet rays of sunlight reach to 2900 Å and lie in the region of stimulative or biologic action. That sunlight is healthy is a universal conviction. Exposure to direct sunlight, together with such factors as may be linked with it, has wonderful power to promote health, bodily vigor and longevity in animals otherwise unable to adapt themselves to markedly adverse environmental conditions.

#### Seasonal Influence on Radiation.

Sun's rays reach their maximum about 1 P.M., and the greatest intensity of short wavelengths occurs at the same time.

Seasonal influences affect both the sun's spectral range and the intensity of the solar radiation. Russel and Russel (3) state that in July the maximum range of the spectrum is found, while in winter the smallest amount of ultra-violet radiation is present. In winter the intensity of ultra-violet radiation at high altitudes varies with that of low, the greatest amount of ultra-violet radiation and calorific



radiation being at high altitudes. In summer this condition does not exist. From May to September the intensity remains fairly constant. From October to April inexplicable sudden variations often occur.

The limits of the solar spectrum are influenced by the seasons, by the clearness of the atmosphere, by the height of the sun above the horizon - that is, the time of day - and by altitude, but it has been found that altitude has very little effect on the range of solar spectrum. However, the spectral range decreases very considerably the lower the sun is in the heavens.

Studying the solar radiation in Chicago Bunde-en et al (4) found that during the winter months comparatively little ultra-violet radiation of known physiologic significance appears in the sun's spectrum and that ultra-violet rays are absorbed to a sufficient degree by the atmosphere.

Tisdall and Brown (5) state that the sun's rays during December, January and February in the latitude of Toronto have a slight but definite biologic effect on rats. They also state that the increase in the biologic effect towards March, April and May is not due to a greater intensity but to a greater range of ultra-violet rays.

#### Biologic Effects of Ultra-Violet Rays.

Ultra-violet rays, emitted from artificial or natural sources, are of biologic significance. These rays are absorbed by the skin. Clark (6) states that all rays shorter than  $3000 \text{ \AA}$  are absorbed by a layer of epidermis .1 mm in thickness. The shorter the wavelength the thinner the layer which will completely absorb it. Macht et al (7), experimenting with rabbits, found



that penetration of ultra-violet rays through the living skin and other tissues is much greater. They also found that some of the shorter ultra-violet rays penetrate more deeply than the longer rays. As a result of the absorption of ultra-violet light in the epidermis, the familiar inflammatory reaction known as sunburn is produced.

#### The Relation Between Ultra-Violet Rays and Vitamin D.

Ultra-violet rays are intimately associated with the food factor commonly known as vitamin D. It seems well at this point to consider the connection between these two important nutritional principles. Ultra-violet rays, of the stimulative region in the spectrum, whether emitted by natural or artificial sources, and acting on the epidermis, have a biologic effect on the body. Related to this biologic effect of the ultra-violet ray is the vitamin D of foods. This food factor, on being taken into the body, produces a biologic effect identical to that of ultra-violet rays. These two factors have a definite physiological function in the nutrition of animals. Ultra-violet rays and vitamin D, having the same role in animal nutrition, are interchangeable - one is replaceable by the other.

#### History of Vitamin D.

It was long known that animals on certain rations which seemed adequate did not do well. In seeking for the cause of this condition research workers developed the theory of vitamins. This discovery is one of recent years. De Kruif (8) gives the names of McCollum, Hart and Steenbock, in collaboration with Dr. Stephen Babcock, as the pioneers in this field.

Along with other vitamins in foods is vitamin D, known





as the antirachitic vitamin. As pointed out, this vitamin is one of physiological significance, having a direct bearing on animal nutrition. Aside from its antirachitic effect and that it is fat soluble, little is known.

#### Parent Substance of Vitamin D.

In seeking the parent substance of Vitamin D, Hess, Weinstock and Helman (9) made the discovery that cholesterol was rendered antirachitic by exposure to ultra-violet light. This fact was discovered independently, and about the same time, by the observers Steenbock and Black, and Rosenheim and Webster.

Although this discovery has since been confirmed and accepted by numerous investigators in many countries, Rosenheim and Webster (10) were able to show in 1926 that cholesterol, purified still further by a chemical method known as bromination, had lost its property of becoming antirachitic by irradiation. It was found that chemically purified cholesterol no longer possesses the absorption spectrum in the ultra-violet region, which is characteristic for cholesterol purified by physical means only. It became evident that the precursor of vitamin D is not cholesterol itself, but of an unknown substance associated with cholesterol. Rosenheim and Webster (10) state that the evidence obtained leads to the view that the impurity is a sterol of an unsaturated and labile type of which ergosterol is the only known representative. The impurity present in cholesterol is found in the proportion of one to two thousand.

Hess and Anderson (11) define ergosterol as an optically active sterol, having three double bonds and containing a hydroxyl radical. Its molecule, therefore, possesses the two factors which have been found to be closely linked with the activation





of cholesterol derivatives.

#### Sources of Vitamin D.

There are two sources of vitamin D which are of practical importance in connection with this study, namely, cod liver oil and forage plants in their natural cured state.

From the commercial standpoint, cod liver oil is the principal source. It is the century old cure of rickets. Vitamin D occurs in the liver and body oils of many species of fish, but the quantity present varies widely for the different species. The liver of cod fish contains a liberal amount of Vitamin D. The oil extract of livers is a bi-product of the cod fishing industry. Not only is cod liver oil rich in vitamin D, but also in the growth promoting vitamin A.

Hays and roughages contain the antirachitic vitamin. Vitamin D of these feeds is closely associated with ultra-violet rays. Bethke et al (12) found that the antirachitic potency of hays is related to exposure to sunlight. Hess and Weinstock (13) found that wheat grown in the dark did not contain vitamin D, but when grown in sunlight possessed the antirachitic vitamin. Green plant tissue contains more vitamin D than dried plant tissue. However, hays and roughages exposed to such adverse conditions as dew and rain lose their vitamin D content in proportion to the degree of exposure.

Different hays and roughages vary as to the amount of vitamin D present. It is believed that alfalfa hay contains a more liberal amount of this vitamin than other hays. Although hays and roughages are sources of vitamin D, their content is not as abundant as in cod liver oil. Bethke et al (12) found that sun-cured hays contained a too feeble amount of vitamin D



to be of importance in some classes of livestock.

#### Physiological Significance of Ultra-Violet Light and Vitamin D.

As pointed out, ultra-violet rays and vitamin D are interrelated and have the same physiological effect on the nutrition of animals. It may be well at this point to consider these two factors in relation to the mechanism involved in bringing them to a point where they may have a physiological potency.

Ultra-violet rays are known to penetrate the epidermal portion of the skin and to activate a substance associated with the cholesterol found in the natural grease of the skin. Rosenheim and Webster (14) state that cholesterol is contained in gall stones, in the sheaths of nerve fibres, in the natural grease of the skin, and widely distributed elsewhere in the body. Hess, Weinstock and Helman (10) offer the following hypothesis bearing on the relation between ultra-violet light and cholesterol: "As is well known, the epidermal portion of the skin contains a large amount of cholesterol. It would seem possible that this cholesterol is normally activated by ultra-violet irradiation and rendered antirachitic. The solar rays and similar artificial radiation are able to bring about this conversion." They presuppose that this activated substance of cholesterol is transported to all parts of the body by way of the circulation, and that unactivated cholesterol is formed in the skin or transported to it from other parts of the body.

Vitamin D of foods, on the other hand, is absorbed from the intestinal tract and then circulated to all parts of the body. Thus it is evident that the antirachitic factor is made available



for use in the body either when the animal is exposed to ultra-violet light or when vitamin D is ingested in connection with the daily ration.

#### Vitamin D in Relation to Bone Development.

Vitamin D and ultra-violet rays have a definite physiological effect on the growth and composition of bone. These food factors are primarily concerned with the laying down in the bone of the proper proportion of calcium and phosphorus.

There are three distinct phases connected with normal bone growth. Bones grow in length by the production of cartilage cells between the epiphysis and diaphysis, and in thickness by the growth of the bone from the inner layers of the periosteum. At the same time the medullary canal is enlarged in proportion to the growth of bone, by the disappearance of the inner layers of bone. As normal bone growth takes place, calcium and phosphorus are deposited in the Haversian canals, especially at the base of these canals. It is at this point that vitamin D, or the antirachitic factor, plays a very important part in the physiological growth of bone. As normal bone growth takes place, calcium and phosphorus are deposited in the Haversian canals as calcium salts. However, this deposition takes place only in the presence of vitamin D. If this factor is lacking these salts are not deposited and, therefore, normal growth cannot take place. Vitamin D serves as a catalyst. The amount of calcium salts deposited is in direct relation to the amount of vitamin D present, at least until an optimum is reached.





## Causes and Pathogenesis of Bone Abnormalities.

As has been indicated, failure in the deposition of calcium salts in the bone may be the result of a lack of vitamin D. Due to a lack of this factor, the disease commonly known as rickets may result. This disease, or nutritional disorder, is prevalent and very noticeable in growing animals due to their bones being in the developing stage. Delafield and Prudden (15) state that in rickets all three phases of bone growth are defective. At the epiphysial plate microscopic examination disclosed irregular and defective arrangement of cartilage cells. Some calcium salts are laid down during the onset of the disease, but these are not deposited normally. The calcium salts that had been previously deposited became reabsorbed by the blood from the base of the Haversian canals, leaving a meshwork of connective tissue with numerous pores. Scattered throughout were a few cartilage cells. This weakens the bones so that under the strain of muscles it bends in various directions. To compensate for this weakness, the bone becomes thicker by excessive growth at the periosteum and the epiphysial plate. The bone marrow canal is not enlarged. In rachitic animals, the bones enlarge due to this excessive growth, the the characteristic enlargement at the joints is seen.

In mature bone, the blood reabsorbs calcium salts from the base of the Haversian canals. Hart et al (16) state that if the vitamin D factor is absent calcium salts are not redeposited, resulting in the disease known as osteoporosis.

Non deposition of calcium salts in the bone is accompanied by lowered inorganic phosphorus and calcium content of the blood. However, Hart and Steenbock (17) state that



a lower inorganic phosphorus content of the blood could not be relied on as an index to rickets.

In view of this thesis being a study of the antirachitic factor in relation to swine production, it would seem well at this point to mention a few words regarding rickets in pigs. This disease is prevalent in pigs throughout all parts of the country during the winter months. The malady may develop to a point where the pig is neither able to stand or to rise, and the trouble, unless relieved, destroys the usefulness of the animal. This trouble has been referred to by a variety of names such as lameness, posterior paralysis, rheumatism, stiffness and rickets. Maynard, Goldberg and Miller (18), in their study of "stiffness" in pigs, found that the terms posterior paralysis and rheumatism were not good ones to use as they did not find lesions in the spinal cord nor rheumatoid arthritis. They point out, however, that it is not to be concluded that paralysis and rheumatism are not possible causes of "stiffness" in some cases. It is now generally accepted that "stiffness" in swine is rickets. Elliot, Crichton and Orr (19) give the gross symptoms of the disease as slowing of rate of growth, lethargy, difficulty in locomotion, shown by a stiff, stilted gait. Later there follows loss of power of the hind legs and deformities in the long bones. death ultimately follows. The cause of the disease being known, a cure was forthcoming.

#### Application of Irradiation and Vitamin D to Animal nutrition.

The application of these nutritional factors to livestock production is a matter of great importance. During the past few years a considerable volume of experimental evidence



has been brought to light on this point. The following references to experimental findings will convey some impression of the interest which the animal husbandman has in the factors under consideration.

Among the domesticated animals, poultry is probably the most susceptible to rickets. This disease is often called "leg weakness". Experimenting with growing chicks, fed a ration lacking vitamin D, and confined indoors, Hart, Steenbock and Lepkovsky (20) showed that in a short period of time rickets developed and death soon followed. When exposed to sunlight, however, chicks grew normally. By irradiating hens, Halpin (21) was able to maintain egg production. Hart, Halpin and Johnson (22) obtained the same result, but they also found that the hatchability of eggs of irradiated hens was high. The egg production and hatchability of eggs of non-irradiated birds decreased as the trial went on. That the potency of the antirachitic factor in eggs is in relation to exposure of the hens was the result obtained by Hughes, Payne, Titus and Moore (23). Hart et al (24) reared chicks successfully by the addition of vitamin D in the form of cod liver oil in the ration. Dunn (25) raised poultry economically in confinement, both for practical and scientific purposes, by the use of cod liver oil in the diet.

Exposure to ultra-violet rays has proven beneficial in the rearing of goats. By irradiating goats, Hart, Steenbock and Elvehjem (26) changed a negative calcium balance to a positive calcium balance. At the same time, the calcium and inorganic phosphorus of the blood was increased.



Early workers believed that ultra-violet irradiation played an important part in the physiology of the dairy cow as regards growth, milk production and calcium balance. Later work, however, does not bear out this supposition. Gullickson and Eckles (27) raised calves successfully in confinement. Hart et al (28) experimenting with dairy cows in confinement state the following:-

1. Ultra-violet light has little, if any, direct influence upon the calcium and phosphorus metabolism.
2. Ultra-violet light has no influence, either favorable or adverse, upon the milk production.
3. Ultra-violet light has no apparent influence upon the calcium and phosphorus content of milk secreted.

They suggest that cows derive the antirachitic vitamin from the feed. However, Steenbock et al (29) found that irradiating the cow increased the antirachitic potency of the milk.

Practically no experimental work has been done with sheep and horses in regard to their connection with ultra-violet light and vitamin D. Mitchell and Keith (30) state that sheep and horses, as well as cattle, fed rations containing large amounts of good roughage and having access to sunlight and pasture part of the year are in little danger of being inadequately nourished in regard to vitamins.

Feeding a vitamin D free diet and in confined quarters, Maynard, Goldberg and Miller (31) produced rickets in pigs within four months, but similar pigs exposed to sunlight did not develop this condition. They state that winter sunlight may be sufficient in amount and efficiency to produce the





maximum possible effect on assimilation of calcium and phosphorus. The work of Steenbock, Hart and Jones (32) is in accord with this statement. Eppard, Culbertson and Hammond (33) found that gains of pigs fed outside were higher than those fed inside, although both lots of pigs had free access to sunlight. Accounting for this result, they state that sunshine was responsible due to the fact that the outside fed pigs were forced to exposure to sunlight. The feed requirement per one hundred pounds gain of this lot was considerably lower. This result was corroborated by Bohstedt, Bethke, Edgington and Robison (34). By artificial irradiation, Eppard et al (35) lowered the feed requirement as compared to non-irradiated confined pigs. By exposing pigs to sunlight, Steenbock, Hart and Jones (32) were able to increase the calcium and phosphorus content of bone ash, and the calcium and inorganic phosphorus of the blood. Maynard, Goldberg and Miller (18) state that the calcium and phosphorus of bone ash were higher in the sunlight pigs.

With the addition of vitamin D through the medium of cod liver oil, Bohstedt, Bethke, Edgington and Robison (34) prevented rickets in confined pigs. This is in accord with the previous findings of Bohstedt and Robison (36). In rickitic pigs, Maynard, Goldberg and Miller (18) alleviated this condition by the addition of cod liver oil to the ration. Together with this alleviation by the use of cod liver oil, Eppard et al (35) increased gains and lowered the feed requirement. Feeding pigs on a ration containing cod liver oil, Bohstedt, Bethke, Edgington and Robison (37) maintained normal calcium and



phosphorus content of the bone and blood. In the chick lot, however, these two mineral elements were reduced as the trial proceeded.

In connection with the winter pig feeding experiment carried on at the University of Alberta during the winter 1926-27, the pigs deprived of sunlight made slow gains on a high feed requirement, with four out of eight pigs eventually developing well marked symptoms of rickets. These pigs were later exposed to sunlight, gains were increased, and the condition of rickets was completely alleviated.

Ultra-Violet Light and Vitamin D  
in Relation to the Growth of  
Fall Farrowed Pigs.

The objects of an experiment conducted at the University of Alberta during the winter of 1927-28 were as follows:

1. To study the effect of sunlight (ultra-violet rays) on the calcium assimilation of fall pigs.
2. To compare sunlight (ultra-violet rays) and cod liver oil (vitamin D) with respect to their antirachitic properties.
3. To make observations on the calcium and phosphorus content of the blood and bone of pigs with access to sunlight and others deprived of sunlight.
4. To note the influence of sunlight as a factor in overcoming general "stiffness" in fall pigs.
5. To study the influences of temperature on the rate and economy of gains of fall pigs.



### Pigs Used.

In this experiment thirty-two pigs, bred on the University Farm, were used. Of this number four were Tamworths, eight were Tamworth-Yorkshire crossbreds, twelve were Berkshire-Yorkshire crossbreds, while eight were Poland-china-Yorkshire crossbreds. The average initial weight of these pigs was 56.6 pounds, with an average initial age of 72.6 days.

### Method of Allotment.

The allotment of pigs was made on the "litter-mate" basis, in order to secure as nearly as possible absolute uniformity of breeding in the various lots. Eight pigs were placed in all groups. The distribution was made as even as possible with respect to size, sex, type and condition. One pig in Lot 11, a purebred Tamworth, died three weeks after the beginning of the experiment from causes not believed to be due to the ration. The number of pigs in this lot was, therefore, reduced to seven.

### Rations Fed.

In this experiment the grain mixture consisted of oats, barley and shorts, equal parts, and 5% mixed supplement. The mixed supplement contained tankage 2.5 pounds, oil meal 1.25 pounds and alfalfa meal 1.25 pounds. Cod liver oil, at the rate of  $\frac{1}{2}$  pound per 100 pounds of grain mixture, was fed to Lot IV. Ground limestone was allowed each lot at the rate of 2 pounds per 100 pounds grain.

With respect to the rations and method of treatment, the various lots were dealt with as follows:





- Lot I - Oats 1, Barley 1, Shorts 1, 5% supplement and ground limestone (sunlight at liberty).
- Lot II - Oats 1, Barley 1, Shorts 1, 5% supplement and ground limestone (no sunlight - confined to pen).
- Lot III - Oats 1, Barley 1, Shorts 1, 5% supplement and ground limestone (sunlight after February 15th).
- Lot IV - Oats 1, Barley 1, Shorts 1, 5% supplement and ground limestone (no sunlight. Cod liver oil  $\frac{1}{2}$  pound per 100 pounds grain mixture).

In connection with this experiment, indoor self-feeding was practised in all lots. Salt was available to the pigs in all lots, in self-feeders. Water, with the chill removed, was supplied three times daily.

#### Description of Feeds.

Oats and barley were supplied by the Gillespie Grain Company. They were of standard quality, namely, 2 C.W. and 3 C.W., respectively. Shorts was obtained from the Canada Biscuit Company. The tankage used was Swift's Digester, with a guaranteed analysis of 50% protein, 6% fat, 8% phosphates and 3% maximum crude fibre. Oilmeal was secured from the Alberta Linseed Oil Company. Alfalfa meal of good quality was bought from the North West Milling Company. The limestone was secured from the Marlboro Cement Company. Cod liver oil, known as commercial crude cod liver oil used by poultrymen and livestockmen, was supplied by the National Drug Company and the Backus Flour, Feed and Seed Company.

#### General Nature of the Ration.

The ration used in this experiment had a nutritive ratio of 1:5.1. Containing animal and vegetable protein, it



was considered adequate from the standpoint of protein. Phosphorus requirements were assumed to be taken care of in the grain mixture. The basis of this determination were made elsewhere (notably Ohio). To make provision for an adequate supply of calcium, ground limestone was added. As a source of sodium and chlorine, common salt was fed "ad libitum".

In order to study the mineral intake of the pigs, an ash analysis was made of all feeds used.

Analysis of Feeds.

	Oats	Barley	Shorts	Supplement
% Ash	2.78	2.85	3.85	12.73
<u>Analysis of Ash</u>				
Potash (K <sub>2</sub> O)	15.76	22.10	30.60	7.01
Soda (Na <sub>2</sub> O)	4.50	5.60	2.68	2.60
Lime (CaO)	3.83	2.43	2.58	45.60
Magnesia (MgO)	6.93	9.98	13.15	2.39
Iron Oxide (Fe <sub>2</sub> O <sub>3</sub> )	0.14	0.24	0.16	0.10
Alumina (Al <sub>2</sub> O <sub>3</sub> )	.00	.00	.00	.00
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	24.30	35.43	48.49	38.59
Sulphates (SO <sub>3</sub> )	0.32	0.13	0.18	1.72
Silica (SiO <sub>2</sub> )	43.90	23.50	1.49	1.82
Chlorine (Cl)	0.52	0.42	0.54	0.32
Carbon Dioxide (CO <sub>2</sub> )	.00	.00	.00	Traces

In order to determine the degree of purity of the limestone, a sample was analyzed with the following result:

Silica	2.01%
Iron Oxide	0.42%
Alumina	0.51%
Carbonate of Lime	93.53%
Carbonate of Magnesia	2.92%
Vegetable Matter	0.34%

Since the limestone was rather coarse, it was deemed advisable to regrind it. This was done in the grinding machine of the Soils Department at the University of Alberta. A physical comparison was afterwards made by means of the soil



sieve method, used by the United States Bureau of Soils for mechanical analysis. The following results were obtained from ten-gram samples:

Sieve	Perforation	Ground Limestone	Reground Limestone
Not penetrating	Sieve 1	13.71%	0.0%
1	1 mm.	21.34%	0.0%
2	.5 mm.	16.61%	0.24%
3	64 meshes per 1"	14.72%	16.80%
4	130 meshes per 1"	33.62%	82.96%

#### Method of Housing.

The pigs were housed in a frame shed 16' x 36', with pens 9' x 12'. The shed contained two small windows facing north, with no other source of light. Thus none of the confined pigs had access to direct ultra-violet light. Lot I had a runway 36' x 22', thus having free access to sunlight. Lot III were given the same privilege after February 15th, in a runway 36' x 27'.

#### Weight of Hogs.

Weights were taken on three consecutive days at the beginning of the experiment, and the average of these taken as the initial weight. The second of these three days was considered as the day on which the experiment began. A similar method was followed at the conclusion of the experiment, weights of three consecutive days being averaged and the second of the three days being considered as the concluding date of the experiment. Throughout the experiment, weights were taken every seven days, in order to study the rate and economy of gains as correlated to temperature.



### Temperature and Sunshine Records.

At the close of the experiment, data was secured from the Dominion Meteorological Bureau, Edmonton, regarding maximum and minimum daily temperatures and daily hours of sunshine. The average weekly temperatures and hours of sunshine were studied in relation to the performance of the various groups in the experiment. Chart 1<sup>\*</sup> indicates the average weekly maximum and minimum temperatures and the average weekly hours of sunshine from November 23rd, 1927, to March 21st, 1928.

### Laboratory Determinations.

Laboratory work included determinations of calcium and inorganic phosphorus content of the blood, ash content of the bones, and calcium, phosphorus and magnesium content of the bone ash, at various stages of the experiment. The blood and bones were obtained from litter-mate pigs in each lot. The determinations made were as follows:

1. November 17. Blood samples and two metacarpel bones from pigs of each lot for calcium and inorganic phosphorus determinations of the blood, and calcium, phosphorus and magnesium content of the bone ash.
2. December 4. Blood samples taken from the ears of pigs for calcium and inorganic phosphorus determinations.
3. December 29. Same determinations as December 4th.
4. January 28. Same determinations as December 4th, but the blood was taken from the tails of pigs.
5. February 16. Same determinations as January 28th.
6. March 15. Same determinations as January 28th.
7. At the close of the experiment, March 22nd, determinations were made as on November 17th.

\* Chart I - page 42.





These analyses constituted a check on the calcium utilization at the various stages of the development of the pigs on trial.

#### Calculation of Data.

All calculations relating to this thesis have been double checked, and, in the case of errors, triple checked, thus avoiding, within reasonable human limits, the element of error.

#### Results.

The results of this experiment will be discussed under the following headings:

1. Calcium and phosphorus intake.
2. Calcium and phosphorus content of the blood.
3. Calcium and phosphorus content of the bone.
4. Rate of gains.
5. Rate of feed consumption.
6. Feed requirement for 100 pounds gain.
7. Influence of temperature on rate of gains and feed requirements.

#### Calcium and Phosphorus Intake.

The supply of calcium and phosphorus for assimilation in the bone is related to the intake of these two mineral elements contained in the ration. If the calcium and phosphorus content of the ration is in abundance, then any noticeable variations occurring in the calcium and phosphorus content of the blood or bone, or bone ash, are assumed to be the result of the presence or absence of the antirachitic factor. The calcium and phosphorus intake of the four lots of pigs in this experiment are shown in table IX.



Table IX - Calcium and Phosphorus Intake.

	No. of pigs	Per 100 pounds live weight daily		Total consumed	
		Ca.	P.	Ca.	P.
		Lbs.	Lbs.	Lbs.	Lbs.
Lot I - sunlight	7	.04300	.02584	45.48	26.79
Lot II - no sunlight	6	.04402	.02628	39.15	23.04
Lot III - sunlight after Feb. 15	7	.04196	.02482	44.16	26.25
Lot IV - cod liver oil	7	.04153	.02422	44.86	26.39

It is noted that the calcium and phosphorus intake of the various lots is approximately the same with respect to the total amount consumed per pig and per 100 pounds live weight.

The calcium and phosphorus ratio of the ration fed in this experiment is found to be 1.7 to 1, while the calcium and phosphorus ratio of the bone and the blood determinations is shown to be 2 to 1.

Since the calcium and inorganic phosphorus content of the blood constitutes the supply of these two elements available for bone building, and since it has been established (38) that this content is correlated to the condition of rickets, it was thought well to make determinations from blood samples of litter mate pigs. The results of these determinations are shown in the following tables:-



Table I - Calcium and Phosphorus Content of Blood in Lot I (sunlight).

Date	Pig No.	Ca.	P.
November 17	484	14.41	5.71
December 4	487	13.40	5.46
December 29	487	14.47	6.52
January 26	487	14.40	5.40
February 16	487	13.20	6.14
March 15	835	16.05	6.90
March 23	835	15.69	6.98
Average		14.517	6.158

Table II - Calcium and Phosphorus Content of Blood in Lot II (no sunlight).

Date	Pig No.	Mgm. per 100 cc. blood serum	
		Ca.	P.
November 17	489	14.01	5.60
December 4	483	15.04	5.48
January 3	483	15.97	5.44
January 26	483	15.40	5.06
February 16	483	15.28	7.50
March 15	833	15.19	7.68
March 23	833	14.84	8.84
Average		15.104	6.514

and  
Table III - Calcium/Phosphorus Content of Blood in Lot III (sunlight after February 15th).

Date	Pig No.	Mgm. per 100 cc. blood serum	
		Ca.	P.
November 17	486	16.11	6.15
December 4	490	16.11	6.30
December 29	490	16.58	7.82
January 26	490	16.00	5.02
February 16	490	15.50	5.94
March 15	836	13.95	9.28
March 23	836	13.10	9.36
Average		15.335	7.124





Table IV - Calcium and Phosphorus Content of Blood  
in Lot IV (cod liver oil).

Date	Pig No.	Mgm. per 100 cc. blood serum	
		Ca.	P.
November 17	492	14.50	5.78
December 4	488	14.04	5.10
December 29	488	15.47	8.28
January 26	488	15.50	5.66
February 16	488	15.60	7.32
March 15	839	14.99	7.14
March 23	839	15.68	9.58
Average		15.111	6.980

A condition which presents itself at the outset in considering the calcium and inorganic phosphorus content of the blood is the part which individuality may play. Litter-mate pigs, newly weaned, and from which blood samples were taken, on November 17th, show calcium contents of 14.41, 14.01, 16.11 and 14.50 in Lots I, II, III and IV, respectively. This occurrence makes comparisons on the basis of average composition by lots unreliable. It would appear that the only reliable method of comparison would be on the basis of a percentage increase or decrease in the calcium and phosphorus content of the blood of individual pigs in the various groups from which blood samples were taken at different dates. Considering pigs No. 487, 483, 490 and 488 in Lots I, II, III and IV, respectively, it is found that the calcium content of the blood in Lot I decreased 1.49% between December 4th and February 16th, increased 1.59% in Lot II, decreased 3.78% in Lot III, and increased 11.11% in Lot IV. The decrease in Lot I and the increase in Lot II are difficult to explain. Individuality may have played an important part in connection with this occurrence. The



decrease of 3.78% in Lot III might be regarded as slightly more significant and would seem to indicate a tendency toward a reduction in the calcium supply in these pigs deprived of sunlight to February 15th. The most marked variation occurs in Lot IV, fed cod liver oil, where an increase of 11.11% in the calcium content of the blood took place. Considering the phosphorus content of the blood of these pigs, it is to be noted that the same general trend is followed. In Lot I an increase of 12.64% occurred, in Lot II an increase of 36.86%, in Lot III a decrease of 5.71%, and in Lot IV an increase of 43.51%. The increase of 43.51% in the phosphorus content of the blood from the pig in Lot IV is the most notable occurrence, and, when considered in conjunction with the increase in the calcium content, would indicate that vitamin D as obtained from the cod liver oil was the factor responsible for this increase.

#### Composition of the Bone Ash.

The percentage of ash in bone is an indication of bone strength, and is a reliable guide as to the utilization of mineral elements in bone development. Variations in calcium, phosphorus and magnesium content of bone ash indicate varying degrees of utilization of the volume of these elements which was available for assimilation. In order to study the effect which the experimental factors under consideration had on the composition of the bone in the various groups, ash determinations were made from litter-mate pigs. The results of these analyses are shown in the following tables:

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Table V - Bone Analysis. Lot I (sunlight).

Date	Pig No.	Ash	Ca.	P.	Mg.
		%	%	%	%
November 17	484	54.09	36.13	18.75	.861
February 16	487	60.61	38.87	18.44	.737
March 23	835	62.67	38.44	18.52	.746
Average		59.123	37.813	18.570	.781

Table VI - Bone Analysis. Lot II (no sunlight).

Date	Pig No.	Ash	Ca.	P.	Mg.
		%	%	%	%
November 17	489	53.65	36.50	18.90	.789
February 16	483	59.91	38.90	18.12	.768
March 23	833	61.58	37.50	18.32	.712
Average		58.38	37.633	18.446	.756

Table VII - Bone Analysis. Lot III (sunlight after February 15th).

Date	Pig No.	Ash	Ca.	P.	Mg.
		%	%	%	%
November 17	486	53.70	36.68	19.07	.793
February 16	490	61.40	38.37	18.49	.808
March 23	836	63.26	37.85	18.84	.919
Average		59.453	37.633	18.80	.840





Table VIII - Bone Analysis. Lot IV (cod liver oil).

Date	Pig No.	Ash	Ca.	P.	Mg.
		%	%	%	%
November 17	492	52.10	36.87	18.53	.803
February 16	488	61.06	39.04	18.22	.753
March 23	839	61.54	37.90	18.50	.820
Average		58.20	37.936	18.416	.792

The percentage of ash of the bones in all lots is remarkably uniform, and in comparing these analyses with those obtained by other workers (37) it may be stated that ash percentages ranging from 58 to 59% indicate good assimilation and very acceptable strength of bone. None of the bones taken from pigs at the conclusion of the experiment (March 23rd) indicate any mineral deficiency or tendency toward faulty assimilation. While it has been pointed out that individuality undoubtedly plays some part in determining bone composition, it is of interest to compare the rate of increase of the percentage of ash in the bone between the initial and final dates of the experiment. The percentage of ash increased 15.86% in Lot I, 14.78% in Lot II, 17.80% in Lot III and 18.12% in Lot IV. The smallest increase took place in Lot II where the pigs were deprived of sunlight during the entire experiment, and the largest increase occurred among the pigs in Lot IV receiving cod liver oil. So far as the calcium content of the bone is concerned, the greatest increase occurred in Lot I where the pigs were allowed access to sunlight, with the smallest increase in Lot II where the pigs were deprived of sunlight. A steady decrease in percentage of phosphorus is to be noted in all lots





as the pigs increase in age. This decrease was greatest in Lot II, and lowest in Lot IV. The magnesium content of the bone does not seem to show any consistent trend with advancing age, and the percentage of increase or decrease cannot be related to any experimental factor. With regard to the ash analyses in connection with this experiment, it cannot be said that any outstanding differences are in evidence. All lots show a high ash percentage. The percentage of calcium by lots is remarkably consistent, and the same may be said with regard to phosphorus.

It would appear that the ration used in all lots had a high degree of antirachitic potency, and this condition overcame the possibility of the ultra-violet rays of the sunlight and vitamin D of the cod liver oil exerting any marked influence.

#### Rate of Gains.

The rate of gains made by the pigs in the various lots is shown in table X.

Table X - Average Daily Gain per Pig.

Lot No.	Average daily gain
	Lbs.
I (sunlight)	1.10
II (no sunlight)	1.06
III (sunlight after Feb. 15)	1.12
IV (cod liver oil)	1.18

The highest average daily gain was made by the pigs in Lot IV receiving cod liver oil, being 11.32% higher than



the gains made by Lot II, the lowest of the four groups. Although the gains made by the pigs in Lot I, having free access to sunlight, were higher than those of Lot II, deprived of sunlight, they were not as high as the gains made by the pigs in Lot IV, receiving the counterpart of sunlight, namely, vitamin D of the cod liver oil. This result was probably due to the fact that the pigs in Lot I, having free access to a runway, were encouraged to take plenty of exercise, a condition which might tend to somewhat lower the rate of gains. The average daily gain made by the pigs of Lot III, deprived of sunlight till February 15th, is somewhat higher than that made by the pigs of Lot I. This is probably due to the pigs of Lot III being in confinement during the larger part of the experiment, and thus held more closely to the feed supply which was available at all times in a self-feeder.

In order to obtain a more detailed comparison of the rate of gains made by the various groups, fourteen day weights of five pigs carried throughout the experiment are plotted on Chart II.\* Of particular interest is the fact that the gains are remarkably uniform in all groups. The rate of gains of the pigs of Lots I, II and III is very close, while the gains in Lot IV were considerably higher, being 14.53% above those of Lot I at the close of the experiment.

Although the average initial weights of the groups were practically the same, the rate of gain in the cod liver oil group was not only higher than in the others, but was the most consistent. The gains of Lot I were fairly consistent throughout the experiment, while the gains of Lot II, deprived of sunlight, showed a tendency to fall off at the latter part of the experiment. The gains of the pigs of Lot III after

\* Chart II - page 43.



exposure to sunlight began to increase slightly, probably due to the beneficial effect of sunlight.

The consistency of the rate of gains of each group seems to suggest that the basal ration used in all lots had a high degree of the antirachitic potency.

#### Rate of Feed Consumption.

The average daily feed consumption, based on 100 pounds live weight of pig, is shown in table XI.

Table XI - Average Daily Feed Consumption.  
per 100 Pounds Live Weight.

Lot No.	Average Daily Feed Consumption
	Lbs.
I (sunlight)	4.31
II (no sunlight)	4.38
III (sunlight after Feb. 15)	4.15
IV	4.08

The average daily feed consumption per 100 pounds live weight of Lot II was the highest, that of 4.38 pounds, followed by Lots I, III and IV with a daily consumption of 4.31, 4.15 and 4.08 pounds, respectively. The average daily feed consumption is related to the average daily gains. Of particular interest in this experiment is the fact that higher gains were made by the lots having a lower daily feed consumption indicating a high degree of utilization.

#### Feed Requirements per 100 Pounds Gain.

It is well known that normal growth of pigs results from good feeding and proper physiological activity within the body. These two factors working together result in a condition





generally spoken of as "thrifft". It has been well established that any physiological derangement has a tendency to produce "unthriftiness". This condition is correlated with the feed requirement. A high feed requirement indicates a low degree of utilization of the food consumed, and a low feed requirement is indicative of a high degree of utilization. The feed requirements per 100 pounds gain of the pigs in this experiment are shown in table XII.

Table XII - Feed Requirement per 100 Pounds Gain.

Feeds	Lot I	Lot II	Lot III	Lot IV
	sunlight	no sunlight	sunlight after Feb. 15	cod liver oil
	Lbs.	Lbs.	Lbs.	Lbs.
Grain	455.61	473.46	434.34	416.70
Mixed supplement	24.00	24.90	22.84	21.94
Limestone	9.6	9.96	9.14	8.77
Salt	1.39	1.94	1.25	1.49
Cod liver oil	.....	.....	.....	2.20
Total	490.60	510.26	467.51	451.1

The feed requirement per 100 pounds gain was highest in Lot II, followed by Lots I, III and IV, respectively. Lot II, confined indoors, had a higher feed requirement of 13.11% as compared to Lot IV, and 4.07% higher than Lot I which had free access to sunlight. It is evident, then, that Lot II did not utilize the feed as efficiently as the groups exposed to sunlight or receiving vitamin D of cod liver oil. It is well to note that Lot IV, confined indoors but fed cod liver oil, had a low feed requirement, namely, 451.1 pounds, a figure

5.



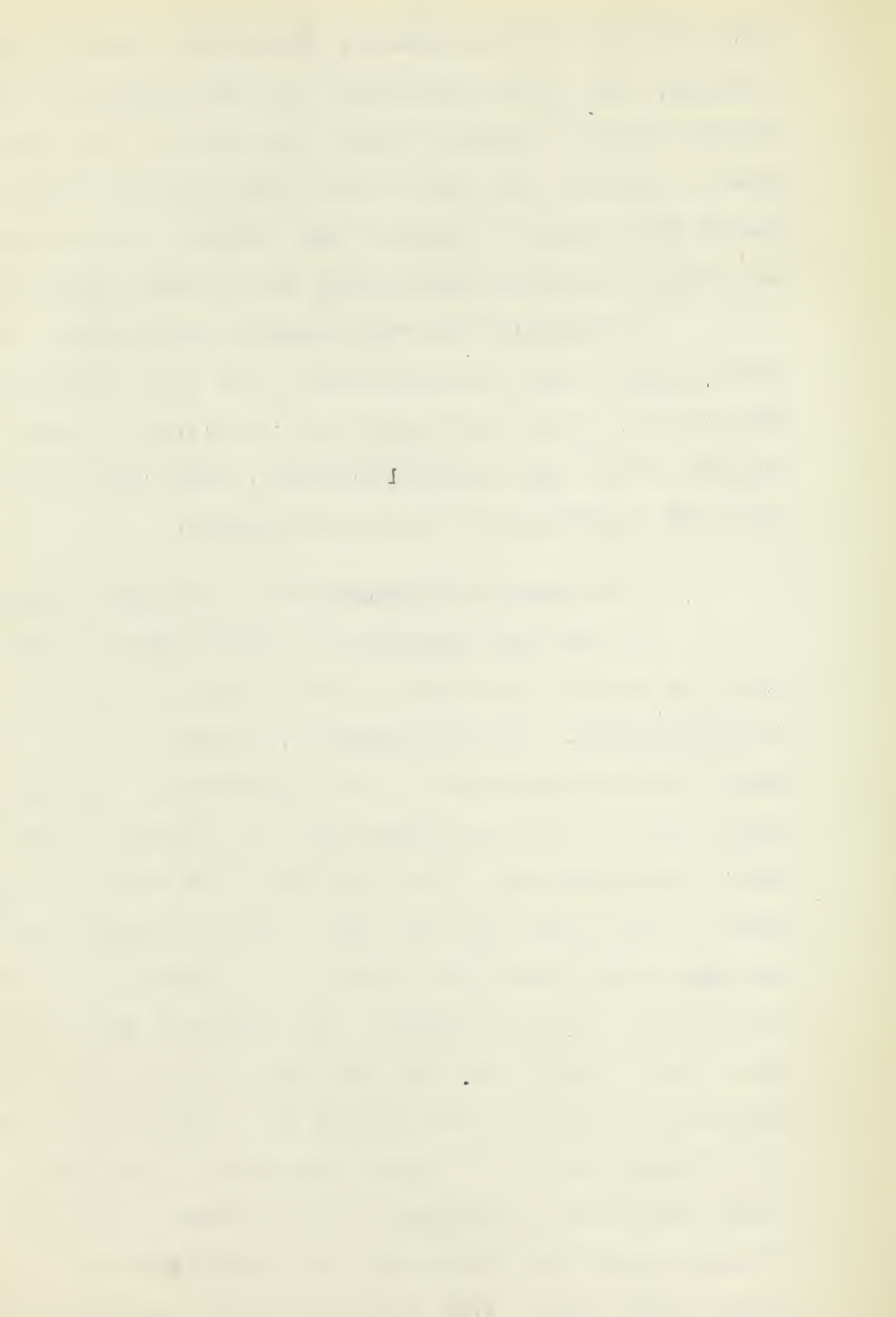
which indicates very economical production. Lot I, receiving sunlight, had a feed requirement per 100 pounds gain of 490.6 pounds, which is somewhat higher than that of cod liver oil group. However, this may be due to the fact that the pigs having free access to sunlight and allowed a runway required more food to maintain body energy lost through exercise.

As regards feed requirements per 100 pounds gain of the groups under consideration, there is an indication that ultra-violet light and vitamin D of cod liver oil tend to promote better physiological activity, thus resulting in more efficient utilization of the feed consumed.

#### Influence of Temperature on the Rate of Gains.

It has been the general opinion that pigs make slower gains and require more feed to make growth in cold weather than in mild weather. It was, therefore, thought well to give this matter some consideration in this experiment. The average weekly gains of the individual lots in relation to the average weekly temperature are shown in chart III.\* From a study of the chart, it was found that the pigs in Lot I, having access to sunlight, made higher gains during the colder weather and lower gains during the mild weather. This occurred during 11 weeks out of the 17 weeks that the pigs were on experiment. Identical results were found in Lots III and IV. The relation noted was not so marked in Lot II, where gains were higher during the colder weather in 9 weeks out of the 17 weeks of the experiment. It would appear that during the cold weather there is a tendency toward higher gains, with lower gains being registered during periods of higher temperatures.

\*Chart III - page 44.



The influence of Temperature on the  
Feed Requirement per 100 Pounds Gain.

The influence of temperature on the feed requirement per 100 pounds gain of Lots I, II, III and IV is shown in charts IV, V, VI and VII, pages 45, 46, 47 and 48, respectively. From a study of these charts it is shown that during the warm weather the feed requirement is increased, and that during cold spells the feed requirement is lowered. This condition is more marked in Lot IV, fed cod liver oil. In cold spells the pigs were not inclined to exercise, and were usually found close to the feed supply. Since the basal requirement is not necessarily increased during cold weather, it would seem reasonable to assume that a high intake over and above the basal requirement would result in greater returns in body growth on the feed consumed and, therefore, a lower feed requirement per 100 pounds gain.

Summary.

The fact that the pigs in this experiment were generally thrifty indicates that the basal ration could be regarded as satisfactory for fall farrowed pigs. That the ration was reasonably adequate from the standpoint of the antirachitic factor was evidenced by the good growth and general thrift of the pigs and by the increase of the calcium and phosphorus content of the blood and bone ash as the trial proceeded. These determinations showed that normal bone growth took place.

That vitamin D of cod liver oil fed in the ration had a beneficial effect is shown by the fact that when added





to the feed allowance of confined pigs the gains were higher and the feed requirement per 100 pounds gain lower as compared with pigs in confinement and receiving the basal ration only. In addition to these beneficial effects, cod liver oil feeding manifested itself in a condition referred to among livestock men as "bloom". It was noticeable throughout the experiment that the pigs fed cod liver oil appeared more thrifty, smoother in the skin, and more lustrous in the hair. At the close of the experiment, the condition, finish and general appearance of these pigs was superior to that of the pigs in the other lots.

That ultra-violet rays exert a beneficial effect was indicated by the higher rate of gains and the lowering of the feed requirement of pigs exposed to sunlight as compared to pigs in confinement. The rate of gains of pigs in confinement was increased when the pigs were exposed to sunlight, an occurrence which adds weight to the suggestion that sunlight exerts a beneficial effect. It was noted that pigs receiving sunlight showed greater indications of thrift in skin and hair than the pigs which were deprived of sunlight during the experiment.

Since the pigs on the basal ration not receiving any special antirachitic treatment made satisfactory growth, it would appear that the results obtained were due, in part, to the vitamin D content of the alfalfa meal, and the availability of the calcium and phosphorus of the ration. It would appear that the ground limestone containing 93.53% of calcium carbonate provided an ample supply of calcium in a readily available form.





These two factors working in harmony prevented any physiological disorders.

Periods of low temperature did not appear to exert a depressing effect on the rate of growth of pigs in this experiment. On the contrary, during periods of cold weather gains were increased, and the amount of feed required for growth was reduced. This result suggests that ordinary Alberta winter weather should not be a limiting factor in fall pig production.

### Conclusions.

From the foregoing data and comments the following conclusions may be drawn:

1. The basal ration used in this experiment contained sufficient calcium and phosphorus and sufficient of the anti-rachitic factor to prevent "stiffness" in fall pigs.
2. Supplying vitamin D in cod liver oil resulted in an increase in the percentage of bone ash, and an increase in the percentage of calcium in the bone.
3. Exposure to sunlight increased the percentage of bone ash and percentage of calcium, although the increase was not as marked as when cod liver oil was fed.
4. While there was some variation in the percentage of bone ash in the various groups, all lots yielded what might be regarded as normal growth.
5. Calcium and phosphorus were present in the bone in the ratio of 2:1, and in the ration fed in the ratio of 1.7:1.
6. Calcium and phosphorus determinations on blood samples did not yield results that could be regarded as suggestive.



Individuality appears to play an important part in this connection.

7. Cod liver oil tends to exert a more beneficial effect on winter grown pigs than exposure to sunlight.

8. Vitamin D of cod liver oil and sunlight promoted an increase in gains and made for a lower feed requirement as compared with pigs on the basal ration only.

9. Cod liver oil fed at the rate of  $\frac{1}{2}\%$  had a replacement value of 43.7¢ per pound, or \$3.75 per gallon. It was actually purchased at a price of \$2.00 per gallon.

10. Ground limestone fed at the rate of 2 pounds per 100 pounds of the grain allowance seemed to constitute a good source of calcium supply.

11. More rapid and economical gains were made during periods of low temperatures than during mild weather.



### CHART 1

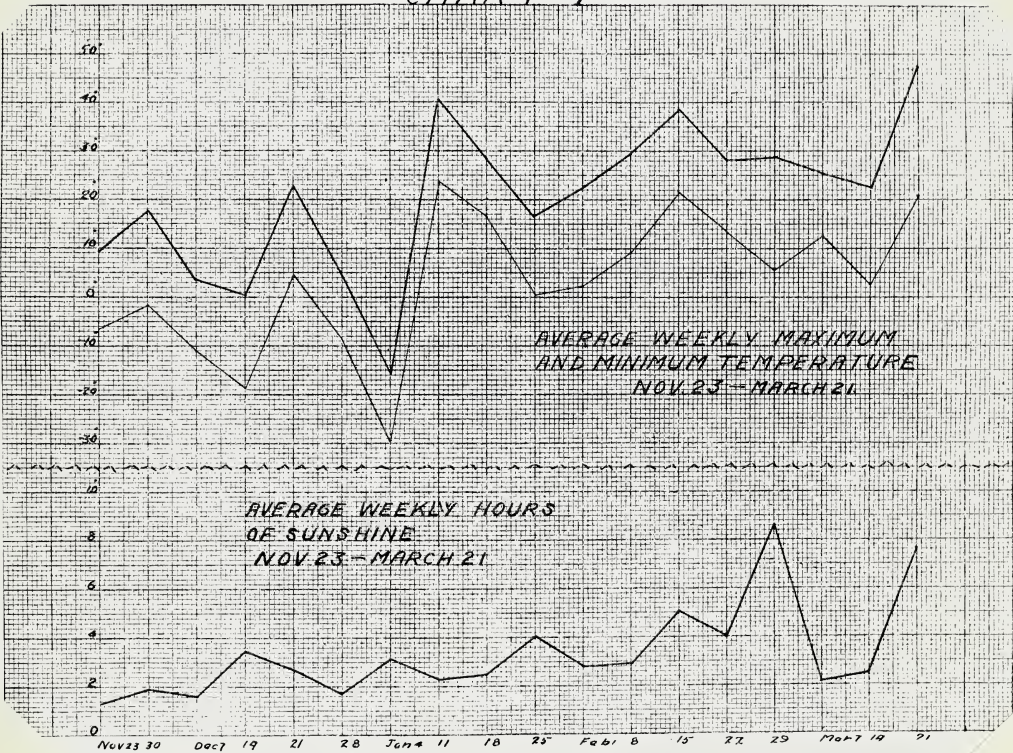


Chart I - Average Weekly Maximum and Minimum Temperature  
and  
Average Weekly Hours of Sunshine.





CHART II

COMPARATIVE RATE OF GAINS  
BASED ON 14 DAY WEIGHTS  
LOTS I-II-III-IV

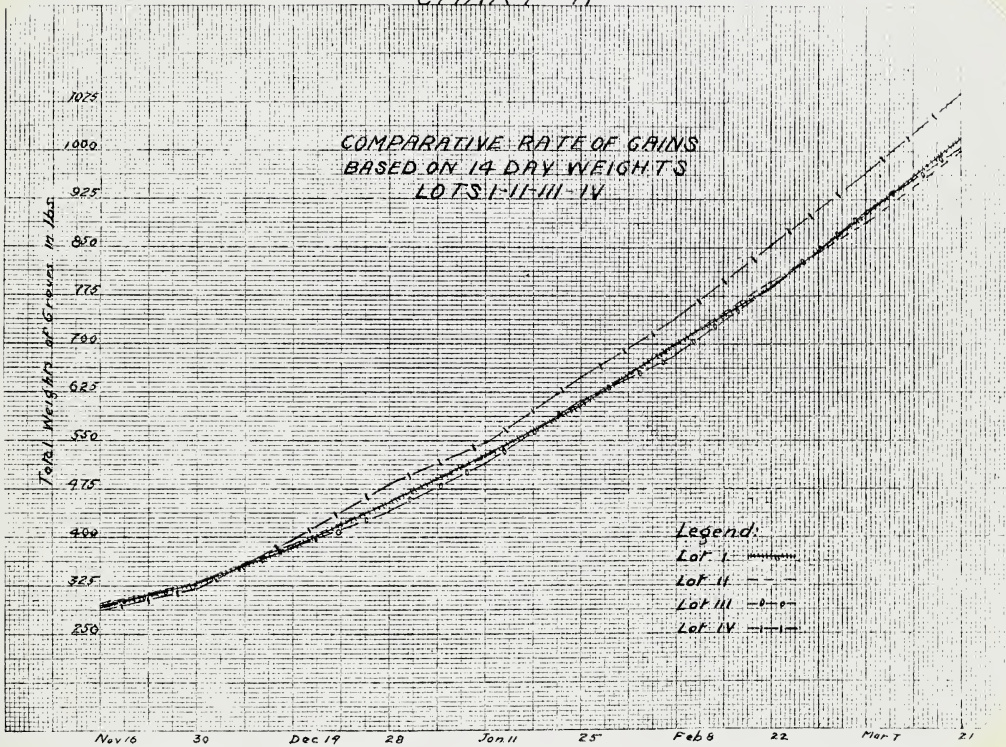


Chart II - Comparative Rate of Gains Based on 14 day Weights.

Lots I, II, III and IV.



CHART III

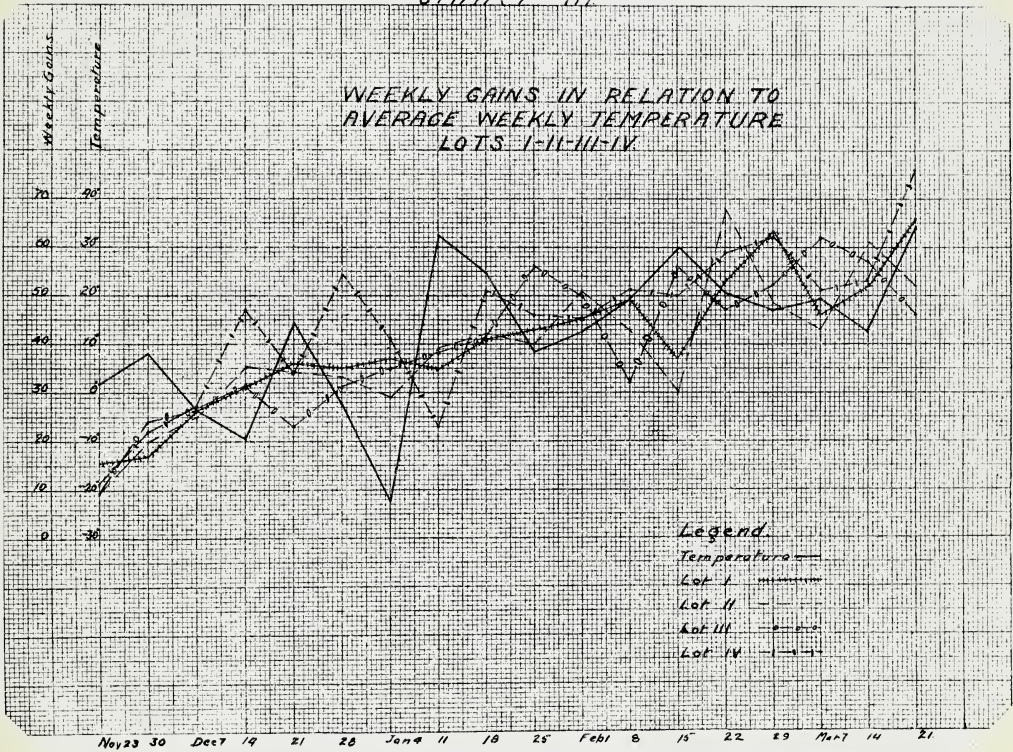


Chart III - Weekly Gains in Relation to Average Weekly Temperature.

Lots I, II, III and IV.





CHART IV

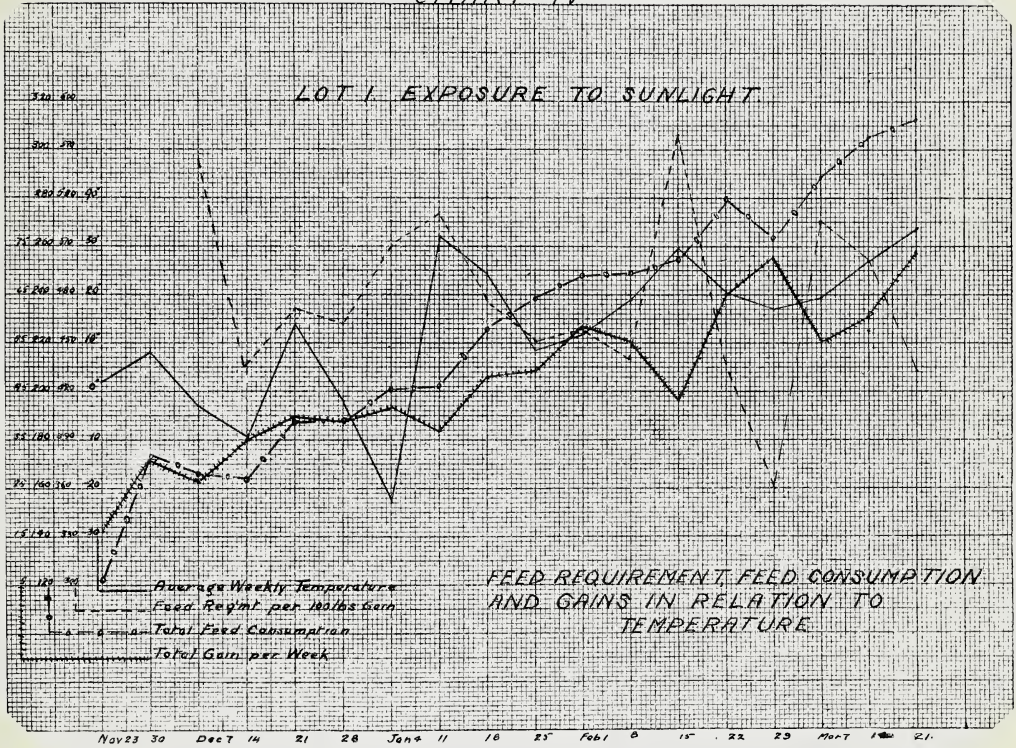


Chart IV - Feed Requirement, Feed Consumption and Gains in Relation to Temperature.

Lot I - Exposure to Sunlight.



CHART V

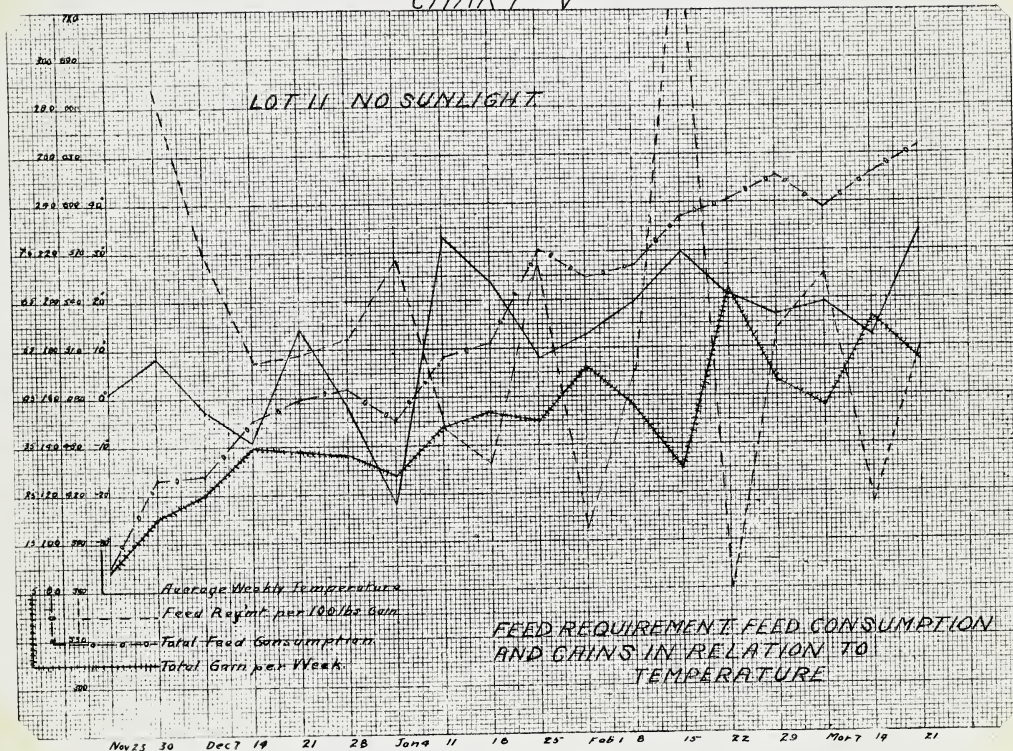


Chart V - Feed Requirement, Feed Consumption and Gains in Relation to Temperature.

Lot I - No Sunlight.





CHART VI

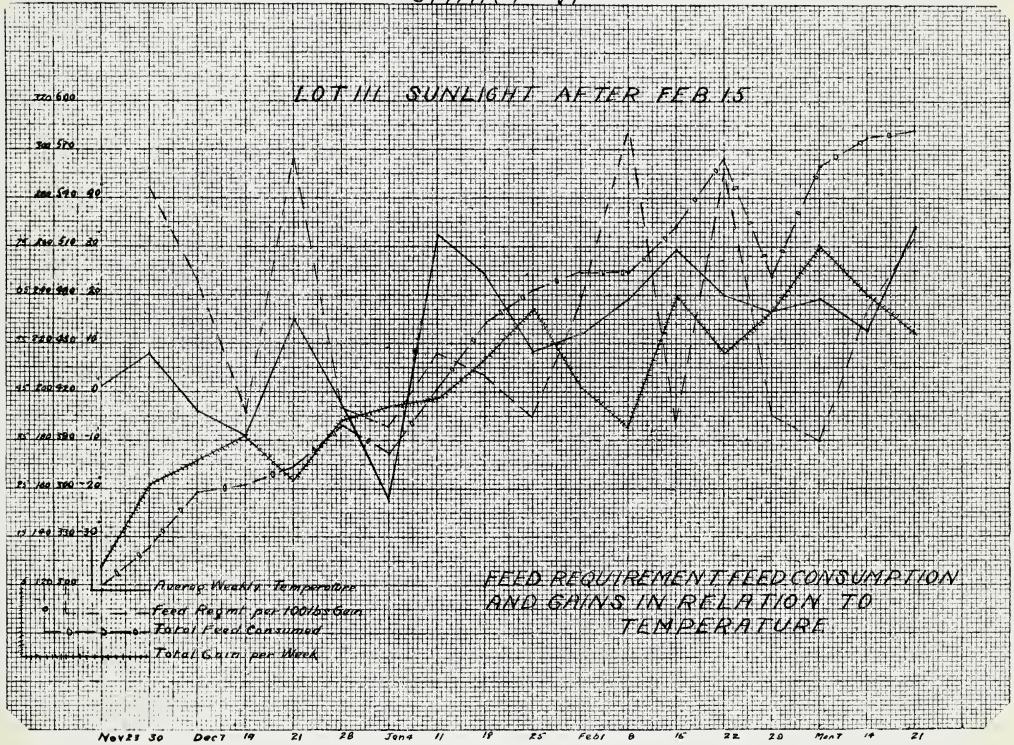


Chart VI - Feed Requirement, Feed Consumption and Gains in Relation to Temperature.

Lot III - Sunlight after February 15.



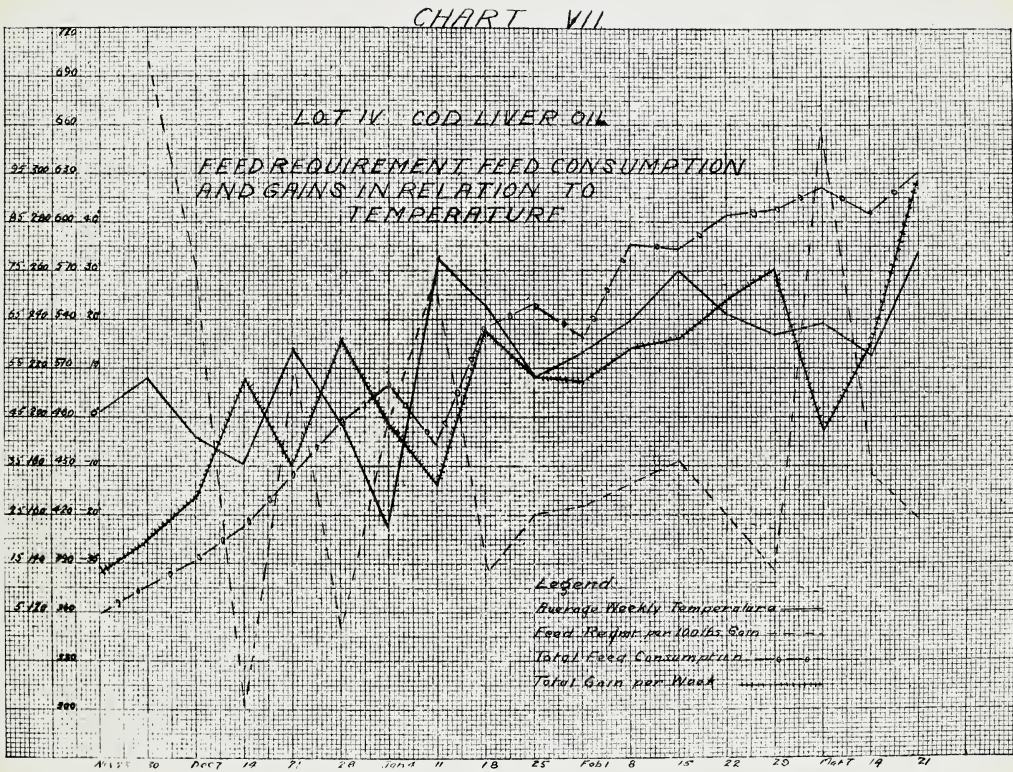


Chart VII - Feed Requirement, Feed Consumption and Gains in Relation to Temperature.

Lot IV - Cod Liver Oil.





Bibliography.

- (1) Ellis, C. and Wells, A. A.  
1925. The Chemical Action of Ultra-Violet Rays, p. 236.  
The Chemical Catalog Co. Inc.,  
New York.
- (2) Ellis, C. and Wells, A. A.  
The Chemical Action of Ultra-Violet Rays. p, 20.  
The Chemical Catalog Co. Inc.,  
New York.
- (3) Russell, E. H. and Russell, W. K.  
1927. Ultra-Violet Radiation and Actinotherapy. p, 38.  
William Wood and Co.,  
New York.
- (4) Bundesen, H. N., Lemon, H. B., Falk, I. S. and Coode, E. N.  
1927. Journal American Medical Association, Vol. 89,  
No. 3. p. 189.
- (5) Tisdall, F. F. and Brown, A.  
1927. American Journal of Diseases of Children, Vol. 34,  
p. 721.
- (6) Clark, J. H.  
1922. The Physiological Action of Light.  
Physiological Reviews, Vol. 2, p. 277.
- (7) Macht, D. J., Anderson, W. T. (Jr.), Bell, F. K.  
1928. Journal of the American Medical Association, Vol. 90,  
No. 3, p. 165.
- (8) De Kruif, Paul.  
1928. "Babcock Finds the Hidden Hunger".  
Country Gentleman, March 22, 1928, p. 22.
- (9) Hess, A. F., Weinstock, M. and Helman, F. D.  
1925. "The Antirachitic Value of Irradiated Phytosterol  
and Cholesterol".  
Journal of Biological Chemistry, Vol. 63, p. 307.
- (10) Rosenheim, O. and Webster, T. A.  
1927. "The Parent Substance of Citamin D".  
The Biochemical Journal, Vol. 21, No. 2, p. 389.
- (11) Hess, A. E. and Anderson, R. J.  
1927. The Activation of Sterol Fractions by Ultra-  
Violet Irradiation.  
Journal of Biological Chemistry, Vol. 74, p. 651.
- (12) Bethke, R. M., Kennard, D. C. and Kik, M. C.  
1925. The Relation of Sunlight and Green Clover Hay to  
Leg weakness in Chicks.  
Journal of Biological Chemistry, Vol. 63, p. 377.





- (13) Hess, A. E. and Weinstock, M.  
1924. "Antirachitic Properties Imparted to Inert Fluids and to Green Vegetables by Ultra-Violet Irradiation".  
Journal of Biological Chemistry, Vol. 62, p. 313.
- (14) Rosenheim, O. and Webster, T. A.  
1927. "Cholesterol and Vitamins".  
Lancet 212, p. 454.
- (15) Delafield, F. and Prudden, T. M.  
1925. Textbook of Pathology, Edition 13, p. 1042.  
William Wood and Co.,  
New York.
- (16) Hart, E. B., Steenbock, H. and Elvehjem.  
1924. "Dietary Factors Influencing Calcium Assimilation".  
Journal of Biological Chemistry, Vol. 62, p. 117.
- (17) Hart, E. B. and Steenbock, H.  
1924. "Prevention of Rickets in Swine".  
Wisconsin Agricultural Experiment Station Bulletin 362, p. 89.
- (18) Maynard, L. A., Goldberg, S. A. and Miller, R. C.  
Cornell University Memoir 86, p. 31.
- (19) Elliot, W. E., Crichton, A. and Orr, J. B.  
1922. British Journal of Experimental Pathology, Vol. 3,  
p. 10.
- (20) Hart, E. B., Steenbock, H. and Lepkovsky, S.  
1923. "The Nutritional Requirements of Baby Chicks".  
Journal of Biological Chemistry, Vol. 58, p. 33.
- (21) Halpin, J. G.  
1926. "Winter Sunshine and Egg Production".  
Bulletin 388, p. 109, Agricultural Experiment Station,  
University of Wisconsin.
- (22) Hart, E. B., Halpin, J. G. and Johnson, O. N.  
1926. "Light Increases Egg Production and Hatchability".  
Bulletin 388, p. 117, Agricultural Experiment Station,  
University of Wisconsin.
- (23) Hughes, J. S., Payne, L. F., Titus, P. W. and Moore, J. M.  
1925. "The Relation Between the Amount of Ultra-Violet Received by Hens and the Amount of Antirachitic Vitamin in the Eggs Produced".  
Journal of Biological Chemistry, Vol. 66, p. 595.
- (24) Hart, E. B., Halpin, J. G. and Steenbock, H., with co-operation of Johnson, O. N. and Black A.  
1922. "The Nutritional Requirements of Baby Chicks".  
Journal of Biological Chemistry, Vol. 52, p. 378.
- (25) Dunn, L. C.  
1924. "The Effect of Cod Liver Oil in Various Amounts and Forms on Growth of Young Chicks".  
Journal of Biological Chemistry, Vol. 61, p. 129.



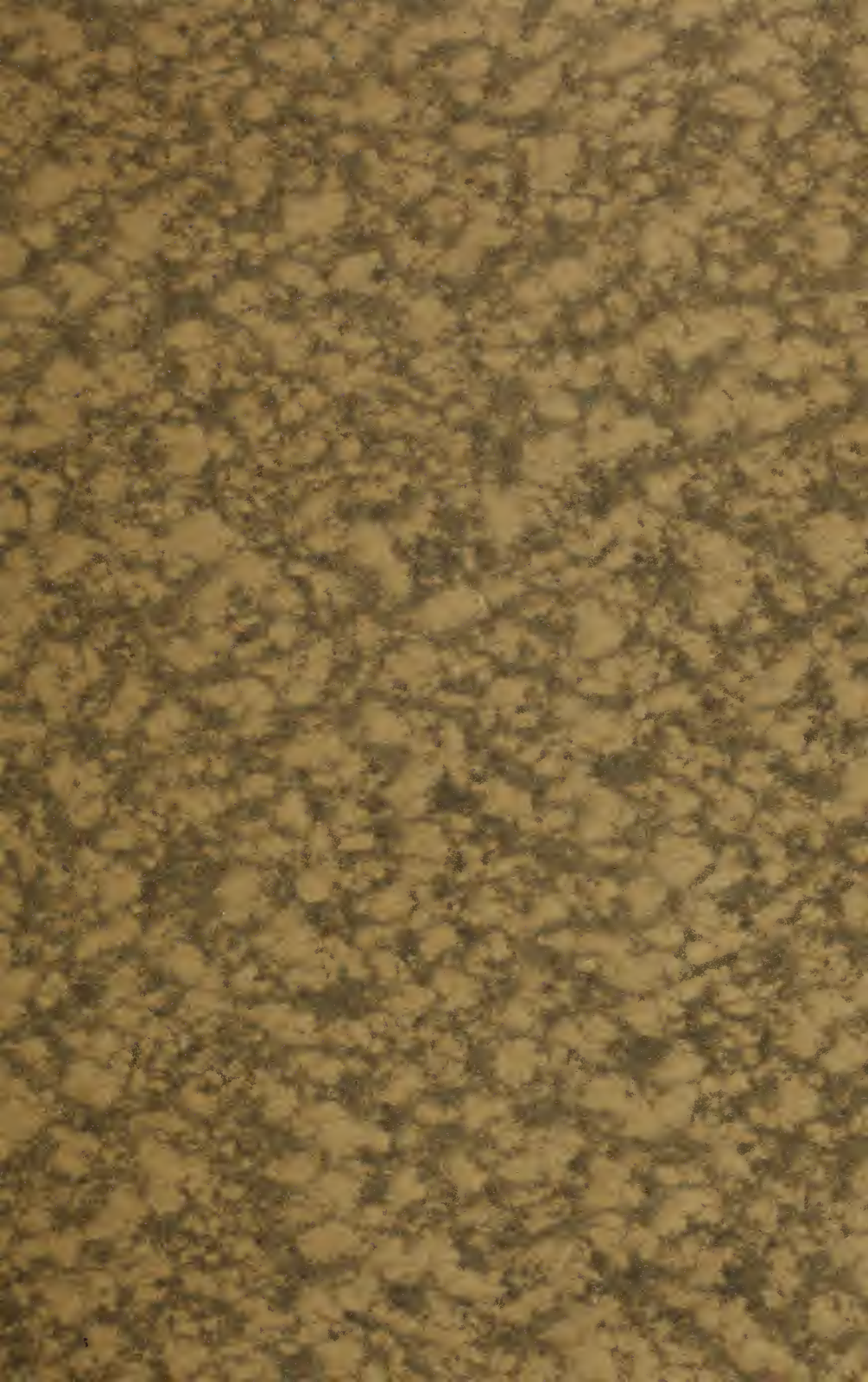
- (26) Hart, E. B., Steenbock, H. and Elvenjem, C. A.  
1924. "Dietary factors Influencing Calcium Assimilation".  
Journal of Biological Chemistry, Vol. 62, p. 123.
- (27) Gullickson, T. W. and Eckles, C. H.  
1927. "Sunlight and Growth of Calves".  
Journal of Dairy Science, Vol. 10, No. 2, p. 94.
- (28) Hart, E. B., Steenbock, H., Scott, H. and Humphrey, G. C.  
1927. "The Influence of Ultra-Violet Light on Calcium  
and Phosphorus Metabolism in Milking Cows".  
Journal of Biological Chemistry, Vol. 73, p. 67.
- (29) Steenbock, H., Black, E. B., Humphrey, C. A. and Black, A.  
1925. The Antirachitic Property of Milk and Its Increase  
by Direct Irradiation and Irradiation of Animals.  
Journal of Biological Chemistry, Vol. 66, p. 441.
- (30) Mitchell, H. H. and Keith, M. H.  
1924. Circular 282, p. 12, Agricultural College and  
Experiment Station, University of Illinois.
- (31) Maynard, L. A., Goldberg, S. A. and Miller, R. C.  
1925. "Influence of Sunlight on Bone Development in  
Swine".  
Journal of Biological Chemistry, Vol. 65, p. 653.
- (32) Steenbock, H., Hart, E. B. and Jones, J. H.  
1924. "Sunlight in its Relation to Pork Production on  
Certain Restricted Rations".  
Journal of Biological Chemistry, Vol. 61, p. 778.
- (33) Evvard, J. M., Culbertson, C. C. and Hammond, W. E.  
1927. "Sunshine, Exercise and Outdoor Feeding".  
American Herdsman, Nov. 1927, p. 5.
- (34) Bohstedt, G., Bethke, R. M., Edgington, B. H. and  
Robinson, W. L.  
1927. Reprint from Bimonthly Bulletin May and June, 1927,  
p. 79. Ohio Agricultural Experiment Station.
- (35) Evvard, J. M., Culbertson, C. C., Hammond, W. E., Bassett,  
C. F., in collaboration with Nelson, H. W.  
Leaflet No. 24, p. 4, Iowa Agricultural Experiment Station.
- (36) Bohstedt, G. and Robinson, W. L.  
1926. Bulletin 395, p. 73, Ohio Agricultural Experiment  
Station.
- (37) Bohstedt, G., Bethke, R. M., Edgington, B. H. and  
Robinson, W. L.  
Bulletin 395, p. 99, Ohio Agricultural Experiment Station.
- (38) Park, E. A.  
1923. "The Etiology of Rickets".  
Physiological Reviews, Vol. 3, p. 106.













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