A STUDY OF THE EFFECT OF DIET ON THE LEUCOCYTE CONTENT OF THE BLOOD OF DAIRY CALVES

THESIS FOR DEGREE OF M. S.

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INTRODUCTION.

Nutrition is a very important factor in the health and well being of all animals. Any deleterious effect of diet upon the health is manifest by a change, either permanent or temporary, in the appearance, composition, or functioning of some organ or tissue of the animal body.

Pathological conditions are also manifest by changes in the appearance, composition, or functioning of some part of the body. Leucocytes, the body's first defense against infection, are the most readily affected by disease.

The ingestion of food causes a temporary change in the leucocyte count of human blood. Disease and infection, also cause an increase in the leucocyte count in the blood of animals.

Nutrition affects an animal's power to overcome disease. It is possible that diet may affect the leucocyte count of the blood.

It was planned in this experiment to determine what effect the diet of an animal, may have on the leucocyte content of the blood of dairy cattle.

GENERAL DISCUSSION AND REVIEW OF LITERATURE

Leucocytes of the blood are an important link in the disease resisting mechanism of animals and are closely associated with the body's power to resist disease.

In human blood the number varies greatly from pathological and dietary factors and it is altogether probable that the same holds true with cattle.

Definition and Discussion

Leucocytes are small, colorless, ameboid cell masses found in the blood stream and tissues of the higher animals. Leucocytes found in the body vary in size, activity, and function.

The American Medical Dictionary (Dorland) gives the following types: (1) Small mononuclear leucocytes or lymphocytes, possessing a relatively large nucleus; (2) Large mononuclear leucocytes containing a large round or oval nucleus surrounded by a zone of protoplasm; (3) Transitional mononuclear leucocytes having a horseshoe-shaped nucleus; (4) The polymorphonuclear leucocytes or polynuclear neutraphil leucocytes, finely granular oxyphil cells with an irregularly shaped nucleus; (5) Eosinophil leucocytes, coarsely granular eosinophil cells with a lobed nucleus; (6) Basophil leucocytes or mast cells, having their origin in lymphoid tissue and found only rarely in the blood; (7) Myelocytes, or marrow-cells, occurring in bone marrow, but found in the blood only in pathologic conditions.

Burnett (1) and Bailey (2) gave the same classification.

Leucocytes have their origin in the embryonic stage along with other tissues of the blood. There are two important theories as to the origin of leucocytes: (3) the polyphylitic and the monophylitic theories. According to the polyphylitic theory the lymphocytes originate in the lymphoid organs while the other leucocytes originate in connective tissue, liver, spleen, and marrow. In adult life, however, they are formed in the marrow.

According to the monophylitic theory, the mesodermic tissue of the embryo gives rise to cells called mesoblasts. Some of these later develop into erythrocytes and others which remain undifferentiated not only throughout pre-natal life but also during post-natal and adult life and retain the power of later differentiating into either erythrocytes, leucocytes or lymphocytes. Weidenreich,(119) a supporter of this theory, states that the mother cell remains undifferentiated throughout adult life and constantly gives rise to more leucocytes to replace those being worn out and destroyed. Morphologically, this mother cell is apparently identical with the lymphocyte.

Lymphocytes, according to MacCallum (4) undoubtedly arise or are produced in the lymph nodes, wherever they occur in the body. The lymphocytes are then turned into the blood stream either venuous or arterial. Bone-marrow, spleen and possibly thymus probably play some part in their production, but it is still an uncertainity as to how large a part each one plays.

Leucocytes never take part in the formation of fixed tissue but are found in practically all tissue of the body in greater or lesser numbers,

(5) but as described above, leucocytes probably arise from fixed tissue.

Function of Leucocytes

Knowledge concerning the function of leucocytes is far from complete, but they probably act as defensive agents of the body against disease and infections. Leucocytes are phagocytes or "tramp cells" (6) adventitious in nature and very readily pass to sites of inflammation where they are instrumental in combating infection. Both Marchand (6) and Metchnikoff (7) agree that the movement of leucocytes is due chiefly to chemicotactic influences. It is chiefly the polymorpho-nuclear neutrophils that are concerned in phagocytosis. (8)

Infections of all sorts cause a regeneration of great intensity of leucocytes. The type of leucocyte produced to the greatest extent varies with the infection or disease. (9) Polymorpho-nuclear leucocytes are the ones usually showing greatest increase in numbers bringing with them an increase in the number of myelocytes. But some infections, as typhoid fever, cause an increase in the mono nuclears, this, probably due to a specific chemiotactic influence. It is difficult to produce an increase of the polymorphs with typhoid fever. According to Murphy (10) lymphocytes or small mononuclears show a relative and occasionally an absolute increase in numbers during typhoid fever. Apparently this type of leucocyte is of greatest value in antagonising this type of an infection. He also found that animals deprived of their lymphocytes by exposure to X-rays, were much more susceptible to tuberculosis than normal animals. In another test he found that implanted tumors grew rapidly in animals

without lymphocytes but that normal animals readily destroyed the implanted tumors.

The function of the polymorpho nuclears is the engulfing of bacteria and other injurious substances, and also producing a proteolytic ferment which acts best in an alkaline medium. These cells appear in greatest numbers in response to an invasion of bacteria or an infection. (11)

MacCallum (11) therefore, concludes that the regeneration of white cells or leucocytes is a selective process, and that the blood forming organs respond very promptly in the production of leucocytes. There is one difference, however, in the regeneration of the white and red cells. With leucocytes the action is to flood the blood stream with an abnormally large number of white cells rather than to merely replace the wasted or worn out cells as is the case in the regeneration of the red corpuscles.

Petterson (12) says that contrary to the opinion of some, the action of leucocytes is not restricted to attacking and destroying only dead or dying bacteria, but that the leucocytes of the animal body are also capable of destroying living bacteria which have the ability to propagate. He also points out that negative results obtained in vitro do not warrant the conclusion that no bactericidal capacity exists even in vivo. His results showed that leucocytes of a guinea pig were able to destroy B. Subtilis without the aid of the serum.

Brunts and Spilman (13) state that the leucocytic reaction in infection and intoxication is characterized at first by a hypoleucocytosis of short duration, which corresponds to the period of invasion. This is succeeded by a hyper-leucocytosis, during which stage the products destined for elimination are collected by certain forms of leucocytes and

conducted to the excretory organs.

M. Pettersson (14) states that his work shows that leucocytes have a bactericidal action.

According to Kobzarenko (15) the leucocytes of the horse possess the property of neutralising diphtheria toxin. This is not dependent upon the physico-chemical properties of their protoplasm but on their vital activity. These leucocytes are capable neither of absorbing or neutralising tetanus toxins. The leucocytes of the rabbit include 15 - 20 per cent of macrophages possessing this property, but the effect produced is not marked.

Action of Leucocytes in Metabolism

Very little is known of the function of leucocytes in metabolism.

Levene and Meyers (16) found that leucocytes turned hexoses into lactic acid. This is apparently the final product of the reaction, since lactic acid remains unchanged in the presence of leucocytes. The quantity of lactic acid produced is proportional to the quantity of sugar which disappeared. Leucocytes acting on glucose, mannose, fructose and galactose produced only lactic acid. Leucocytes also produced lactic acid from methyl glyoxal.

In a later experiment than the above, Levene and Meyers (17) reported that leucocytes practically free from bacteria were found to change sugars into methyl-glyoxal, and this in turn into lactic acid. By substituting glucose derivatives for glucose it was found that glycolytic enzymes of animal tissue had no effect on those hexoses in which one or more hydrogen atoms had been replaced by other radicles.

Leucocytes are small white ameboid cells found both in the blood stream and scatter/ed throughout the body tissue. They probably originate in the embryo from the "blood spots" found in the "area vasculosa" but in adult life from the spleen, bone marrow and lymph nodes. Their chief function is to protect the animal body from bacterial infection and from toxins. Leucocytes may possibly have some function in the intermediary metabolism of carbohydrates but this is doubtful.

Normal Leucocyte Count of Bovine Blood

Like most biological factors the number of leucocytes in the blood shows great individual variation. H. M. Feinblatt (20) states that the leucocyte count varies greatly due to many factors. Even the drinking of a glass of milk may give a 100 per cent increase. Single counts, he says are not reliable for diagnosis, but a number of counts giving a curve may be reliable, but this question requires more work. P. J. Du-Tait (18) states that the total leucocytes in healthy growing cattle normally vary between 5,000 and 10,000 with an average of 8,000 per cubic millimeter. About 49 per cent of these he finds are lymphocytes. Compared with human blood, ox blood shows a higher percentage of lymphocytes. The blood of calves usually has a higher leucocyte count than mature individuals, the leucocyte content normally reaching 12,000 - 15,000 per cubic millimeter and containing more lymphocytes, often as high as 80 per cent of the total leucocyte count being of this type.

Burnett (19) gives the total leucocyte count of cattle as found by Storch as follows: Bulls, 7,800; oxen, 9,400; cows, 8,200; young cattle, 11,600; and calves 15,700 per cubic millimeter. Hibbard and Neal (19)

found a leucocyte content of 8,950 per cubic millimeter for young cattle and Dimock and Thompson (19) found a total leucocyte count of 5,500 per cubic millimeter of blood for cattle of all ages.

Bastrom (21) states that the leucocyte count varies in different parts of the circulatory system. Wells (22) found the count varied between the sides of the heart, being higher in the right than in the left ventricle.

Semakine (118) on the other hand, found the leucocyte count practically the same in all parts of the circulatory system. He contrasts his work with that of Reeder and Schultz and others, who disagreed with him. Semakine (118) gives the explanation that the other investigators obtained their blood samples from dead animals while he obtained his from living animals or immediately after the death of the animals. His conclusions were that in living animals the count was the same in all parts of the circulatory system but the count did not remain uniform after the death of the animal.

Kjer and Peterson (24) say there is a variation in leucocyte count in blood drawn from different regions of the body. On the other hand, Ellerman and Erlandsen found no variation in 110 double examinations from 64 women. Apparently the evidence is in favor of the conclusion that the leucocytic content of the blood is fairly constant throughout the body.

Utendorfer (23) gives the following data as a result of his work with leucocytes of cattle: The number of leucocytes in the blood of cattle varies with age, being the highest in calves and young cattle. Sex and castration apparently have no influence on the number of white cells in the blood. There is no leucocytosis in cattle during digestion or pregnancy.

Ward (26) gives a normal variation of 3,000 in the leucocyte count of man with a "daily curve". The leucocytic content of the blood is lowest in morning and highest about five o'clock in the afternoon. The count increases after each meal except the last one and then gradually falls off during the period of rest or night.

In general then we may say the leucocyte content of bovine blood normally ranges from 5,000 to 10,000 per cubic millimeter with an average of 8,000. The leucocyte count of calves and young cattle probably is from 2,000 to 5,000 higher normally than the normal level of the count in mature animals. The leucocyte count is subject to rather wide variations.

Leucocytosis, Leucopenia, and Factors Causing Them

There are various types of leucocytosis but the American Medical Dictionary defines leucocytosis as "a temporary increase in the number of leucocytes in the blood".

Since the chief function of the leucocytes is the defense of the body against bacterial invasion and infection and toxic actions of various substances, there is no doubt a very definite relation between leucocytosis and disease resistance.

Causes of Leucocytosis

There are many factors which cause leucocytosis of greater or less duration and varying intensity. The causes vary from a mere change in position of the body to fatal infections and diseases.

Novy and Hazel Eppler (117) concluded that leucocytosis may be due to a chemical condition of the body. Urea, creatinin or amino acids may,

by their diuretic salt action, reduce the H_2O reserve of the body and produce a colloidal upset and increased protein metabolism with a resulting leucocytosis, but the diuretic salts themselves exerting no direct influence on the white cells. The leucocytosis induced indicates a postive chemotropism, exerted by some unidentified part of the protein molecule. Digestive leucocytosis points to the above conclusion. Leucocytosis from muscular exertion is accompanied by an increased metabolism and points to the above conclusion.

In bacterial infection there is a modification of the body colloids and water, causing a water shortage. An experimental leucocytosis results from an acute water shortage with a corresponding increase in body temperature and non protein, and blood nitrogen, and has many points in common with the physiological increase in count of digestive leucocytosis and leucocytosis from exercise.

The causes of leucocytosis may arbitrarily be grouped under experimental leucocytosis and leucocytosis from natural causes. The latter may be again subdivided into leucocytosis normally occurring and leucocytosis due to pathological conditions.

Leucopenia is defined by the American Medical Dictionary as "a deficiency in the number of leucocytes in the blood or a hypoleucocytosis". Leucopenia because of its intimate connection with leucocytosis and the causes of leucocytosis will be discussed with it and its causes.

The causes of leucopenia may be divided into the same general classes or groups as the causes of hyper leucocytosis.

Wells (28) gave the following discussion of leucocytosis and leucopenia.

There are two theories pertaining to the mechanism of leucopenia: (1) Actual destruction of the white cells. (Lowit) (29) and (2) a withdrawal of the cells from circulation into the capillaries of internal organs. (Goldscheider and Jacobs) (30). Leucocytosis of course would be the opposite action of the two above theories.

In support of the first theory, an intravenous injection in rabbits of dead bacteria caused leucopenia (chiefly of polymorphs) followed by leucocytosis. Sections of the spleen showed marked hyperemia; of bone marrow, hyperemia and an increased leucoblastic activity. The amount of material used in the injection did not appear to be a factor.

Goldscheider and Jacobs' (30) theory of repellant chemiotaxis of injected proteins in the blood probably explains the leucopenia immediately following the injection. No doubt forcing the white cells out of the peripheral circulation. It may also account for the increase in white cells in the spleen, liver, and bone marrow.

Wells on the other hand says it is postive chemiotaxis. The dead bacteria of the injected material are filtered from blood stream in the spleen and liver, and since the polymorphs are chiefly concerned in phagocytic activity they are drawn to these organs, and the decrease in the white cells during the period of leucopenia is almost entirely in polymorphs. The other types remaining practically normal throughout. The hyper-leucocytosis which followed the period of leucopenia, is probably caused by a discharge of the leucocytes back into the peripheral blood stream from the liver and spleen, where they had withdrawn during leucopenia.

Causes of Leucocytosis (Hyper and Hypo)

Pathological Causes Chief among the causes of leucocytosis are the common infectious diseases.

Findlay (27) found that both pellagra and beriberi cause an increase in the white cells content of the blood. Both of these diseases are "vitamin deficiency " or nutritional diseases, according to the American Medical Dictionary.

Johnson (31) reported that in at least 45 out of 50 cases, leucocytosis is present in tuberculosis, and always, if cavities are present and the vital resistance of the patient is low.

Muller and Reed (32) reported that hyperleucocytosis accompanies tuberculosis and lobar pneumonia. The leucocytosis increases with the severity of the disease.

Murrel (33) reported cases of spleenic leukemia which terminated in pulmonary tuberculosis. The white cell count reached the enormous figure of 695,000 per cubic millimeter of blood.

Baldwin and Wilder (34) reported a case of tuberculosis with high lymphocyte count. The other types of leucocytes remained normal or below normal. The lymph glands were enlarged. The erythrocyte count was low. On December 1st the leucocyte count reached a million and on December 10th death occurred.

Utendorfer (23) however, reports that leucocytosis appears during tuberculosis, but contrary to Baldwin & Wilder, he states that the relative importance of the various types of leucocytes does not change. He found that just before death from tuberculosis the white cell count falls until below normal. Tuberculin, he found, also causes leucocytosis in cows.

Tuberculosis and tuberculin both cause fever in cows. The fever thus caused, he states, probably induces the leucocytosis which follows, thereby giving the animal greater resistance with which to ward off the attack.

Sonnenberg and Federmann (35) reported that as the abscess develops in appendicitis the leucocyte curve increases. Bushnell (36) gives the same results.

According to Longridge (37), except in (1) mild catarrhal variety (2) fulminating appendicitis, where resistance of patient is too feeble to react to toxemia, and (3) where an abscess is of some standing and is thoroughly walled off, leucocytosis accompanies appendicitis in greater or less degree, depending on the virulence of the case. It is characterised by an increase of the polymorphs nuclears out of proportion to the total count.

Thayer of Johns Hopkins University (38) found a very marked eosinophilic leucocytosis in cases of trichinosis, sometimes as high as 68 per cent of total white count. Polymorphs decreased and small and large mononuclears same or lower in count than normally. Brown's work (39) substantiated the work of Thayer on trichinosis. Both men found a high total white cell count due largely to the increase in eosinophils, the other types decreasing in number.

Morse (40) found a hyper leucocytosis in both diphtheria and pneumonia but a somewhat higher count in diphtheria than pneumonia. Leucocytosis was severer in acute cases than in mild cases.

Gray (41) reported leucocytosis among soldiers in the following cases: (1) Slight leucocytosis in patients with "irritable heart"; (2) types classed as "constitutional inferiors" have a high leucocyte count; (3) lymphocytosis in patients with "irritable hearts".

File' (42) reported that leucocytosis always accompanied diphtheria. The leucocytic content of the blood increases with the severity of the disease and decreases during convalescence until a normal condition is marked.

Muir (120) found a decrease in neutrophiles in cases of smallpox but an increase in total leucocytic count.

Meunier (43) found hyper-leucocytosis as one of the first symptoms of whooping cough in every one of 102 cases.

Rogers (44) found that leucocytosis always accompanies Asiatic cholera. The intensity of leucocytosis increases with the severity of the attack. The leucocyte count very often reaches 40,000 per cubic millimeter of blood.

Charles (45) found that in Malta fever the polymorphonuclears were nearly absent, only the lumphocytes showing an increase. In other types of fever there was no such absence of polymorphs. He also found that inflammations caused by injections induced leucocytosis.

Saldanka (46) found extreme leucocytosis always accompanied cancer. Other investigators also reported leucocytosis accompanying cancer. None, however, reported cases of cancer without leucocytosis.

Head (47) reported extreme leucocytosis in dogs affected with septic infection, often reaching the extent of 400 per cent above normal.

Capps (48) reported presence of leucocytosis in cases of gastric ulcer but in only two out of five cases of gastric catarrh. He reported leucocytosis in cases of cancer but no digestive leucocytosis in 15 out of 17 cases of cancer of the stomach.

Ryfkagel (49) stated that leucocytosis accompanies or is found in all infectious diseases except typhoid fever, unless an abscess, peritonitis or

malaria is present along with the typhoid fever as a complication.

Russel (50) announced that leucocytosis in typhoid fever indicates perforation. In uncomplicated cases of typhoid fever the count is usually normal. In 37 examinations he found that it ranged from 2,000 to 12,000 per cubic millimeter.

Nageli (51) found that no leucocytosis accompanies typhoid fever, but rather as the disease progresses leucopenia develops. At the beginning of the disease the percentage of eosinophils increases but soon becomes normal in number.

Bryant (52) substantiates the work of Nageli.

From the above it appears that leucocytosis is present in all infectious diseases except typhoid fever. Leucocytosis is also present in pellagra and beriberi, both of which are nutritional diseases.

Artificial Causes of Leucocytosis

Injections Muir (103) found that subcutaneous and intra-peritoneal injections of Staphylococcus pyogenes in rabbits caused an immediate leucopenia, followed by leucocytosis in the case of intraperitoneal injection. Muir stated that his results agreed with the results Goldscheider and Jacobs obtained with intravenous injections of proteins. With the subcutaneous injection, leucopenia was not as well defined as it was in the intraperitoneal injection.

Wells (104) injected dead bacteria into splenectomized and non-splenectomized rabbits. In both cases leucopenia followed the injection in a very short time. The leucopenia in a few hours was followed by a marked leucocytosis. There was a slight tendency toward an increase in count following splenectomy.

Pepper and Miller (110) produced leucopenia in rabbits by the injection of living or dead typhoid bacilli into the peripheral circulation. Leucopenia is followed by a subsequent leucocytosis.

Webb (105) gave dogs anaphylactic treatments with horse serum. Blood counts from capillaries, liver, portal, intestinal, and kidney blood all showed leucopenia comparable to the leucopenia of the peripheral blood. Sections of these organs showed no aggregation of leucocytes. Leucopenia was present in spleenic blood, the bone marrow was deprived of its circulatory leucocytes to the same extent as the peripheral blood. He could not show that the leucocytes were actually destroyed in leucopenia. He also found that the pulmonary vein contained fewer leucocytes than the pulmonary artery during the anaphylactic shock. Sections of the lungs at the same time showed enormous quantities of polymorphs crowding the capillaries of the pulmonary organs.

Roemer (106) was able to produce leucocytosis by the injection of Buchner's protein into the circulation of rabbits, using eight cc. of a 10 per cent solution. The number of leucocytes per cubic millimeter of blood increased about threefold. One injection caused leucocytosis with the cells unevenly distributed and collected in small masses. Repeated injections increased the number of the masses of cells. The increase was found only in venous blood and leucocytosis disappeared when the protein action ceased.

Lassabliere and Richet (107) were able to produce leucocytosis by intraperitoneal injection of peptone which persisted for two and one-half months. The amount injected had little or no effect on intensity or duration of the leucocytosis.

Hooper, Robscheit and Whipple (68) found that hemoglobin exerted no marked effect on the leucocyte count whether administered orally, intravenously, or intraperitoneally.

Lassabliere and Rechet (108) found that a leucocytosis was induced by intraperitoneal injections of muscle serum diluted in 7.5% NaCl solution and that this leucocytosis was independent of the amount injected. They found that the effect of the muscle serum was due to a heat coagulable protein. They thought that ordinary toxin effects from small doses are corrected by the nervous system but that leucocytes are not controlled by the nervous system, which accounts for leucocytosis after very small doses.

Gray (41) found a marked leucocytosis after the injection of epinephrin in men. This increase in white cell count was much greater in patients with a positive reaction, than in men who did not respond to the drug. He found no greater variation in the differential formula after the injection than was found in the same subjects before the injection.

Berthelot and Betrand (109) gave guinea pigs intraperitoneal injections of allantoin and found it to increase the animals' resistance to local infection due to leucocytosis. The action of allantoin in promoting cuatrization is due in part, at least, to the favorable action of the substance on phagocytosis.

Castrin (102) injected 1 mg. of adrenaline into a man and within 30 minutes he found a marked increase in both lymphocytes and polymorphonuclear leucocytes.

Hatigon (111) produced leucocytosis by the subcutaneous injection of one mg. of adrenaline. The first hour showed an increase of lymphocytes,

the second hour a decrease in lymphocytes but an increase of neutrophils. He found it usually required six hours for the count to again become normal. With a double dose (two mg.) he found that leucocytosis persisted twice as long.

Harvey (112) produced almost immediate leucocytosis by injections of pilocarpin, muscarine, and barium chloride. None of these had any effect when administered orally.

Shaw (113) was able to produce leucocytosis in only eight of fifteen cats by intravenous injections of sodium cinnamate. Animals were anaesthetized with ether before blood was drawn from the juglar vein. Total count did not change in the remaining seven animals, but the percentages of the various types changed.

Lisin (114) found that intravenous injections of soluble mercury salts led to various leucocytic changes: either hyper leucocytosis and hypo-leucocytosis, or an increase of polymorphs or eosinophils may result. Subcutaneous injections had little effect on the leucocytes. Mercury probably has no specific effect on the leucocyte count of the blood.

Lassabliere and Rechet (115) found that intraperitoneal injections of one cc. of .7 per cent NaCl solution was followed by leucocytosis to the extent of 14,500 per cubic millimeter of blood. A similar injection of one cc. of propeptone gave an average leucocytosis of 18,800 per cubic millimeter.

Bastrom (21) found that an injection of $NaHCO_3$ was followed by increase in white cell count in heart blood. He accounted for this increase

by a simultaneous decrease in the number of white cells in the cutaneous vessels and in the liver and spleen.

Acids, Bastrom found had the opposite effect, that is a decrease in the white cell count in the heart blood and an increase in the liver, spleen and cutaneous blood vessels. He attributes leucocytosis to a redistribution of the leucocytes in the body due to a change in their adhesive power which is strengthened by acids and weakened by alkalies.

Margarette Levy (116) was able to produce leucocytosis by single injections of radium. Small doses had much greater effect, proportionately than large doses.

Changes in Leucocyte Count due to Normal Conditions

Digestive Leucocytosis Digestive leucocytosis is a temporary leucocytosis occurring normally after eating a meal.

Cabot (Chemical examination of the Blood 1900) (53) classes the increase of white cells during digestion as polymorphonuclear leucocytosis. Ehrlich and Logarus (53) claimed the relative proportions did not change. Aseoli (53) described a digestive leucocytosis which he considered, like leucocytosis of infection, as due to a chemiotactic influence exerted upon the white cells. Pohl (53) claims there is an excess of leucocytes in the veins during digestion, not an increase in leucocytes of the body.

According to Kroluntsky (54) digestive leucocytosis is the second stage of blood reaction during digestion and is due to absorption of digested material which reaches the liver by way of the portal vein and then excites the liver to the production of anti-leucocytolysins; the

latter neutralizes the leucocytolysins secreted by the spleen and thus cause the appearance of hyper-leucocytosis. This sequence is readily produced by intra rectal injection of amino acid. In an earlier paper Kroluntsky (55) obtained very similar results with the intrarectal injection of nutritive liquids either before or after the ingestion of food. The decrease in leucocytes (due to increased secretion of leucocytolysins) immediately after physical excitation or ingestion of food after an intrarectal injection, indicates the existence of a functional relation (through the nervous system or otherwise) between the spleen and bone marrow, whereby the latter is excited to the production of leucocytes to repair the loss occasioned by theleucocytolysins originating in the former.

Manoukhine (56) criticized Kroluntsky's technique and interpretation of results. He says leucocytolysis (due to leucocytolysins produced in the spleen and appearing in the blood) is of initial occurrence; this is followed by leucocytosis (occasioned by the neutralizing action on the leucocytolysins of the anti-leucocytolysins produced by the liver) and the latter is in turn replaced by a leucocytolysis. This entire sequence (simultaneous leucocyte count and determination of leucocytolytic power of the serum)was observed within two hours after an intrarectal injection of 20 cc. of a one per cent Witte peptone solution in a dog.

Claude, Santinoise and Schiff (57) substantiated the work of Kroluntsky in that they believed digestive leucocytosis follwoing a meal is due to a functional relation between the liver and the vago-sympathetic tone.

Gelstein (58) advanced the theory that digestive leucocytosis depends not only on the motor and secretory functions of the stomach and intestines but also on the functional capacity of the bone marrow in producing leucocytes.

Voronoff and Riskin (59) working with dogs and men during fasting and absolute rest found the leucocyte count to vary during the day, the changes being different in different individuals. The count increased at the usual meal hour showing a "habitual leucocytosis". An exaggerated leucocytosis appeared in dogs under certain external stimuli associated with sham feeding. This leucocytosis was found to be due to a conditional reflex. The alleged digestive leucocytosis is evidently not a constant reaction from absorption of products of digestion and secretion but is a conditional reflex reaction, in this same way.

Van Leeuwen, Bien and Varekamp (60) worked with humans and found that within one to two minutes after a meal there was a sharp fall in the leucocyte count of the blood, but a rise again in ten to twenty minutes. Occasionally a second fall occurred in thirty to fifty minutes and a second, slow but gradual rise in the leucocyte curve.

Quite often the "curve" after a meal varies greatly from the curve described above. They found that the counts at twenty minute intervals on the same patient after eating the same food on different days, usually gave somewhat different and occasionally widely divergent results.

Gottlieb and Waltner (61) worked with forty-five children. They made three or four counts in order to control their results, but found no constant variation in the leucocyte count before and after meals. They found the variation equally as great after meals as before meals. They concluded, therefore, that a genuine alimentary leucocytosis did not exist. They may have erred in considering only the variation rather than the number showing an increase in leucocyte count after a meal as over and against those showing a decrease in leucocyte count after a meal.

According to Brodin and Saint Girons (62) the leucocyte count remains fairly constant during fasting, but immediately after the ingestion of food the leucocyte count falls and then it increases, the largest number being found at from two to three hours after ingestion, then a second fall and another increase, reaching a second maximum in from four to six hours. They also found that the intensity of digestive leucocytosis varied with the kind of food ingested. Raw eggs and potatoes, ranked about the same, boiled milk slightly more in its effect and much greater effect from the juice of raw meat than from the three foods named above. Raw meat exerts a greater influence on the count than does cooked meat. Usually there is an abrupt fall in the count after the maximum is reached which occurs in about five hours. The work of Goodall, Gulland and Paton (63) agreed with the work of Bradin and Saint Giron throughout.

Therefore, we may say that digestive leucocytosis is a temporary increase in the leucocyte count of the blood probably due to a combination of a functional or conditional reflex action on the nervous system due to the physical presence of food in the stomach and a chemiotactic influence of some nature exerted by the food in the stomach on the blood itself.

The Effect of Diet on the Leucocyte Count

Howe and Hawk (64) recorded an increase of the polymorphonuclears, followed by a drop below normal at the end of seven days in fasting men. The opposite course held for lymphocytes. The taking of food of any form tended to return the count to its normal condition. In dogs they obtained the same results except no initial rise in polymorphs but animmediate de-

crease. Brodin and Saint Giron (62) reported the leucocyte count as constant during fasting.

Whipple, Hooper and Robscheit (65) found that during fasting there was no regeneration of blood in anemic dogs. There was in one group merely a maintenance and no increase in the leucocyte count. Age of the animal was no factor. In their second trial (66) they found a great variation in leucocyte count of anemic dogs during fasting. In no case was there a regeneration of the blood on an increase in white cell count, but rather a decrease. In some the decrease was small but in other individuals it amounted to a fifty per cent decrease from the original count.

In all the results given above it was found that immediately upon the ingestion of food after a period of fasting there was an increase in the leucocyte count, either returning to the normal condition or causing leucocytosis.

Goodall, Gulland and Paton (69) fed dogs meat and water after fasting and found an immediate leucocytosis produced. They concluded it to be digestive leucocytosis.

Fasting, then, probably does not greatly affect the leucocyte count, except in cases of prolonged fasting where it reduces the count. The increase in leucocyte count following the end of the period of fasting is probably digestive leucocytosis.

Brinchman (70) found that feeding fresh ox spleen caused a reduction of the leucocyte count in both guinea pigs and rabbits. No such reduction of white cell count occurred in animals fed an equal amount of fresh raw meat in which the iron content had been adjusted to that of ox spleen. In anemic animals spleen acts like other iron preparations, decreasing the

destruction and favoring the regeneration of blood cells.

Leake (71), on the other hand, found that a marked leucocytosis followed the oral administration of the combined extracts of spleen and red bone marrow to either dogs or rabbits. The increase amounted to fifty per cent in rabbits. The higher count was maintained as long as the daily administration of the extracts was continued.

Whipple, Hooper and Robscheit (65) produced secondary anemia in dogs by drawing a certain per cent of their blood, in order to produce the same degree of anemia in all animals, then worked on the effects of various feeds on the regeneration of the blood and on the leucocyte count.

During fasting there was no regeneration, merely a maintenance of the leucocyte count, but when the dogs were fed meat there was an immediate rise in white cell count which usually rose above normal limits. The rate of increase in the leucocyte count was increased when a larger quantity of meat was added to the diet.

In a second experiment with dogs with experimentally induced anemia, Whipple, Hooper and Robscheit (66) found a decrease in leucocyte count due to fasting. When the animals were fed a diet of yeast, bread and milk there was produced a change in the leucocyte count of the animals' blood but the results varied too much to draw any definite conclusions. About an equal number showed a slight increase and a slight decrease in leucocyte count. Sugar feeding following both fasting and a bread and milk diet, invariably gave a decrease in white cell count. If the sugar diet was followed by a meat diet there was another rise in count immediately following the feeding of the meat ration which continued while the meat was fed.

In a third experiment along the lines of the first two, Hooper, Whipple and Robscheit (67) found that the leucocyte count of dogs varied greatly on a bread and milk diet. If the dogs received an unlimited amount of bread and milk after a period of restricted bread and milk feeding their leucocyte count would increase. The animals varied in reaction to a mixed diet containing meat, after a period of bread and milk feeding. All of the dogs on the mixed diet over two days showed a constant or an increased leucocyte count. Of the animals on the mixed diet only one day, some showed a slight lowering of leucocyte count and the others showed an increase over the previous day's leucocyte count.

With two dogs a cracker meal, lard and butter diet gave an increased white cell count over the count while on a bread and milk diet, the addition of milk powder to the ration gave no further increase in the leucocyte count. Cracker meal, alfalfa meal, lard and butter, fed for only one day, gave an increase in the count over the bread and milk diet but not enough greater than the count while on butter, lard and cracker meal diet, to warrant drawing any very definite conclusions. In another case the alfalfa meal, cracker meal, lard and butter combination gave a slight decrease in count after the change from a bread and milk diet.

The feeding of boiled rice, potatoes and milk to three dogs after a bread and milk diet showed a decrease of approximately fifty per cent in the leucocyte count. In a fourth animal the count remained practically unchanged at first, then a drop in count, and in a fifth there was a slight rise in count, then a drop to slightly below the count on the bread and milk diet. These animals were next placed on a mixed diet, which immedi-

ately raised their leucocyte count, and then returned to the rice-potato-milk diet. When returned to the rice-potato-milk diet, four of them showed a drop in count ranging from 25 to 75 per cent of the original count. The one showing a slight increase at first in the first trial varied greatly in leucocyte count in this trial. It alternately showed a count higher, then a count lower than the count while on the mixed diet, finally becoming nearly constant at a count approximately the same as the count it had while on the mixed diet.

One dog, fed bread and milk, gave a normal leucocyte count in anemic condition. On changing its diet to include cane sugar and glucose there was a fall in its leucocyte count. A second change to include casein and cane sugar in the diet gave a very decided second drop in the leucocyte count. The same diet with an increased amount of casein gave a small increase in the leucocytic content of the blood. A diet of sugar, casein, lard and butter caused a very decided increase in the count and an increase in the casein content of the feed at this point caused the count to remain constant a day or two followed by a drop in the count. Gliadin in the ration instead of casein, gave no change in the count after a bread and milk diet.

In another trial (67) they found that in all their animals except two, a lean meat diet following a diet of bread and milk caused an increase in the leucocyte count of the blood. In these two cases the count was abnormally high at the time the diet was changed, being 45,000 and 26,000 per cubic millimeter of blood, respectively. A mixed diet following the diet of lean meat gave a decrease in white cell count.

Pure diets of heart or liver tissue gave a lower blood leucocyte count when following a bread and milk diet. A mixed meat and vegetable diet following these diets gave an increased count. Liver tissue added to the bread and milk diet increased the leucocyte count. Liver tissue and beef extract with bread, milk and sugar in various combinations gave no conclusive results as to their effect on leucocyte count. When fed after a bread and milk diet, the count in nearly all cases remained essentially the same. The changes were no greater than a normal variation in the leucocyte count of an animal's blood from day to day on a bread and milk diet.

Using a procedure similar to the one used in the preceding work, Whipple, Hooper and Robscheit (68) found that iron in the form of Bland's pills had no influence on the leucocyte count of dogs. Hemoglobin administered orally exerted no influence on the leucocyte count of dog's blood.

Goodall and Paton (72) produced leucocytosis in small animals by feeding high protein diets. The animals were killed and autopsied. The leucocytosis was not permanent, lasting only while the high protein diet was fed.

Julia Jenks (73) working with rats along the line that Hooper, Whipple and Robscheit worked with dogs, found that any diet permitted greater regeneration of blood after artificial anemia than could be attained during fasting. Proteins supported a more rapid regeneration than either carbohydrates or fats as a sole nutrient. Diets of vitamin-rich food supported a more speedy regeneration of blood than any other diet containing only

one food factor. While she does not give any data concerning the changes in leucocyte count it is probable that the count follows the blood regeneration curve rather closely as it did in the work of Whipple, Hooper and Robscheit. That is, diets permitting rapid regeneration of blood allow an increase in the leucocyte count and those not supporting blood regeneration cause no change, or a drop in the leucocyte count.

Heintz and Welker (74) found that the ingestion of three yeast cakes daily by normal humans induced a decided leucocytosis, which continued as long as the yeast was ingested.

Cramer (75) found that rats on a vitamin free diet had leucopenia. Rats on a diet poor in vitamin B showed leucopenia. Rats on diets low in A and B showed no different results from those on diet low in B. A normal leucocyte count was found in rats on a diet deficient in vitamin A, but with an abundance of B. Feeding vitamin B in the form of yeast after causing leucopenia by its deficiency, immediately causes a return to the normal "count level".

Dr. Cramer then concluded that the effect of vitamin-rich diets in causing leucocytosis (chiefly lymphocytosis) was due to a stimulation of the functional activity of lymphoid tissue and that this is associated with more rapid growth and a general improvement in condition.

Mitchell (76) found that bottle fed babies do not constantly show leucocytosis, but that more show leucopenia. This decrease is greatest from one to two and one half hours after taking milk when the count tends to become normal again. When a rise in count does occur it is usually immediately after feeding and begins to decline within thirty minutes after tak-

ing the milk, Crying, struggling or cooling the part of the body from which the blood is drawn increases the count.

Adelsburger (77) reported that after taking its mother's milk, infants show immediate leucopenia. Artifical food mixtures cause or induce leucocytosis. The changes in leucocyte count were not influenced by the bacterial flora of the milk ingested. These results are in direct contradiction of the results reported by Mitchell.

Liotta (78) was able to induce a slight leucocytosis in guinea pigs by feeding them a diet of oats until they were reduced to scurvy.

Puxeddu (79) was able to show that sodium bicarbonate taken orally, even while fasting caused leucopenia in addition to its indirect effect by reducing the hydrochloric acid of the stomach. He also found that hydrochloric acid taken while fasting induced leucocytosis.

Pagniez and Plichet found that the ingestion of 50-150 cc. of 0.4 per cent hydrochloric acid caused leucocytosis in normal subjects. This increase in leucocyte count is quite analogous in degree and in duration to that observed after the ingestion of a protein rich meal. A patient suffering from gastric neoplasm and showing marked achlorhydria, and who usually reacted with leucopenia after a protein meal (milk) showed a distinct leucocytosis after the ingestion of hydrochloric acid. This led Pagniez and Plichet to believe that the secretion and absorption of hydrochloric acid during digestion furnishes at least one factor in the mechanism of alimentary leucocytosis.

Ciaccio (81) also found that leucocytosis occurred in thirty minutes after the introduction of hydrochloric acid into the stomach of a fasting dog, reaching a maximum in about one hour, then diminishing and disappear-

ing between the second and fifth hours. In some individuals leucocytosis was preceded by leucopenia. Ciaccio believed that digestive leucocytosis then was not due to the digestion of proteins but to the hydrochloric acid secreted by the stomach during digestion.

Seyderhelm (82) and Hamonn reported that ether, ($CHCl_3$) chloroform, ethyl bromide, chloral hydrate, urethan, alcohol, sulfonal and morphine when administered orally to rabbits in quantities to cause narcosis, also cause leucocytosis. The degree of leucocytosis depends upon the severity of the narcosis. Seapolamine, does not cause narcosis, neither does it cause leucocytosis. They concluded that the leucocytosis was in response to the toxin effects of the drug or chemical rather than a reaction to the so-called fatigue leucocytosis as indicated by the correlation between the production of narcosis and leucocytosis.

Adelsberger (77) found that the application of concentrated salt solutions to the intestines led to leucocytosis. After the feeding there is a great individual variation as to the time of the appearance of the leucocytosis, but it usually occurs in from two to three hours.

According to Dixon (83) colchicin taken orally causes leucopenia at first, chiefly of the polymorphonuclears, then a rise in count to above normal number, causing leucocytosis. The cells increased in number and became swollen. Colchicin causes a slow death unless given in increasingly large doses.

De Rengi and Boeri (84) found that calomel, sublimate, magnesium, sulphate, podophyllin and croton when introduced into the intestine cause an increase in the leucocytes throughout the system. However, they were

unable to demonstrate any protective action against disease by this leucocytosis.

Schwarz (85) took thirty patients suffering with various diseases and treated them for thirty days with amounts of silicon dioxide mineral water. In every case there was a decided increase in the leucocytic content of the blood. He attributed this leucocytosis to the mineral water.

According to Roth (86) quinine given in single doses acted as follows: (1) Preliminary leucocytosis appeared shortly after drug is given and is probably caused by a contraction of the spleen and other tissue. (2) Leucopenia followed in one to two hours. (3) A secondary leucocytosis was very marked.

If administered to a dog for a long period the blood picture is essentially the same, but death results.

High protein diets cause greater leucocytosis than other types of diets. Any diet after fasting will increase the leucocyte count. In fasting the count usually remains about constant or may decrease. Pure diets of liver or spleen tissue cause leucopenia. Many drugs taken orally cause leucocytosis. Any causing narcosis cause leucocytosis.

Parturition and the Leucocyte Count

Baer (87) found leucocytosis during pregnancy, appearing during the ninth month and increasing until after parturition. Leucocytosis was more marked in primiparas than in secundiparas and slight in women who have borne more than three children. The maximum of the curve was reached the first day of puerperium, after which there was a rapid and constant decline to

about the tenth day when the count was again normal. Leucocytosis he found was increased by a duration of labor beyond twenty-four hours.

The onset of lactation did not affect the count except in primiparas, on the fourth day there was a slight elevation in count over the count of the preceding day. Age was no factor except in primiparas. Women twenty years old or younger in primipara showed greater leucocytosis than any other group.

Hofbaurr (88) claimed that there is a distinct leucocytosis during and after parturition, up to twelve hours when the count began to gradually drop to normal again. Henderson (89) gave the normal leucocyte count of women as 8,000; immediately after parturition as 21,000; and 12,000 at the end of five days after parturition.

Hibbard and White (90) found leucocytosis present in over 75 per cent of all labor cases. Leucocytosis was more frequent and higher in primipara than in other cases. During convalescence the count fell, rapidly at first, and then slower until the leucocytic content of the blood was again normal. About the seventh day they found there was usually a small secondary rise in the count. They found the count to be universally higher in young women during puerperium, regardless of the number of children previously borne by them. Hibbard and White (90) found that the count increased as the labor advanced, being highest at the completion of labor.

They found that breast inflammation even though mild causes an immediate leucocytosis, so a leucocyte count is of no value in the diagnosis of a breast abscess.

All authorities agree that there is a decided leucocytosis during primipara and secundipara but that it is much less severe in polypara and less severe in in older women than in young women, and that pregnancy does not cause leucocytosis. Leucocytosis due to parturition usually disappears in from five to twelve days after labor is complete.

Heat and Cold and Leucocyte Count

Lapinski and Svenson (91) found that cold baths temporarily increased the leucocyte count in humans. Thayer (92) also found a very distinct increase in leucocyte count as early as thirty minutes after a cold bath.

Hames (93) worked with 29 humans. He found an increase in leucocyte count from 3,000 to 5,000 or more per cubic millimeter of blood in every case, fifteen minutes after natural or induced sweating. In some cases the increase amounted to 100 per cent. One half hour after being wiped dry and being transferred to a fresh bed, their leucocyte counts were back to normal.

Apparently a change of external temperature, surrounding the body to either extreme, hot or cold, induces temporary leucocytosis.

Light Rays and the Leucocyte Count

Orr (94) found no constant difference in the leucocyte counts of patients located in the ward and those treated in the open air with only their faces exposed. Patients suffering from fever and having leucocytosis in the ward showed a slight decrease in leucocyte count when treated in the open air with only their faces exposed. The lowering of the leucocyte

count was probably due to the alleviation of the fever and not to the exposure.

Taylor (95) reported that theexposure of white men to the tropical sun tended to increase the number of lymphocytes in their blood resulting in lymphocytosis. He compared the action of the sun on men to the action of X-rays on small animals. He ascribes the action to the ultra-violet light or ray, which is rather high in the tropical sun.

Aschenhein (96) subjected 31 patients to a leucocyte count before and after one hour's exposure of the naked body to the direct action of the sun's light. In 80 per cent of the cases he found there was a general leucocytosis in the peripheral blood, a relative increase in lymphocytes and a decrease in polymorphs. Lymphocytosis is regarded by many authors as a defensive reaction against tuberculosis. Aschenhein suggest that this may account for the favorable action of sunlight in combating tuberculosis.

Campbell and Hill (97) found that ultra-violet rays markedly increased the leucocytic content of frog's blood.

Clark (98) obtained the following results by direct radiation on rabbit's ears of light from an iron arc. (1) Region of ultra violet light has no effect on absolute number of polymorphs (wave shorter than 300 microns) but produces a marked lymphocytosis which lasted about three weeks. (2) The near ultra violet light (330 - 390 microns) has a marked depressing effect on the lymphocytes and to a less degree on the polymorphonuclears. (3) The region between 450 - 650 microns has a stimulating action on both, and (4) the wave lengths longer than 650 microns (red and infra-red light) produce no effect on blood beyond the immediate drop in lymphocytes which

occurs upon exposure to light of any kind.

Mattrom and Russ (99) exposed white rats to "soft X-rays" (low penetrating power) for twelve minutes. At the end of that time they found that leucopenia to the extent of 50 per cent or more had resulted. Exposure to B rays for 34 minutes also produced leucopenia, but to a slightly less degree than the "soft X-ray", probably due to its lower penetrating power.

Buchanan (100) used X-ray treatment for leukemia and found an immediate and rapid reduction in the leucocyte count. Others not mentioned here noted the same results. Buchanan ascribed the lowering of the count to (1) inhibiting of over production of leucocytes by the red bone-marrow and (2) a destructive influence on the white cells themselves. Cramer (75) found that X-rays destroyed the circulating lymphocytes.

Sunlight then increases the leucocyte count but exposure to X-rays and B ray lowered the white cell count, being especially effective in destroying the circulating lymphocytes.

Exercise and Position and Leucocyte Count

Jorgensen (101) found the leucocyte count of man to be higher when reclining than when erect. In some cases the involved increase in count may be as high as 100 per cent. The high count remains practically constant as long as the position is maintained. The change in count occurred whether the change in position was affected immediately or gradually.

Castrien (102) reported that a marked increase in lymphocytes and polynuclears followed muscular exertion resulting in an increase of the

total white cell count. This Castrein attributed to the driving out of the leucocytes from the blood forming organs.

Summary of Review of Literature

Leucocytes are small colorless phagocytic cells found in blood and body tissues, whose chief function is the defense of the body against bacterial invasion. They have their origin in the red bone marrow and the lymph nodes. There are several types of leucocytes, each type apparently having a specific function in combating disease. The number of leucocytes normally found in cows' blood varies from 5,000 to 10,000 with an average of 8,000 per cubic millimeter of blood in mature cattle. Sex and castration have no influence on the number. Young cattle have a higher leucocyte count than mature animals, 13,000 per cubic millimeter being about the average for calves at birth but 15,000 is considered normal.

The count normally decreases during the night and increases during the day, being greatest around five o'clock. It increases after each meal except the last one of the day.

Among the natural causes (causes occurring in nature) of leucocytosis, disease is probably the most important from a health standpoint.

If an animal becomes infected with either a local infection or an infectious disease there follows a preliminary leucopenia which corresponds to the period of invasion of the organism. In all cases of infection and all diseases, except typhoid fever, there follows a gradual increase in leucocyte count, or leucocytosis. This indicates that the animal body is resisting the disease. In typhoid fever there follows a continued fall

in total white cell count but the per cent of eosinophils increases. Leucocytosis in typhoid indicates perforation.

Digestive leucocytosis occurs after the ingestion of food of any kind. It appears to be due to a combination of chemical stimulation and a physical stimulation due to the presence of food in the stomach. It appears to be a precaution of nature against dangerous bacteria which may gain entrace to the body by way of the digestive tract.

Diet also affects the leucocyte count. Foods high in protein or acid in nature tend to raise the count.

Pregnancy does not affect the leucocyte count but parturition causes leucocytosis.

Either extreme heat or cold on the body surface causes leucocytosis.

X-ray and B ray causes leucopenia and ultra-violet ray tends to increase the white cell count. Sunlight on the body, or exposure to tropical weather all tend to increase the leucocyte count.

Muscular exertion increases the count. There is also an increase in man's blood upon reclining.

Since some foods, sunlight, all infectious diseases, and some nutritional diseases cause a change in the leucocyte count of humans, it is very probable that feed will also affect the count of bovine blood.

EXPERIMENTAL WORK.

OBJECT OF EXPERIMENT

Authorities agree that pathological conditions affect the leucocyte count of the blood. Several investigators found that diet affected the white cell count of the blood of rats.

Investigators agree that ingestion of food causes a digestive leucocytosis, which varies in duration and intensity with the type of food ingested.

In the course of experiments conducted by the Department of Dairy Husbandry, leucocyte counts were made in gathering data on the various animals on experiment. These counts showed variations much greater than should be found in normal animals on a normal diet.

The object of this experiment is to determine the effect of different rations on the leucocyte count of the blood of dairy cattle.

PLAN OF EXPERIMENT

1. It is planned to feed rations restricted in quality and quantity of roughage in order to study their effect, if any, on the leucocyte count of the animals' blood.

2. The rations fed in some cases will develop nutritional diseases and disorders. Where these develop the basal ration will be supplemented in an attempt to cure the disease.

It is planned to use as many calves on as widely varying rations as possible in order to study the variations caused in leucocyte count by a change in, or restriction of roughage.

A leucocyte count of the animals' blood will be taken each week or oftener if the condition of the animal warrants it. This will be done in order to get a "leucocyte curve" rather than individual counts.

Determinations will also be made of the blood calcium, phosphorus, chlorine, carbon dioxide, non-protein nitrogen.

A study will also be made to determine if there is a seasonal variation in the leucocyte count of an animal's blood irregardless of other conditions.

Observations regarding health and appearance of the animals will be made from time to time.

METHOD OF PROCEDURE

Choice of Animals

Grade Holstein, Jersey, and Brown Swiss calves were used in this experiment.

Choice of Feeds

The rations fed consisted of the following feeds: (1) whole milk from Holstein herd, (2) skim milk from mixed dairy herd, (3) powdered calcium carbonate, acid phosphate, sodium carbonate, tri-calcium phosphate, magnesium phosphate, iron oxide all chemically pure, (4) finely ground limestone rock, raw rock phosphate, bone meal, commercial grades, (5) precipitated bone meal, (6) syrup of iron phosphate U. S. P., (7) alfalfa meal, finely powdered green alfalfa leaves, (8) oat hulls, outer covering of the oat grain, (9) wheat straw, (10) wheat bran, (11) Norwegian cod liver oil, (12) oxidized Norwegian cod liver oil, (13) tankage, sixty per cent protein, (14) blood meal, eighty per cent protein, (15) flowers of

sulphur, (16) pure corn starch, (17) alfalfa tea, the water extract of alfalfa hay, (18) alfalfa mineral mixture, composed of finely powdered chemically pure minerals.

Preparation of Feeds

Oxidized cod liver oil was prepared by passing air through cod liver oil heated to a temperature of one hundred and forty degrees Centigrade for a period of twelve hours.

The alfalfa tea, was the water extract of alfalfa hay prepared by leaching the dried green alfalfa hay with luke warm water for twenty-four hours.

The alfalfa mineral mixture was prepared by the tabulated amounts of finely powdered materials:

1,365.0 gr.	casein
56.0	$Na_2 H PO_4$
26.6	Na Cl
47.5	$Na H CO_3$
162.0	$K_2 SO_4$
26.4	$K CO_3$
282.2	$Ca CO_3$
140.0	$Mg CO_3$

The syrup of iron phosphate was made by dissolving eight and six tenths grams of iron wire in sixty-two and five tenths cubic centimeters of phosphoric acid diluted with sixty-two and five tenths cubic centimeters of distilled water. The resulting solution was then filtered into seven hundred cubic centimeters of U. S. P. syrup and made up to one liter by adding distilled water.

Care, Shelter and Feeding Methods

The animals were under the care of a competent feeder under the supervision of the men in charge of the experiment. The animals were sheltered in the experimental barn. They were all kept and fed in individual stalls and allowed to exercise in a lot which was free of all edible material. In all except a few noted cases the animals were bedded on shavings. The animals had free access to water in the exercise lot.

The animals were fed regularly twice daily. Milk scales, graduated in tenths of one pound, were used in weighing all milk and concentrates. Silage and dry roughage were weighed on a larger set of pound scales.

Supplements as, cod liver oil, oxidized cod liver oil, raw linseed oil, paraffin oil and syrup of iron phosphate were measured in a cylinder graduated in cubic centimeters. Ferric oxide and minerals of its nature fed in small amounts were weighed on small gram balances. All feeds used as supplements to milk were stirred into it well before feeding. Materials used as supplements to the grain ration were mixed with it before feeding.

Weighing

All animals on the experiment were weighed when started and at intervals of ten days thereafter. At the end of each thirty days, the animals were weighed on three consecutive days. The average of the three were taken as the animal's true weight. All weighings were made early in the morning before feeding or watering.

Measurements

The following measurements of each animal were taken the first of each month: highest point at the withers and height at the rump, depth and width of chest, width of barrel, hooks and thurls, the circumference of chest and barrel, the length of rump and length from hook point to point of shoulder.

Record of Feed

The feeder kept a permanent record of all feed given each animal at each feeding period.

Health Observations

All symptoms of sickness and disease were recorded each day in a book provided for that purpose.

Collection of Blood Samples

Blood samples were taken regularly each week for blood cell counts. A sample was taken simultaneously for chemical analysis. The blood was drawn from the juglar vein without stasis. The blood for the blood cell counts was allowed to flow freely into the palm of the hand, which had previously been washed and dried with alcohol. From the hand five tenths of a cubic millimeter of blood was drawn into a Spencer blood counting pipette and diluted with Toisson's Fluid (appendix) giving a dilution of 1:200. Toisson's fluid stains the leucocytes a deep blue and leaves the erythrocytes unstained, thus permitting both types of blood cells to be counted from the same sample. After thoroughly mixing with the diluting fluid a sample of the diluted blood is placed on a Spencer-Thoma-Ziess haemacytometer to be counted. The Spencer-Thoma-Ziess haemacytometer is ruled into four hundred squares measuring one-twentieth of a millimeter on the side. The film of blood in the counting chamber is one tenth of a millimeter thick, after the cover glass is in place. The haemocytometer is then placed under the microscope and the cells counted under "high power" lens.

The leucocytes in the entire four hundred squares were counted and the total multiplied by two thousand to obtain the leucocyte count per

cubic millimeter of blood. For the red cell count only the cells in twenty-five squares in each corner of the ruled area or one hundred of the four hundred squares were counted and the total multiplied by eight thousand to obtain the red cell content of one cubic millimeter of blood.

The samples of blood drawn for chemical analysis were drawn from the juglar vein into a special tube under paraffin oil with lithium citrate as an anti-coagulant. The chemical analyses were run by the Department of Experiment Station Chemistry.

Autopsy of Animals

All animals that died or were killed were autopsied by the Department of Animal Pathology.

EXPERIMENTAL DATA

A description of the calves used in this experiment will be found in Table Number I of the appendix. Tables showing the leucocyte count of the blood of each animal and the ration of each animal from time to time, as well as other information about the animal, will be found with the discussion of each animal.

In Table Number III on page 4a of the appendix will be found a tabulated resume of the results of the experiment.

C-31, C-40, C-42, C-53, C-54, and C-62

These grade Holstein (C-31, C-42, C-53, C-54, C-62) and Jersey (C-40) calves were placed on a diet of whole milk at birth. Shavings were used for bedding.

Notes and Observations

None of these calves made normal growth after three months of age. They were all in poor physical condition and showed lack of proper nutrition. C-31 died in convulsions at 175 days, C-42 at 348 days and C-54 at 173 days of age. C-40 died from paralysis at 465 days of age and C-53 died at night at the end of 272 days, probably in a convulsion. C-62 is 186 days old and still alive, but is in poor physical condition.

C-31 gave a leucocyte curve above the normal level. C-40 gave alternate periods of high and normal counts but no counts were below normal.

The leucocyte count of the blood of calf C-42 was normal most of the time.

C-53 showed alternate periods of normal and high leucocyte counts. The blood of C-54 was normal in respect to leucocytes up to 89 days of age, at which time the count increased and continued a little above normal until the animal died in a convulsion at which time the leucocyte count was normal again.

C-31

Holstein Bull Calf Born 7-7-24

Date	Age	Ration	Count
10-21-24	106	Whole Milk	23,000
12- 3-24	149		28,000
12-10-24	156		10,000
12-15-24	161		24,000
12-29-24	175		36,000
12-29-24	175	Died in convulsion	

C-40

Jersey Bull Born 11-14-24

Date	Age	Ration	Count
1-10-25	57	Whole Milk	14,000
7-7-25	235		8,000
7-13-25	241		8,000
7-21-25	249		12,000
7-28-25	256		30,000
8- 4-25	263		24,000
8-12-25	271		14,000
8-20-25	279		22,000
8-26-25	285		16,000
9- 4-25	294		18,000
9-10-25	300		10,000
9-16-25	306		6,000
10-21-25	341		12,000
10-28-25	348		16,000
11- 4-25	355		8,000
11-11-25	362		8,000
11-18-25	369		6,000
11-28-25	379		12,000
12- 2-25	383		16,000
12- 9-25	390		26,000
12-16-25	397		26,000
12-23-25	404		22,000
1- 6-26	418		8,000
1-15-26	427		8,000

C-40 (Continued)

Date	Age	Ration	Count
1-20-26	432	Whole Milk	18,000
1-23-26	435		18,000
1-29-26	441		20,000
2- 6-26	449		18,000
2-12-26	455		24,000
2-17-26	460		14,000
2-19-26	462		12,000
2-22-26	465	Died paralyzed	

C-42

Holstein Heifer Born 1-3-25

Date	Age	Ration	Count
7- 7-25	185	Whole Milk	8,000
7-13-25	191		8,000
7-21-25	199		8,000
7-28-25	206		22,000
8- 4-25	213		10,000
8-11-25	220		14,000
8-18-25	227		22,000
8-19-25	228		14,000
8-20-25	229		10,000
8-21-25	230		16,000
8-26-25	236		24,000
9- 4-25	244		8,000
9-10-25	250		16,000

C-42 (Continued)

Date	Age	Ration	Count
9-16-25	256	Whole Milk	12,000
10- 7-25	277		16,000
10-21-25	291		10,000
10-28-25	298		16,000
11- 4-25	305		12,000
11-11-25	312		8,000
11-18-25	319		4,000
11-25-25	326		8,000
12-2-25	333		8,000
12- 8-25	339		4,000
12-16-25	347		10,000
12-17-25	348	Died in convulsion	

C-53

Holstein Bull Calf Born 5-17-25

Date	Age	Ration	Count
6-25-25	39	Whole Milk	16,000
7- 7-25	51		10,000
7-13-25	57		14,000
7-21-25	65		24,000
7-28-25	72		20,000
8- 4-25	79		12,000
8-20-25	95		12,000
8-26-25	101		14,000
9- 4-25	110		16,000
9-10-25	116		22,000

C-53 (Continued)

Date	Age	Ration	Count
9-16-25	122	Whole Milk	20,000
10-14-25	150		12,000
10-21-25	157		8,000
10-28-25	164		22,000
11-5-25	172		18,000
11-11-25	178		12,000
11-18-25	185		12,000
11-25-25	192		2,000
11-28-25	195		16,000
12-3-25	200		10,000
12-10-25	207		24,000
12-17-25	214		20,000
1-6-26	234		24,000
1-16-26	244		12,000
1-22-26	250		16,000
1-27-26	255		10,000
2-6-26	265		12,000
2-12-26	271		6,000
2-13-26	272	Died	

C-54

Holstein Bull Calf Born 4-30-25

Date	Age	Ration	Count
6-25-25	56	Whole Milk	4,000
7-7-25	68		8,000
7-13-25	74		8,000
7-21-25	82		10,000

C-54 (Continued)

Date	Age	Ration	Count
7-28-25	89	Whole Milk	22,000
8-4-25	96		14,000
8-13-25	105		22,000
8-19-25	111		16,000
8-27-25	119		12,000
9-17-25	140		14,000
10-20-25	173	Died in Convulsion	10,000

C-62

Holstein Bull Calf Born 11-20-25

Date	Age	Ration	Count
12-2-25	12	Whole Milk	6,000
12-9-25	19		3,000
12-16-25	26		6,000
12-23-25	33		6,000
1-8-26	49		10,000
1-16-26	57		6,000
1-22-26	63		8,000
1-27-26	68		10,000
2-3-26	75		6,000
2-10-26	82		20,000
2-17-26	89		4,000
2-24-26	96		10,000
3-5-26	105		14,000
3-12-26	112		4,000
3-19-26	119		6,000
3-26-26	126		12,000

C-63 (Continued)

Date	Age	Ration	Count
4-1-26	132	Whole Milk	26,000
4-9-26	140		14,000
4-16-26	147		4,000
4-23-26	154		8,000
4-30-26	161		8,000
5-20-26	181		14,000
5-25-26	186		8,000

C-62 has shown a nearly normal leucocyte curve with only five points of the curve above the normal limits and four below the normal limit.

Therefore, in the group on whole milk alone, two animals showed an increased leucocytic blood content, three which had alternate periods of high and normal counts, and two which were normal at first but were above normal as the experiment advanced. In cases where the animals' leucocyte count fell in the range of normality the count was usually near the upper limits of the range rather than the average or the lower limit of a normal count.

Calf C-16.

This calf was placed on a ration free from grass or hay. At the age of 190 days, the first blood count was taken, the last one at 706 days. During this time, the ration was varied somewhat. Whole milk, skimmilk, cod liver oil, alfalfa mineral mix, blood meal, syrup of iron phosphate, sodium chloride and oathulls were fed during the experiment. She was bedded with shavings.

Notes and Observations. Except for a very few instances, this animal showed a high leucocyte count and of these all except the last one, which was six thousand per cubic millimeter, were above the average for normal bovine blood. This animal was suffering from depraved appetite over the entire period covered by the blood counts and was still afflicted with the disease when dropped from this experiment. The mineral supplements were used in attempt to alleviate this condition but all attempts were unsuccessful. In October 1924, the animal developed an emaciated and run down condition. Consequently, half of the skimmilk of the ration was replaced by whole milk at this time. The animal was muzzled while in the exercise lot but not in the barn. During the winter months, this animal consumed about four pounds, daily, of the shavings used for bedding. It is obvious that the high count and depraved appetite were neither due to an absence of minerals or a lack of roughage or volume in the ration.

C-16

Holstein Heifer Born 10-13-23

Date	Age	Ration	Count
4-20-24	190	Whole milk, alfalfa mineral, cod liver oil	21,000
5-20-24	220		41,000

C-16 (continued)

Date	Age	Ration	Count
7-14-24	275	Whole milk, alfalfa mineral cod liver oil	23,000
8-7-24	299	7-29-24 blood meal added 8-28-24 syrup of iron phosphate added 9-15-24 skimmilk added	8,000
10-21-24	313		11,000
12-1-24	415	12-26-24 whole and skimmilk and syrup of iron phosphate	18,000
1-20-25	465		16,000
1-31-25	476	4-25-25 skimmilk discontinued	18,000
7-17-25	640	7-17-25 oat hulls added	10,000
8-20-25	677		12,000
9-10-25	698		24,000
9-18-25	706		6,000

Calf C-22.

A grade Holstein calf born December 15, 1923, was placed on a whole milk and alfalfa tea diet. The ration was varied later according to the condition of the animal. Whole and skimmilk, alfalfa tea, cod liver oil, wood ashes, tankage, syrup of iron phosphate, wheat bran and iron oxide were fed. Shavings were used for bedding.

Notes and Observations. C-22 was 122 days of age when first bled for blood count and 635 days old when taken off experiment. This animal's leucocyte count was above the average for bovine blood in all cases and above normal limits in all except three instances. C-22 was on a diet similar to that fed C-16. C-22 developed depraved appetite about June 6, 1924, and her leucocyte count was

higher before this date than after it. On December 5, 1924, C-22 was down in her stall unable to rise, due to a weakened condition. The blood count at this time was no higher than it had been previously. The following day, however, she was able to get on her feet without assistance, but walked with difficulty. This animal showed a high leucocyte count without roughage. This animal did not eat shavings, but developed a craving for hair. In May, 1925, she regurgitated three hair balls.

C-22

Holstein Heifer Born 12-17-23

Date	Age	Ration	Count
4-15-24	122	Whole milk and alfalfa tea	34,000
5-20-24	157		145,000
6-24-24	192	6-11-24 wood ashes added 6-25-24 tankage added	35,000
7-14-24	212	Cod liver oil added	10,000
8-7-24	236		15,000
10-22-24	312	8-28-24 syrup of iron phosphate added 9-17-24 whole and skimmilk added half and half	23,000
12-1-24	352		11,000
12-5-24	356		16,000
1-20-25	402	Wheat bran added 12-26-24 syrup of iron phosphate discontinued 1-15-25 wood ashed discontinued 1-25-25 cod liver oil "	20,000
1-31-25	413	4-25-25 no skim, all whole milk 6-23-25 iron oxide added	23,000

C-22 (Continued).

Date	Age	Ration	Count
7-20-25	583		8,000
8-17-25	611		16,000
9-10-25	635		16,000

Calf C-25.

A grade Jersey heifer born April 1, 1924, was placed on a whole milk ration. She was bled first at 49 days of age and continued on the experiment until she died in a convulsion August 5, 1925. The diet varied from time to time, depending on the condition of the calf. Whole milk, oxidized cod liver oil, unoxidized cod liver oil, bone flour, bone meal, syrup of iron phosphate, alfalfa meal and wheat bran were fed during the experiment . Shavings were used for bedding.

Notes and Observations. C-25 showed a leucocyte curve very similar to C-16 and C-22, her white cell count being the average or above during the experiment and in all except four cases it was higher than the limits of a normal white cell count. This heifer also developed a depraved appetite, but it apparently did not affect the leucocyte count. On December 15, 1924, she was placed on a diet of whole milk and wheat bran which ameliorated the depraved appetite, but did not appreciably affect the leucocytic content of the blood. On August 5, 1925, this calf died in a convulsion. The leucocyte count was exceedingly high on August 1, being 38,000 per cubic millemeter. C-16, C-22, C-25 receiving very similar rations, all without hay or grass, showed a leucocyte

count almost uniformly above the limit of normal variation.

C-25

Jersey Heifer Born 4-1-25.

Date	Age	Ration	Count
5-20-24	49	Whole milk 6-9-24 cod liver oil	28,000
6-24-24	84	Oxidized cod liver oil for cod liver oil 7-19-24 bone flour added	17,000
8-7-24	128	8-28-24 syrup of iron phosphate added, cod liver oil discontinued	14,000
9-8-24	160	Alfalfa meal added, bone flour stopped	31,000
10-9-24	191		26,000
10-21-24	203		25,000
12-1-24	244		8,000
12-15-24	258	Alfalfa meal stopped, wheat bran added	8,000
1-7-25	281		20,000
1-31-25	305		16,000
2-7-25	312		16,000
2-12-25	317		10,000
7-10-25	465		10,000
8-1-25	487		38,000
8-5-25	491	Died convulsion	

C-18, C-19, C-20 and C-21.

These four grade Holsteins were born November 6, November 8, November 24 and December 17, 1923, respectively. They were raised under practically the same conditions until four months of age. During this period their ration consisted of whole milk, skimmilk, corn, oats and timothy hay (ad libitum). At the end of four months

they were placed on a ration of timothy hay (one pound daily), potatoes and a grain mixture of the following composition:

150.0# hominy
100.0# distillers grain
50.0# wheat bran
25.0# cotton seed meal
2.0# sodium chloride
1.0# sodium phosphate
1.0# di-sodium phosphate
0.5# magnesium carbonate
0.5# magnesium phosphate
0.25# potassium chloride
0.25# potassium carbonate
20.0 grams iron lactate

Heifers C-18 and C-20 received the above grain mixture and five pounds of potatoes in addition to the one pound of timothy hay. The amount of grain was increased until the animals were getting eight pounds daily. C-19 and C-21 received the same rations except that three per cent of the grain mixture consisted of calcium carbonate. Shavings were used for bedding.

Notes and Observations. These animals were bled the first time after being on this ration from three to five months, depending on the animals. All of them had depraved appetite at the time of the first bleeding, August 11, 1924. All four of the animals showed an abnormal leucocyte count at this time but C-18 and C-20,

the calves receiving a basal ration low in calcium showed a much higher count than either calf receiving calcium carbonate. The counts taken later however, do not indicate that the calcium carbonate has any effect in keeping the leucocyte count low.

This ration was adequate in every respect except an abundance of well cured hay. The leucocyte count was abnormally high in all four animals, except one or two counts on three of the animals, C-18 being above normal in every instance.

C-18

Holstein Heifer Born 11-6-23.

Date	Age	Ration	Count
8-11-24	279	Grain, timothy and potatoes	42,000
9-26-24	325		27,000
10-23-24	352		18,000
12-2-24	392		21,000
12-15-24	405		18,000
1-20-25	441		16,000
7-13-25	615		16,000
8-18-25	651		28,000
9-10-25	674		12,000

C-19

Holstein Heifer Born 11-24-23.

Date	Age	Ration	Count
8-11-24	261	Grain ($CaCo_3$), timothy and potatoes	24,000
9-26-24	307		13,000

C-19 (Continued).

Date	Age	Ration	Count
10-23-24	334	Grain ($CaCo_3$), timothy and potatoes	32,000
12-2-24	374		25,000
12-15-24	387		28,000
12-17-24	389		22,000
1-7-25	410		22,000
1-20-25	423		22,000
7-10-25	594		12,000
7-29-25	613		34,000
8-18-25	633		20,000
9-10-25	656		12,000
1-7-26	775		6,000

C-20

Holstein Heifer Born 11-8-23.

Date	Age	Ration	Count
8-11-24	257	Grain, timothy and potatoes. Same as C-18. No Ca CO_3.	103,000
10-23-24	330		27,000
12-2-24	370		11,000
12-15-24	383		16,000
1-20-25	419		28,000
7-13-25	593		8,000
8-20-25	631		4,000
9-15-25	657		18,000

C-21

Holstein Heifer Born 12-17-23.

Date	Age	Ration	Count
8-11-24	230	Grain, timothy and potatoes (3% $Ca\ Co_3$). Same as C-19.	19,000
10-24-24	314		42,000
12-2-24	353		17,000
1-20-25	402		30,000
7-13-25	576		18,000
8-20-25	614		20,000
9-13-25	638		20,000
11-10-25	696		12,000
11-13-25	699		6,000
11-25-25	711		8,000

Died 11-28-25

C-27, C-58, C-60, C-61 and C-64.

These are grade Holsteins, except C-64, which is a Holstein, Brown-Swiss cross. C-27, C-58, C-60 and C-61 are bull claves, and C-64 is a heifer calf. C-27 and C-64 were fed a ration of whole milk and syrup of iron phosphate. The others were fed a normal ration of whole milk or skimmilk, corn and oats, alfalfa hay and cod liver oil until from three to four months of age. At this time they were placed on the experiment with a diet of whole milk and syrup of iron phosphate. Shavings were used for bedding.

Notes and Observations. None of these calves showed depraved appetite. The leucocyte count of C-27's blood was continually high, both before and after feeding syrup of iron phosphate ,with

an occasional normal count.

The leucocytes in the blood of C-58 varied greatly but the count usually remained within the "normal limits", occasionally going below normal, as well as above.

C-60 showed a high leucocytic blood content, continually.

C-61 acted in much the same manner as C-58, giving both high and low leucocyte counts, but having a normal count the majority ot the time.

C-64 shows a normal leucocyte count in every instance, save on March 31, 1926 when it rose to 20,000 per cubic millimeter of blood and May 22, 1926 when it again reached the same figure.

C-27

Holstein Bull Calf Born 5-8-24.

Date	Age	Ration	Count
8-18-24	102	Whole milk, syrup of iron phosphate	31,000
10-22-24	167		20,000
12-1-24	207		10,000
12-10-24	216		12,000
1-7-25	244		26,000
1-31-25	268		30,000
2-7-25	275		10,000
7-10-25	428		16,000
7-27-25	445	7-15-25 syrup of iron phosphate discontinued	18,000
8-1-25	450		2 6,000
8-6-25	455		32,000

C-27 (Continued).

Date	Age	Ration	Count
8-7-25	456	Whole milk	22,000
8-8-25	457		24,000
8-10-25	459		6,000
9-10-25	490		12,000
9-18-25	498	9-20-25 alfalfa added 12-21-25 " stopped 2-9-26 syrup added again	24,000
3-5-26	666		16,000
3-20-26	681	Killed(Butcher)	

C-58

Holstein Bull Calf Born 8-28-25.

Date	Age	Ration	Count
8-28-25	0	Whole milk	8,000
9-2-25	5	Cod liver oil and alfalfa added	
9-8-25	11		24,000
10-9-25	42		6,000
10-12-25	45	Skim for whole milk	
10-22-25	55		14,000
10-28-25	61	Corn and oats added	
11-6-25	70		8,000
11-20-25	84		6,000
12-3-25	97		20,000
12-11-25	105	Whole for skimmilk. Syrup of iron phosphate added	
12-17-25	111	Whole milk and syrup of iron phosphate sole diet	8,000
1-11-26	136		10,000

C-58 (Continued).

Date	Age	Ration	Count
1-18-26	143	Whole milk and syrup of iron phosphate	14,000
1-25-26	150		6,000
2-10-26	166		8,000
2-17-26	173		6,000
2-24-26	180		16,000
3-3-26	187		2,000
3-10-26	194		8,000
3-17-26	201		12,000
3-24-26	208		12,000
3-31-26	215		2,000
4-7-26	222		12,000
4-14-26	229		10,000
4-21-26	236		6,000
4-28-26	243		4,000
5-12-26	257		4,000
5-20-26	265		10,000
5-25-26	270		6,000

C-60

Holstein Bull Calf Born 10-7-25.

Date	Age	Ration	Count
10-7-25	0	Whole milk Cod liver oil added	10,000
10-12-25	5	Alfalfa added	
11-6-25	30		16,000

C-60 (Continued).

Date	Age	Ration	Count
11-20-25	44	Whole milk, cod liver oil and alfalfa	14,000
12-1-25	55	Corn and oats added	
12-4-25	58		16,000
12-11-25	65		10,000
12-31-25	85	Syrup of iron phosphate added, alfalfa discontinued	
1-11-26	86		18,000
1-18-26	103		16,000
1-25-26	110		10,000
1-28-26	113	Died pneumonia and kidney trouble	

C-61

Holstein Bull Calf Born 11-6-25

Date	Age	Ration	Count
11-6-25	0	Whole milk	14,000
11-11-25	5	Cod liver oil and alfalfa added	
12-4-25	28		2,000
1-10-26	65	Skim for whole milk, corn and oats added	
1-11-26	66		16,000
1-18-26	73		4,000
1-25-26	80		4,000
2-9-26	95	Whole milk and iron phosphate sole diet	
2-10-26	96		12,000
2-17-26	103		6,000

C-61 (Continued).

Date	Age	Ration	Count
2-24-26	110	Whole milk and iron phosphate	12,000
3-3-26	117		12,000
3-10-26	124		8,000
3-17-26	131		12,000
3-24-26	138		14,000
3-31-26	145		16,000
4-7-26	152		2,000
4-14-26	159		8,000
4-21-26	166		8,000
4-28-26	173		16,000
4-30-26	175		8,000
5-12-26	187		14,000
5-20-26	195		4,000
5-25-26	200		10,000

C-64

Brown-Swiss Heifer Born 2-22-26.

Date	Age	Ration	Count
3-3-26	9	Whole milk, syrup of iron phosphate	14,000
3-12-26	18		8,000
3-19-26	25		6,000
3-24-26	30		4,000
3-31-26	37		20,000
4-7-26	44		12,000
4-16-26	53		12,000

C-64 (Continued).

Date	Age	Ration	Count
4-21-26	58	Whole milk, syrup of iron phosphate	12,000
4-28-26	65		8,000
5-12-26	79		10,000
5-22-26	89		20,000

C-52, C-57.

These grade Holstein calves were placed on a whole milk ration. Later the whole milk was supplemented with a mineral mixture containing managanese ,iron, fluoride, silicon and aluminum.

Ferric oxide was added to the ration some time later than the above mentioned mineral mixture. Shavings were used for bedding.

Notes and Observations. Neither of these calves developed normally and lacked vitality. C-52 developed depraved appetite, manifested by chewing wood. C-52 did not show a high leucocyte count until thirty-seven days of age. The leucocyte count continued high until the mineral mixture was added, when it reached a normal level and continued so with an occasional count slightly above normal, until the animal died of convulsions at two hundred seventy-six days of age.

C-57 unlike C-52, had no period of high leucocytic blood count. The leucocyte count of this animal's blood was practically normal after the mineral was added. It is possible, then, that this mineral mixture may tend to keep the leucocyte count down in the absence of grass or hay.

C-52

Holstein Heifer Born 6-14-25.

Date	Age	Ration	Count
6-25-25	11	Whole milk	9,000
7-7-25	23		10,000
7-14-25	30		8,000
7-21-25	37		18,000
7-28-25	44		16,000
8-4-25	51		24,000
8-11-25	58		14,000
8-20-25	67		20,000
8-26-25	73		22,000
9-2-25	80	Minerals added (manganese, iron, fluoride, silicon and aluminum)	
9-4-25	82		14,000
9-10-25	88		10,000
9-16-25	94		14,000
10-21-25	129		8,000
10-28-25	136		14,000
11-4-25	143	Iron oxide added	12,000
11-11-25	150		2,000
11-18-25	157		18,000
11-25-25	164		6,000
12-2-25	171		10,000
12-10-25	179		16,000
12-16-25	185		16,000
12-23-25	192		6,000

C-52 (Continued).

Date	Age	Ration	Count
1-6-26	206		4,000
1-16-26	216		10,000
1-22-26	222		10,000
1-27-26	227		14,000
2-6-26	237		14,000
2-12-26	243		16,000
2-19-26	250		6,000
2-26-26	257		6,000
3-5-26	264		14,000
3-12-26	271		6,000
3-17-26	276	Died in convulsion	

C-57

Holstein Heifer Born 8-11-25

Date	Age	Ration	Count
8-19-25	8	Whole milk	16,000
8-28-25	17		16,000
9-2-25	22	Minerals added (manganese, iron, fluoride, silicon and aluminum)	
9-17-25	37		8,000
10-15-25	65		6,000
10-22-25	72		4,000
10-29-25	79		4,000
11-5-25	86		6,000
11-13-25	94		8,000

C-57 (Continued)

Date	Age	Ration	Count
11-19-25	100	Whole milk, minerals	16,000
11-25-25	106		12,000
12-2-25	113	Ferric oxide added	
12-3-25	114		4,000
12-10-25	121		8,000
1-6-26	148		14,000
1-16-26	158		18,000
1-23-26	165		4,000
1-27-26	169		10,000
2-6-26	179		8,000
2-12-26	185		10,000
2-19-26	192		16,000
2-26-26	199	Died in convulsion	

C-28

This grade Holstein bull calf received a diet of whole milk supplemented with flowers of sulphur. Shavings were used for bedding.

Notes and Observations. This calf showed a continual high leucocyte count and died in a convulsion at two hundred twenty-eight days of age. C-28 also showed depraved appetite.

C-28

Holstein Bull Calf Born 5-11-24.

Date	Age	Ration	Count
5-20-24	9	Whole milk	33,000
6-24-24	34		27,000
7-17-24		Sulphur added	
8-18-24	99		11,000
10-9-24	151		17,000
10-22-24	164		13,000
12-3-24	206		30,000
12-22-24	225		22,000
12-25-24	228	Died in convulsion	

C-30

This grade Holstein bull calf born 6-13-24, received a ration of whole milk and raw linseed oil as a supplement. Shavings were used for bedding.

This calf did not develop well and was killed at four hundred sixty-five days of age. The blood of C-30 was continually high in leucocytes, at only two points did the count come within the range of normality and these two counts were 11,000 and 10,000 per cubic millimeter respectively. He also developed depraved appetite.

C-30

Holstein Bull Calf Born 6-13-24.

Date	Age	Ration	Count
8-18-24	65	Whole milk, raw linseed oil	21,000
10-21-24	130		11,000

C-30 (Continued.)

Date	Age	Ration	Count
12-4-24	174	Whole milk, raw linseed oil	32,000
12-10-24	182		26,000
1-10-25	211		14,000
1-31-25	232		18,000
7-9-25	391		18,000
7-13-25	395		16,000
7-16-25	398		20,000
7-23-25	405		10,000
7-30-25	412		14,000
8-6-25	419		14,000
8-13-25	426		30,000
8-27-25	440		20,000
9-21-25	465	Killed by Butcher	

C-36

This grade Holstein bull calf was born September 2, 1924. and received a varying diet up to February 5, 1925. Whole milk, skimmilk, corn, oats, oat hulls and bone meal were fed. On February 5, 1925, at one hundred fifty-six days of age, he was placed on a diet of whole milk, bone meal and cod liver oil. Shavings were used for bedding.

Notes and Observations. C-36 did not develop normally and was in poor physical condition when he died at the end of one hundred sixty-five days.

C-36

Holstein Bull Calf Born 9-2-24.

Date	Age	Ration	Count
10-22-24	50	Milk, skimmilk, corn and oats	11,000
12-4-24	93		20,000
12-6-24	95	Oats for corn and oats	
1-5-25	125	Oats and hulls for oats	
1-10-25	130		24,000
1-15-25		No oats. Bone meal added and whole for skimmilk.	
1-22-25	142		30,000
1-26-25	146		28,000
2-5-25	156	Cotton seed oil added	
2-7-25	158		22,000
2-12-25	163		20,000
2-14-25	165	Died during night.	

The first blood count of this animal, taken at fifty days of age, while on a normal ration, was normal but every count thereafter was far above normal. This animal also showed depraved appetite.

C-28, C-30, and C-36, all on a whole milk diet with various supplements, but no roughage, show an abnormal leucocytic blood content.

C-51, C-55, C-56, C-63.

These grade Holstein calves were placed on a ration of whole milk, cod liver oil and alfalfa hay. Corn and oats were added as soon as the calves would eat them. Shavings were used for bedding.

Notes and Observations. These calves all developed normally. Each of these animals were normal in respect to the number of leucocytes in the blood.

C-51

Holstein Bull Calf Born 5-23-25.

Date	Age	Ration	Count
7-9-25	42	Whole milk, cod liver oil, alfalfa	18,000
7-16-25	49		10,000
7-23-25	56		12,000
7-27-25	60	Skim for whole milk, corn and oats added	
7-30-25	63		16,000
8-5-25	69		8,000
8-19-25	83		14,000
8-28-25	92		6,000
9-2-25	97	Cod liver oil discontinued	
9-14-25	109		6,000
10-15-25	140		8,000
10-29-25	154		10,000
11-6-25	162	Cod liver oil added	
11-13-25	169		4,000
11-27-25	183		10,000
12-1-25	187	Cod liver oil discontinued	
12-4-25	190		6,000
12-6-25	192	Skimmilk, corn and oats discontinued. Grain, silage and alfalfa sole diet	
12-17-25	203		8,000

C-51 (Continued).

Date	Age	Ration	Count
1-11-26	228	Grain, silage and alfalfa	12,000
1-25-26	242		6,000

300# corn
100# oats
100# cotton seed meal
1% salt
} grain mix

C-55

Holstein Heifer Born 7-3-25

Date	Age	Ration	Count
7-3-25	0	Whole milk, cod liver oil and alfalfa ad libitum	16,000
7-17-25	14		6,000
7-23-25	20		8,000
7-31-25	28		20,000
8-7-25	35		14,000
8-13-25	41	Died	

C-56

Holstein Heifer Born 8-11-25

Date	Age	Ration	Count
8-11-25	0	Whole milk	28,000
8-23-25	11	Alfalfa added	
8-27-25	15		4,000
9-4-25	23		22,000

C-56 (Continued).

Date	Age	Ration	Count
9-5-25	24	Whole milk, alfalfa. Cod liver oil added	
10-2-25	51	Corn and oats added. Cod liver oil discontinued.	
10-9-25	58		10,000
10-22-25	71		4,000
10-27-25	76	Cod liver oil added.	
11-6-25	86		8,000
11-20-25	100		4,000
12-3-25	113		12,000
		Taken off experiment. No appetite.	

C-63

Holstein Bull Calf Born 1-8-26.

Date	Age	Ration	Count
1-8-26	0	Whole milk, cod liver oil and alfalfa	16,000
2-3-26	26		10,000
2-12-26	35		20,000
2-19-26	42		12,000
2-26-26	49		20,000
3-5-26	56		8,000
3-12-26	63	Corn and oats added	24,000
3-19-26	70		4,000
3-26-26	77		26,000
4-1-26	83		14,000
4-9-26	91		16,000

C-63 (Continued).

Date	Age	Ration	Count
4-16-26	98	Whole milk, cod liver oil, alfalfa, corn and oats	6,000
4-23-26	105		6,000
4-30-26	112		6,000
5-19-26	131		4,000
5-22-26	134		14,000
5-26-26	138		12,000

C-44, C-45.

These grade Holstein bull calves received whole milk, skimmilk, calcium carbonate, cod liver oil, alfalfa hay, corn, oats, wheat straw, a grain mixture, gluten feed and corn distiller's grain, according to the growth and condition of the calf, until approximately two hundred and thirty days of age. They were then placed on a ration of wheat straw and the following grain mixture:

Corn	200#
Corn distiller's grain	100#
Diamond gluten feed	400#
Salt	1%

Shavings were used for bedding.

Notes and Observations. Neither calf developed well. C-44 became very stiff in his legs and walked only with difficulty. At about nine months of age he became totally blind.

C-45 was also stiff jointed and walked with difficulty. About the time C-44 became blind, C-45 lost his appetite and

became blind.

During a period of about six weeks, while receiving a ration of grain, straw and skimmilk, both calves showed a high leucocytic blood content.

Corn, oats and gluten feed with no skimmilk was then substituted for the grain mixture. For this period the count was practically normal.

The calves were next changed to the grain mixture with no skimmilk. On this diet the leucocyte counts varied considerably.

These two calves did not show leucocytosis on a concentrate ration void of hay or green feed when no milk was fed, but there was a leucocytosis when skimmilk was in the ration.

C-44

Holstein Bull Calf Born 3-27-25.

Date	Age	Ration	Count
3-28-25	1	Whole milk, calcium carbonate, cod liver oil and alfalfa.	14,000
4-11-25	15	Skim for whole milk.	
6-24-25	89	Corn, oats and wheat straw added, alfalfa discontinued.	
6-27-25	92	Calcium carbonate and cod liver oil discontinued.	
7-8-25	103		6,000
7-15-25	110		8,000
7-22-25	117		20,000

C-44 (Continued).

Date	Age	Ration	Count
7-26-25	121	Corn and oats discontinued. Grain mixture added.	
7-29-25	124		22,000
8-5-25	131		14,000
8-11-25	137		24,000
8-17-25	143		20,000
8-25-25	151		24,000
9-8-25	165		12,000
9-12-25	169	Grain mix discontinued, gluten, corn and oats added.	
9-14-25	171		18,000
10-2-25	189	Skimmilk discontinued	
10-12-25	199		8,000
10-19-25	206		16,000
10-27-25	214		4,000
11-2-25	220		6,000
11-9-25	227		10,000
11-12-25	230	Grain mix for corn, oats and gluten	
11-16-25	234		6,000
11-25-25	243		6,000
12-1-25	249		18,000
12-9-25	257		6,000
12-17-25	265		6,000
12-22-25	270		28,000

C-44 (Continued).

Date	Age	Ration	Count
1-8-26	287		6,000
1-15-26	294		16,000
1-20-26	299		8,000
1-29-26	308		24,000
2-10-26	320		14,000
2-17-26	327		10,000
2-24-26	334		10,000
3-3-26	341		10,000
3-10-26	348		12,000
3-17-26	355		10,000
3-24-26	362		6,000
3-31-26	369		10,000
4-7-26	376		14,000
4-9-26	378		18,000
4-14-26	383		8,000
4-21-26	390		20,000
4-23-26	392		8,000
4-28-26	397		10,000
4-30-26	399		6,000
5-12-26	411		6,000
5-19-26	418		10,000
5-25-26	424		16,000

Grain Mix.

Corn	2 parts
Corn distiller's grain	1 "
Diamond gluten	4 "
1% salt	

C-45

Holstein Bull Calf Born 3-29-25.

Date	Age	Ration	Count
5-29-25	0	Whole milk, calcium carbonate, cod liver oil and alfalfa	16,000
5-5-25	37	Corn and oats added	
5-11-25	43	Skim for whole milk	
6-24-25	87	Corn gluten added, wheat straw for alfalfa. Calcium carbonate and cod liver oil discontinued.	
7-8-25	101		8,000
7-15-25	108	Corn distiller's grain for gluten	12,000
7-22-25	115		10,000
7-29-25	122	Grain mix, skimmilk and straw sole diet	16,000
8-5-25	129		12,000
8-17-25	141		20,000
8-25-25	149		16,000
9-8-25	163		8,000
9-11-25	166	Corn gluten, corn and oats for grain mixture.	
9-14-25	169		6,000
10-2-25	187	No milk	
10-12-25	197		4,000

C-45 (Continued).

Date	Age	Ration	Count
10-19-25	204		4,000
10-27-25	212		6,000
11-2-25	218		4,000
11-9-25	225		4,000
11-12-25	228	Grain mix for gluten, corn and oats	
11-16-25	232	Grain mix and straw sole diet	10,000
11-25-25	241		6,000
11-27-25	243		6,000
12-1-25	247		4,000
12-9-25	255		10,000
12-17-25	263		8,000
12-22-25	268		4,000
1-8-26	285		12,000
1-15-26	292		4,000
1-20-26	297		10,000
1-23-26	300		2,000
1-29-26	306		18,000
2-10-26	318		4,000

Taken off due to poor condition.

On verge of pneumonia. Did not eat.

Grain Mix.

Corn	2 parts
Corn distiller's grain	1 "
Dia. gluten	4 "
1% salt	

C-35, C-37, C-38, C-39, C-46 and C-50.

These grade Holstein heifers were fed a normal ration consisting of whole milk, skimmilk, calcium carbonate, cod liver oil, alfalfa hay, corn and oats until they were approximately ninety days old.

At this time C-35, C-46, C-50 and C-38 were placed on a ration of wheat straw, silage and the following grain mixture:

300# corn (yellow)
100# oats
100# cotton seed meal
5# salt

C-37 and C-39 received the same basal ration plus 3% of the grain mixture as magnesium phosphate.

Shavings were used for bedding.

Notes and Observations. These six calves all developed normally and were in excellent condition at the time they were placed on the restricted ration, containing no hay. Soon after being placed on the restricted diet, C-35, C-37, C-38 and C-39 showed signs of depraved appetite which lasted only a short time. C-46 developed irritability which has persisted to the present time. C-50 was irritable, but not so much so as C-46.

All of these calves showed normal leucocyte counts up to three months of age, the count usually being higher in younger calves than in calves nearer maturity.

When placed on the restricted diet without hay or milk, C-35, C-37, C-38 and C-39 showed leucopenia for a period of approximately two months, then an increase in leucocyte count to above normal. This leucocytosis persisted for a period

ranging close to two months, when the leucocyte content of their blood again became normal. The blood count then remained normal in these animals as long as they were continued on the experiment.

The leucocyte count of C-46 and C-50 did not vary from the normal constituency to any appreciable degree. These two showed a steady lowering of the leucocyte count as their age increased.

C-35

Holstein Heifer Born 8-19-24.

Date	Age	Ration	Count
8-19-24	0	Whole milk (birth)	22,000
9-6-24		Calcium carbonate and cod liver oil added	
10-23-24	65		10,000
10-14-24	56	Skim for whole milk, corn and oats added	
11-26-24	99	Calcium carbonate and cod liver oil discontinued, alfalfa added	
12-4-24	107		10,000
1-3-25	137	Straw ad libitum	
1-10-25	144	Alfalfa discontinued	8,000
3-1-25	194	Grain mix, silage and straw sole diet	
5-6-25	260		6,000
5-20-25	274		4,000
5-26-25	280		12,000
6-11-25	296		10,000
7-6-25	321		10,000
7-13-25	328		12,000

C-35 (Continued).

Date	Age	Ration	Count
7-20-25	335	(8:30 A. M.)	40,000
7-20-25	335	(8:30 P. M.)	22,000
7-27-25	342	(8:30 P. M.)	24,000
8-3-25	349		30,000
8-11-25	357		18,000
8-21-25	367		24,000
8-26-25	372		16,000
9-5-25	382		22,000
9-13-25	390		2,000
9-18-25	395		12,000
10-16-25	423		6,000
10-30-25	437		10,000
11-13-25	451		2,000
11-28-25	466		2,000
12-18-25	486		16,000

Grain Mix.

300# corn

100# oats

100# cotton seed meal

5# salt

C-37

Holstein Heifer Born 9-20-24.

Date	Age	Ration	Count
9-20-24	0	Whole milk	14,000
10-7-24	17	Calcium carbonate and cod liver oil added	
10-27-24	37	Skim for whole milk. Corn, oats and alfalfa added	
11-7-24	48		14,000
12-4-24	75		14,000
12-10-24	81		8,000
12-26-24	97	Calcium carbonate and cod liver oil discontinued	
1-10-25	112		12,000
2-9-25	142	Magnesium phosphate added. Wheat straw for alfalfa	
4-1-25	193	Grain mix, silage and straw sole diet (wheat)	
5-10-25	242		6,000
5-26-25	248		8,000
6-11-25	264		18,000
7-6-25	289		14,000
7-13-25	296		8,000
7-20-25	303		20,000
7-27-25	310		20,000
8-3-25	317		28,000
8-11-25	325		18,000
8-21-25	335		22,000
8-26-25	340		24,000
9-5-25	350		20,000
9-13-25	358		14,000

C-37 (Continued).

Date	Age	Ration	Count
9-18-25	363	Grain mix, silage and wheat straw	26,000
10-14-25	389		16,000
10-30-25	405		6,000
11-14-25	420		6,000
11-28-25	434		12,000
12-18-25	454		4,000
4-9-26	566		22,000
4-14-26	571		4,000
4-15-26	572		4,000
4-16-26	573		8,000

Grain Mix.

300# corn

100# oats

100# cotton seed meal

5# salt

3% magnesium phosphate

C-38

Holstein Heifer Born 9-25-24.

Date	Age	Ration	Count
9-26-24	1	Whole milk	9,000
9-29-24	4	Cod liver oil and calcium carbonate added	
11-6-24		Skim for whole milk, corn and oats added	
11-7-24	43		10,000

C-38 (Continued).

Date	Age	Ration	Count
11-26-24	62	Alfalfa added	
12-3-24	69		10,000
12-26-24	92	Calcium carbonate and cod liver oil discontinued	
1-10-24	107		8,000
2-9-25	137	Wheat straw for alfalfa	
4-7-25	194	Grain, straw and silage sole diet	
5-6-25	223		6,000
5-20-25	237		8,000
5-26-25	243		8,000
6-11-25	259		20,000
7-6-25	284		6,000
7-13-25	291		8,000
7-26-25	298		22,000
7-27-25	305		16,000
8-3-25	312		20,000
8-11-25	320		14,000
8-21-25	330		22,000
8-26-25	335		16,000
9-5-25	345		12,000
9-13-25	353		10,000
9-18-25	358		10,000
10-16-25	386		8,000
10-30-25	400		4,000
11-14-25	415		16,000
11-28-25	429		12,000

C-38 (Continued).

Date	Age	Ration	Count
12-18-25	449	Grain, straw and silage	4,000
3-15-26	536		8,000
3-28-26	549	Died after calving	

Grain Mix.

300# corn

100# oats

100# cotton seed meal

5# salt

Identical with C-35.

C-39

Holstein Heifer Born 9-26-24.

Date	Age	Ration	Count
11-7-24	42	Skimmilk, calcium carbonate and cod liver oil	8,000
11-10-24	45	Corn and oats added	
11-26-24	61	Alfalfa added	
12-3-24	68		8,000
12-26-24	91	Calcium carbonate and cod liver oil discontinued	
1-10-25	106		18,000
2-9-25	136	Magnesium phosphate added. Wheat straw for alfalfa	
4-7-25	193	Silage, wheat straw and grain sole diet	
5-20-25	236		14,000
5-26-25	242		8,000
6-11-25	258		6,000

C-39 (Continued).

Date	Age	Ration	Count
7-6-25	283	Silage, wheat straw and grain mix	8,000
7-13-25	290		10,000
7-20-25	297		22,000
7-27-25	304		20,000
8-3-25	311		36,000
8-11-25	319		20,000
8-21-25	329		22,000
8-26-25	334		18,000
9-5-25	344		10,000
9-13-25	352		8,000
9-18-25	357		10,000
10-14-25	383		8,000
10-30-25	399		22,000
11-14-25	414		16,000
11-28-25	427		8,000
12-18-25	448		6,000

Grain Mix.

300# corn

100# oats

100# cotton seed meal

5# salt

3% magnesium phosphate

Identical with C-37.

C-46.

Holstein Heifer Born 3-29-25.

Date	Age	Ration	Count
3-29-25	0	Whole milk, calcium carbonate and cod liver oil, alfalfa, corn and oats	36,000
5-12-25	44	Skim for whole milk	
7-9-25	102		4,000
7-16-25	109		18,000
7-23-25	116		14,000
7-29-25	122	Skimmilk, grain mix, silage and wheat straw sole diet	
7-30-25	123		16,000
8-6-25	130		8,000
8-28-25	152		14,000
9-16-25	171		4,000
9-29-25	184	Skimmilk discontinued	
10-15-25	200		6,000
10-30-25	215		14,000
11-13-25	229		10,000
11-27-25	243		12,000

Grain Mix.

300# corn

100# oats

100# cotton seed meal

1% salt

Same as C-35. Still alive.

C-50.

Holstein Heifer Born 5-22-25.

Date	Age	Ration	Count
5-22-25	0	Whole milk	4,000
5-25-25	3	Whole milk, cod liver oil, alfalfa	
6-27-25	36	Skim for whole milk	
7-9-25	48		18,000
7-15-25	54	Corn and oats added	
7-16-25	55		14,000
7-23-25	62		10,000
7-30-25	69		16,000
8-8-25	78		6,000
8-19-25	89		18,000
8-28-25	98		16,000
9-15-25	116		4,000
10-2-25	133	Wheat straw for alfalfa	
10-15-25	146		18,000
10-29-25	160		10,000
11-13-25	175		12,000
11-27-25	189		4,000
11-29-25	191	Corn, oats and skimmilk discontinued. Silage and grain added	
12-10-25	202		14,000

Grain Mix.

300# corn

100# oats

100# cotton seed meal

1% salt.

C-32.

A Holstein bull calf born July 22, 1924 and placed on a ration of whole milk, skimmilk, cod liver oil, calcium carbonate, corn, oats and alfalfa.

C-32.

Holstein Bull Calf Born 7-22-24.

Date	Age	Ration	Count
7-24-24	2	Whole milk, cod liver oil, calcium carbonate	20,000
8-18-24	27		16,000
8-18-24	27	(Scours)	33,000
9-17-24		Skim for whole milk, corn and oats and alfalfa added	
10-27-24		Cod liver oil and calcium carbonate discontinued	
11-16-24		No roughage	
1-7-25	169		28,000
2-7-25	200		12,000
2-12-25	205		24,000
6-21-25		Oats for oats and corn	
7-10-25	353		22,000
7-22-25	365		20,000
7-25-25		Corn and oats for oats	
7-29-25	372		40,000
8-7-25		Cotton seed meal, no milk	
8-27-25	401		18,000
9-11-25	416		46,000
9-17-25	422		22,000
9-27-25	432	Died in lot - nephritis	

The ration of this animal was gradually changed until it consisted of corn and oats, and cotton seed meal, with no hay or roughage. Shavings were used for bedding.

Notes and Observations. This calf showed a continually high leucocyte content from birth until death, which occured from nephritis at 432 days of age.

This calf showed no depraved appetite, but after being placed on concentrates alone, it was in poor condition, his legs being very stiff and his coat rough. This calf had several convulsions, some of which were very severe.

C-43.

A Holstein bull calf born January 12, 1925. This calf received a normal ration of whole milk, corn, oats, alfalfa, cod liver oil and calcium carbonate until 103 days of age. At this time, it was changed to a diet of corn and oats, wheat straw, cotton seed meal and whole milk. The whole milk was taken from the ration three months later. Shavings were used for bedding.

Notes and Observations. This calf showed no depraved appetite. The leucocyte count was continually high, reaching a normal level in only a few single counts.

It finally died in the exercise lot, probably due to a convulsion.

C-43

Holstein Bull Calf Born 1-12-25.

Date	Age	Ration	Count
1-12-25	0	Whole milk	20,000
1-15-25	3	Calcium carbonate and cod liver oil added. Alfalfa ad libitum	
4-1-25	79	Corn and oats added	
4-25-25	103	Calcium carbonate and cod liver oil discontinued. Cotton seed meal added. Wheat straw for alfalfa.	
7-8-25	177		10,000
7-15-25	184		12,000
7-22-25	191	Milk discontinued	18,000
7-29-25	198		16,000
8-5-25	205		34,000
8-11-25	211		32,000
8-17-25	217		30,000
8-24-25	224		28,000
9-8-25	239		8,000
9-14-25	245		16,000
9-29-25	260		14,000
10-3-25	264		24,000
10-7-25	268		20,000
10-9-25	270		12,000
10-19-25	280		4,000
10-27-25	288		24,000
11-3-25	295		6,000
11-9-25	301		14,000
11-16-25	308		14,000
11-18-25	310		6,000

C-43 (Continued).

Date	Age	Ration	Count
11-27-25	319		10,000
12-1-25	323		20,000
12-8-25	330		20,000
12-15-25	337		20,000
12-22-25	344		16,000
1-2-26	355	Died in lot after struggling. Probably had convulsion.	

C-47.

This grade Jersey bull born March 31, 1925, was placed on a normal ration the same as C-43 received until ninety days of age, when it was placed on skimmilk, corn, oats, wheat straw and cotton seed meal. The skimmilk was discontinued three months later. Shavings were used for bedding.

Notes and Observations. This calf, like C-43, showed no depraved appetite, but was very stiff in the legs, especially so the last month of life.

This calf also showed a high leucocyte count. The count was not exceedingly high, but it was most always above normal.

C-47

Jersey Bull Calf Born 3-31-25.

Date	Age	Ration	Count
		Whole milk	
		Skimmilk, calcium carbonate, cod liver oil, alfalfa, and corn and oats.	
6-29-25	90	Skimmilk, cotton seed meal, corn and oats and wheat straw	

C-47 (Continued).

Date	Age	Ration	Count
7-8-25	99		10,000
7-15-25	106		16,000
7-22-25	113		24,000
7-29-25	120		16,000
8-5-25	127		4,000
8-11-25	133		16,000
8-17-25	139		24,000
8-25-25	147		22,000
9-8-25	161		20,000
9-14-25	167		12,000
10-2-25	185	Skimmilk discontinued	
10-12-25	195		6,000
10-27-25	210		10,000
11-2-25	216		6,000
11-9-25	223		12,000
11-16-25	230		12,000
11-27-25	241		14,000
12-1-25	245		22,000
12-8-25	252		30,000
12-15-25	259		16,000
12-22-25	266		12,000
1-8-26	283		16,000
1-9-26	284	Died. Scarred tissue pyloric end of stomach.	

C-49.

This Holstein bull was born May 11, 1925 and received the same ration as C-43. Shavings were used for bedding.

Notes and Observations.

This calf showed no depraved appetite, but like C-32, C-43 and C-47, it showed a blood high in leucocytes. It was also stiff and sore in his leg joints, and died when three hundred and one days old.

C-49

Holstein Bull Calf Born 5-11-25.

Date	Age	Ration	Count
5-12-25	1	Whole milk, cod liver oil, alfalfa	2,000
7-9-25	59	Corn and oats added	8,000
7-16-25	66		20,000
7-23-25	73		18,000
7-29-25	79		6,000
8-5-25	86		12,000
8-11-25	92	Wheat straw for alfalfa	18,000
8-12-25	93	Cotton seed meal added. No cod liver oil	
8-18-25	99		22,000
8-26-25	107		24,000
9-17-25	129	Whole milk discontinued	18,000
9-29-25	141		16,000
10-3-25	145		18,000
10-7-25	149		16,000
10-9-25	151		20,000
10-22-25	164		6,000
11-5-25	178		14,000

C-49 (Continued).

Date	Age	Ration	Count
11-10-25	183		6,000
11-27-25	300		28,000
11-28-25	301	Died	

Seasonal Variation.

About July 20, 1925, the white cell count of animals C-35, C-37, C-38, C-39, C-40, C-42, C-43, C-44, C-45, C-47, C-49, C-52, C-53 and C-54 showed an increase that persisted. The counts of C-46 showed an irregular variation, as was the case with C-50, C-51 and C-55. In other words, fourteen animals showed a definite increase while four showed no definite variation.

During September animals C-16, C-18, C-19, C-21, C-25, C-27, C-28, C-30, C-32, C-35, C-37, C-38, C-39, C-40, C-42, C-43, C-44, C-45, C-46, C-47, C-49, C-50, C-51, C-52, C-53, C-56, C-57 and C-58 had a lower leucocyte count than during the preceding month of August. In some of these animals the leucocyte count increased in October over the September figures, but usually remained below the August figures.

Twenty-eight animals showed less leucocytes in the blood during the fall or the month of September, while only three animals, C-20, C-22 and C-54 showed no definite change or an increase.

It is interesting to note here that animals, on which data is available, show an increase in leucocyte count in

July and a decrease in leucocyte count in September.

Exposure of human beings to the direct sunlight (96) or the tropical sun (95) will increase the leucocyte count of their blood. A possible explanation of this phenomena, then, is the more concentrated rays of the sun during the summer months.

Discussion of Experimental Results.

The effect of certain rations on the leucocyte, as found in this experiment is shown in Table III on page of the appendix.

Of six animals on a whole milk diet, C-31, C-53, and C-54 had a high leucocyte count, C-40 and C-53 with alternate periods when the count was high and normal. C-42 was normal most of the time, but with a number of high counts, which indicated a tendency to leucocytosis. C-62 had a normal leucocyte count with several counts both above and below normal.

In the next group, C-16 received whole milk and skimmilk with various supplements as cod liver oil, alfalfa mineral mixture, blood meal, syrup of iron phosphate, sodium chloride and oat hulls. This animal showed continual leucocytosis.

C-22 received a ration very similar to that of animal C-16 which contained at different times whole milk, skimmilk, alfalfa tea, wood ashes, tankage, syrup of iron phosphate,

cod liver oil and wheat bran.

This animal also showed leucocytosis the same as C-16. C-25 received a ration of whole milk, oxidized cod liver oil, unoxidized cod liver oil, syrup of iron phosphate, alfalfa meal, bone flour and wheat bran. This animal also showed leucocytosis. C-16, C-22 and C-25 also showed depraved appetite.

C-18 and C-20 received potatoes, grain and one pound of timothy hay, while C-19 and C-21 received the same ration plus the addition of three per cent calcium carbonate, to the grain ration. These four animals all developed depraved appetites and showed leucocytosis.

. The results with syrup of iron phosphate were contradictory. Of the animals receiving whole milk and this supplement, C-27 and C-60 showed leucocytosis while C-58, C-61 and C-64 all continued to have a normal leucocyte count. None of this group evidenced depraved appetite.

C-52 and C-57 received whole milk and a mineral mixture containing iron, manganese, fluorine, aluminum and silicon. C-52 developed depraved appetite, but C-57 did not, neither however developed leucocytosis.

C-28 developed both leucocytosis and depraved appetite on a ration of whole milk and flowers of sulphur.

C-30 was given whole milk and raw linseed oil. This calf developed both depraved appetite and leucocytosis.

C-56 at first received a ration of whole milk, corn and oats and showed a normal blood count, but when placed on whole

milk, bone meal and cod liver oil he developed leucocytosis.

Calves C-51, C-55, C-56 and C-63 received a normal ration of whole milk, cod liver oil, alfalfa hay, corn and oats, and silage in C-51's ration. These calves developed normally and had a normal leucocyte count.

C-44 and C-45 received a rather varied ration containing at different times, whole milk, skimmilk, calcium carbonate, cod liver oil, alfalfa hay, corn, oats, wheat straw, a grain mixture, gluten feed and corn distillers grain.

Neither calf developed well, due to the unpalatibility of the feed, after being placed on the restricted ration. Both calves became very stiff and lame. C-45 lost his appetite and was taken off the experiment. C-44 did not eat well and became totally blind. When first placed on a ration of wheat straw and the grain mixture, they were receiving skimmilk and showed leucocytosis. The grain mixture was changed to corn, oats and gluten feed (lower in protein than the grain mixture), and a normal leucocyte count resulted.

These calves when again placed on wheat straw and the old grain mixture received no skimmilk. During this feeding period the blood count of both calves varied considerably, but could not be called leucocytosis.

C-35, C-38, C-46 and C-50 all received a ration of silage, wheat straw and a grain mixture. C-37 and C-39 received the same ration except that the grain mixture contained three per cent magnesium phosphate.

All of these calves gave a normal leucocyte count until placed on the above ration at three months of age. C-35, C-37, C-38 and C-39 showed leucopenia the first two months on this ration. The second two months, however, they showed leucocytosis which was followed by normal counts. These four animals all developed depraved appetites before or about the time the leucocyte counts increased.

The leucocyte count of the blood of C-46 and C-50 remained normal. They were not on the restricted rations as long as the preceding four animals. They did not develop depraved appetite.

C-32 received a varied ration but was finally placed on corn, oats and cotton seed meal. This calf showed leucocytosis on whole milk, corn and oats. It also showed distinct leucocytosis on corn, oats and cotton seed meal.

C-43, C-47 and C-49 received a normal ration until they were placed on corn, oats, cotton seed meal, wheat straw and skimmilk at approximately three months of age. The skimmilk was taken from the ration a short time later. None of these three calves developed depraved appetite, but all of them showed leucocytosis on the restricted concentrate ration without hay or silage.

According to Table IV on page 6a of the appendix, three animals on milk alone show distinct leucocytosis and four were variable in leucocyte counts. Two of these four had periods of leucocytosis alternating with periods when their counts were normal. The remaining two cases were normal the

majority of the time, but had occasional high counts, with one of these showing some low counts.

Of three calves on whole milk with grain supplements without hay or grass, all showed leucocytosis.

Five calves received whole milk and syrup of iron phosphate. Three of these continued to have a normal leucocyte count, while the other two manifested leucocytosis. These results are not conclusive either way.

Two animals that received whole milk and a mineral mixture containing several elements gave only a normal leucocyte count.

Three calves which received flowers of sulphur, raw linseed oil and bone meal respectively, with whole milk, all showed leucocytosis.

Four other calves receiving a normal ration of whole milk, alfalfa hay, cod liver oil and corn and oats gave only normal blood counts.

Two calves received skimmilk, wheat straw and corn and oats gave normal leucocyte counts. These same calves showed leucocytosis when a high protein grain mixture was substituted for the corn and oats, but when the milk was taken from their ration and they received only wheat straw and the grain mixture their blood count varied, being normal one time and high at another.

Of all cases receiving milk, either whole or skim, and various supplements other than hay, thirteen animals showed leucocytosis, seven animals a normal leucocyte count, and six

animals showed considerable variation. Of these six, all of them tended to be high, having normal or high counts with few or no low leucocyte counts. In agreement with this, three calves that received milk, corn, oats and alfalfa hay, all gave a continued normal leucocyte count.

Four cases are noted of calves receiving potatoes, grain and one pound of timothy hay daily. These calves all showed leucocytosis. Four others are listed which received corn, oats, cotton seed meal and wheat straw. These all developed leucocytosis. Of seven others that received a normal grain mixture, wheat straw and silage, three gave normal counts and four varied. These four showed leucopenia when first placed on this ration. This period of leucopenia was followed by a two month period when the animals showed leucocytosis. The count then became normal and continued normal as long as they were on the experiment.

Fifteen cases of depraved appetite are listed. Ten of these showed distinct leucocytosis, one a normal count and the remaining four varied. The four that varied had a low count when the depraved appetite developed, but later the count became abnormally high.

With only two cases listed, both of them showed a higher count with calcium carbonate in their ration than did either of two other calves on the same ration minus the calcium carbonate.

The data available on seasonal variation in the leucocyte

count of bovine blood shows that in July fourteen animals showed an increase in the number of leucocytes in the blood over the preceding month. Four animals showed no definite variation, that is, they remained the same or the counts were too variable in one or both months to make an accurate comparison possible.

For the autumn months there are twenty-eight animals showing a fall in the leucocytic content of the blood during September and only three animals which either showed an increase or no definite change.

These animals were under abnormal conditions, but there probably is a seasonal variation in the leucocyte count of the blood.

Conclusions.

1. Leucocytosis occurs in calves raised on milk alone, and milk with various supplements other than hay, grass or silage.
2. Leucocytosis occurs in calves fed a ration without hay, grass or silage.
3. Depraved appetite is usually accompanied by leucocytosis.
4. There appears to be an increase in the leucocyte count during the summer.

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APPENDIX.

I.

Calf No.	Sex	Born	Date on	Last count off	Age On	Age Off	Died
C-16	F	10-13-23	4-20-24	9-18-25	190	706	
C-18	F	11-6-23	8-11-24	9-10-25	279	674	10-27-25 K
C-19	F	11-24-23	8-11-24	1-7-26	261	765	2-24-26 K
C-20	F	11-8-23	8-11-24	9-15-25	257	657	2-6-26
C-21	F	12-15-23	8-11-24	11-25-25	240	711	11-28-25
C-22	F	12-15-23	4-15-24	9-10-25	122	635	
C-25	F	4-1-24	5-20-24	8-5-25	49	491	8-5-25-491
C-27	M	5-8-24	8-18-24	3-5-26	102	681	Killed 3-20-26-681
C-28	M	5-11-24	5-20-24	12-22-24	9	228	12-25-24
C-30	M	6-13-24	8-18-24	8-27-25	65	440	9-21-25 K
C-31	M	7-7-24	10-21-24	12-29-24	106	175	12-29-24
C-32	M	7-22-24	7-24-24	9-17-25	2	422	9-27-25-432
C-35	F	8-19-24	8-19-24	12-18-25	0	486	
C-36	M	9-2-24	10-22-24	2-12-25	50	163	2-14-25-165
C-37	F	9-20-24	9-20-24	4-16-26	0	573	
C-38	F	9-25-24	9-26-24	3-15-26	1	536	3-28-26-549
C-39	F	9-26-24	11-7-24	12-18-25	61	479	
C-40	M J	11-14-24	1-10-25	2-19-26	57	462	2-22-26-465
C-42	H	1-3-25	7-7-25	12-16-25	185	347	12-17-25-348
C-43	M	1-12-25	1-12-25	12-22-25	0	344	1-2-26-355
C-44	M	3-27-25	3-28-25	5-25-26	1	424	
C-45	M	3-29-25	3-29-25	2-11-26	0	318	Off Exp. 2-10-26 Killed 3-20-26
C-46	H	3-29-25	3-29-25	11-27-25	0	243	
C-47	M J	3-31-25	7-8-25	1-8-26	99	283	1-9-26-284
C-49	M	5-11-25	5-12-25	11-27-25	1	200	11-28-25-201
C-50	F	5-22-25	5-22-25	12-10-25	0	202	

I. (Continued).

Calf No.	Sex	Born	First Count Date On	Last Count Date Off	On	Age Off	Died	Age
C-51	M	5-28-25	9-9-25	1-25-26	41	242		
C-52	F	6-14-25	6-25-25	3-12-26	11	271	3-17-26	276
C-53	M	5-17-25	6-25-25	2-12-26	39	271	2-13-26	272
C-54	M	4-30-25	6-25-25	10-20-25	56	173	10-20-26	173
C-55	F	7-3-25	7-3-25	8-7-25	0	35	8-13-25	41
C-56	F	8-11-25	8-11-25	12-3-25	0	113	2-9-26	181
C-57	F	8-11-25	8-19-25	2-19-26	8	192	2-26-26	199
C-58	M	8-28-25	8-28-25	5-25-26	0	270		
C-60	M	10-7-25	10-7-25	1-25-26	0	110	Pneumonia 1-28-26	113
C-61	M	11-6-25	11-6-25	5-25-26	0	200		
C-62	M	11-20-25	12-2-25	5-25-26	12	186		
C-63	M	1-8-26	1-8-26	5-26-26	0	138	Butcher 6-9-20	152
C-64	F	2-22-26	3-3-26	5-22-26	9	89		
C-65	M							
P-1	M							
P-2	M							

II.

Toisson's Fluid.

Sodium Sulphate (Na_2SO_4)	8 grams
Sodium chloride (NaCL)	1 "
Glycerin, neutral	30 cc.
Distilled H_2O	160 cc.
Methyl violet 5B	.025 grams

III.

Calf No.	Diet	Count
C-31	Whole milk	Leucocytosis
C-54	" "	"
C-40	" "	Alternate high and normal.
C-42	" "	Normal most of time. Some high.
C-53	" "	Alternate high and normal.
C-62	" "	Normal with high and low points.
C-16	Whole milk. Various supplements (D.A.)	Leucocytosis
C-22	" " " "	"
C-25	Whole milk. Varied supplements (D.A.)	"
C-32	Whole milk. Corn and oats.	"
C-18	Grain, potatoes, 1# timothy (DA)	"
C-19	Grain, potatoes, 1# timothy, $CaCO_3$ (DA)	"
C-20	Grain, potatoes, 1# timothy (DA)	"
C-21	W " " " $CaCO_3$ (A)	"
C-27	Whole milk, syrup of iron phosphate	"
C-58	" " " "	Normal
C-60	" " " "	Leucocytosis
C-61	" " " "	Normal
C-64	" " " "	"
C-52	Whole milk, mineral mix (DA)	"
C-57	" " " "	"

III (Continued).

Calf No.	Diet	Count
C-28	Whole milk, flowers of sulphur (DA)	Leucocytosis
C-30	Whole milk, raw linseed oil (DA)	"
C-36	Whole milk, cod liver oil, bone meal, (DA)	"
C-55	Whole milk, cod liver oil, alfalfa, corn and oats	Normal
C-56	" " " "	"
C-63	" " " "	"
C-51	" " " " silage	"
C-44 & C-45	Skimmilk, wheat straw, grain mix " " " corn and oats Wheat straw, grain mix	Leucocytosis Normal Variable
C-35	Wheat straw, silage, grain (DA)	Low leuco-normal
C-37	" " " " and $MgPO_4$ (DA)	" " "
C-38	Wheat straw, silage, grain (DA)	" " "
C-39	" " " " and $MgPO_4$	" " "
C-46	Wheat straw, silage, grain	Normal
C-50	" " "	"
C-32	Corn, oats, cotton seed meal	Leucocytosis
C-43	Cotton seed meal, corn and oats, wheat straw	"
C-47	" " " "	"
C-49	" " " "	"

IV.

Ration	Count High	Normal	Low	Variation
Whole milk	2			4
Whole milk and supplements (minerals or grain)	3			
Whole milk, syrup of iron phosphate	2	3		
Whole milk, mineral mixture, (manganese, silicon, fluorine, iron, aluminum)		2		
Whole milk, sulphur, raw linseed oil, bone meal	3			
Whole milk, alfalfa, cod liver oil, corn and oats		4		
Skimmilk, wheat straw, grain mix	2			
" " , corn & oats		2		
Wheat straw, grain mix				2
Potatoes, grain, 1# timothy	4			
Wheat straw, grain mix, silage		2		4 - low - high normal
Corn, oats, cotton seed meal, wheat straw	4			
Depraved appetite	10	1		4 - low - high
$CaCO_3$	2			

Increase in count in July	14
No definite change	4
Decrease in September	28
No definite change	3