

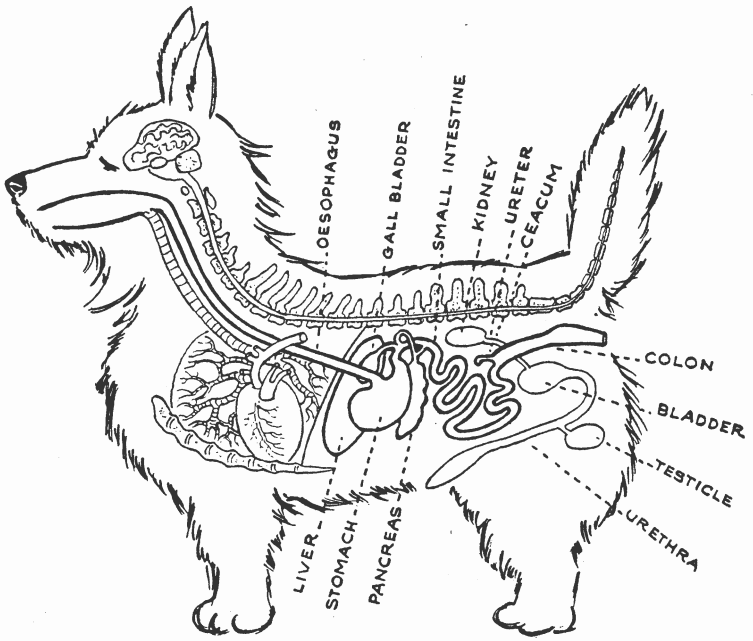


Diagram of a dog, with apologies to anatomists and Cairn Terriers

NUTRITION OF THE DOG

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DEDICATED TO

those researchers of the past and their experimental animals that have contributed their lives in order that men and dogs might have better health during the brief span spent on this earth.

PREFACE

THE PURPOSE of this work is to improve the health and happiness of my favorite pet, the dog. There is probably more misinformation concerning the nutrition of the dog than of any other species; as a result, many fine animals have aged prematurely, and died early. This work presents only information supported by evidence gained from experiments, and gleaned from the technical literature of the world.

To satisfy the needs of both the pet owner and the scientist, each chapter is arranged so that essential, applied knowledge is presented in the introduction. As the subject is developed, the complete technical picture is presented. For the benefit of veterinarians and other scientists, a bibliography of the most important papers is included.

CLIVE M. McCAY

Ithaca, New York

CONTENTS

Preface	v
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CHAPTER

I. Americans and Their Dogs	i
II. Carbohydrates for Dogs	7
III. Fat in the Diet of Dogs	17
IV. Proteins for Dogs	25
V. Mineral Requirements of Dogs	39
VI. Vitamins for Dogs	54
VII. Modern Dog Feeds	84
VIII. The Ingredients of Dog Feeds	99
IX. Testing Dog Feeds	106
X. Practical Feeding and Management of Dogs	118
Author Index	135
Subject Index	138

CHAPTER I

AMERICANS AND THEIR DOGS

NO NATION has ever taken a greater interest in its dogs than America. Part of this interest is probably an inheritance from the Anglo-Scotch tradition; and part, the appreciation of the pioneer for the friend who guarded his home from the Indians, brought the cows from the pasture in the evenings, and churned the butter between times.

Even today, when dogs no longer earn their livings in these services, they probably have an even greater value as the sole link between thousands of city dwellers and animal life. The dog is the great teacher of nutrition and of biology and physiology to the boys and girls of America.

Most Americans do not doubt the value of the part the dog plays in wholesome family relationships. To some, the dog teaches philosophy; to some, friendship; and to others, an appreciation, constantly renewed, of the pleasures of living.

The dog is supposed to have been the earliest of the wild animals tamed by man. Some have assumed that this species was tamed because of the attractiveness of puppies. In modern times, however, two other theories have been advanced. According to the first, summarized by Stockard, man and the dog joined forces because the two could work together to admirable advantage in killing wild animals for their common food supply. The dog could scent the game, pursue it rapidly, and drive it to cover; while man could use his hands and crude weapons in the killing.

A more recent theory suggests that the dog was kept primarily because it was such an excellent scavenger. Among primitive peoples large numbers of dogs have been observed. By eating the refuse of bones and garbage, the dogs help prevent the development of the

stench of the waste heap, as well as of the flies and insects that thrive on the putrid refuse. Thus primitive peoples can occupy encampments for longer periods.

In his work on the Lena Delta, Melville noted still another service rendered by the sled dogs and their puppies. All were housed together with the people in their crude huts under the snow in winter. The dogs licked the children, and thus saved the mothers the trouble of bathing them. Here again, the dog may have played a very important part in the sanitary arrangements of early man.

Whatever services the dog may have rendered, there is little doubt that he has provided throughout the ages the most satisfying companionship that man has known. Human friendships may rise and fall; but the dog is constant in his affection. No price is too great to pay for this spiritual satisfaction. The author pretends to know nothing of life after death, but he contemplates without much pleasure any heaven not well populated with dogs.

In 1938 the dog population in America was estimated at about fifteen millions. Anyone who has lived in the South appreciates the errors in such estimates; it would be difficult to determine the number of dogs on the hinterland farms. In 1938 Americans spent about one hundred and twenty million dollars for dog shows, and the state of New York collected over nine hundred thousand dollars in dog taxes. The public is willing to pay well for the support of its favorite pet. Few investments return equal pleasure.

A COMPARISON OF THE NUTRITION OF DOG AND MAN

Down through the ages man has used his friend, the dog, for testing his food. Long before the word "vitamin" was coined, studies with dogs laid the basis for much of our modern knowledge of nutrition. Fortunately, the dog's body functions like that of man. With one major exception the nutritional needs of the dog are like those of man: Man develops scurvy if his diet lacks vitamin C, whereas the dog makes this vitamin within his body.

The Russians have erected a monument to Pavlov's famous dog, the dog that taught so much about digestion early in the present cen-

ture.¹ Hundreds of such monuments should dot the civilized nations; they would remind the fanatics who oppose experiments with animals that these dogs gave their lives that men might learn more about disease. Thus knowledge grows and prevents the suffering of millions of men and their dogs.

A few illustrations will show the important part the dog has played in promoting human welfare by providing a better knowledge of nutrition: Some time ago, at a meeting of a kennel club, a woman made this statement: "I have heard that the dog has no pancreas and cannot, therefore, digest starch and sugar." The answer was that if the dog had not had a pancreas functioning like that of man, insulin would probably have remained undiscovered, and, as a result, thousands of people suffering from diabetes would not be alive today.

The pancreas of both dog and man is an organ that manufactures several substances vital for the body; the dog has made their discovery possible. The discovery of the functions of the pancreas of the dog is worthy of much attention, because it has contributed much to the basic knowledge of practical nutrition. This organ makes the utilization of cooked starch possible for both men and dogs. Most of America was still occupied by the Indians when, in 1664, Regnier de Graaf (1641-73) published a monograph upon the pancreas of the dog and its secretion.² He devised methods for collecting the secretions both of the salivary glands and the pancreas of the dog.

Nearly two hundred years later, the importance of the pancreatic juice for the digestion of fat in the intestine of the dog was recognized. A few years later, the digestion of starch by this juice was also appreciated. Still later, other dogs and other men proved that protein was also digested by this important juice. Finally, it was found that this gland made other special substances that passed into the blood, and that these made the burning of sugar possible. The isolators of this important protein, named insulin, were awarded the Nobel Prize in 1923. A hundred generations of dogs and fifteen generations of scientists made this great discovery possible. Today, evidence is accumulating that the pancreas not only provides insulin and the enzymes that pass through its duct into the intestine, but that it also

provides another substance which, like insulin, goes directly into the blood stream.

The discovery of the value of liver in the diet is another outstanding example of the contribution of the dog to human welfare. About 1912, scientists in California started taking part of the blood from dogs just as it is now taken from people for the use of others. For

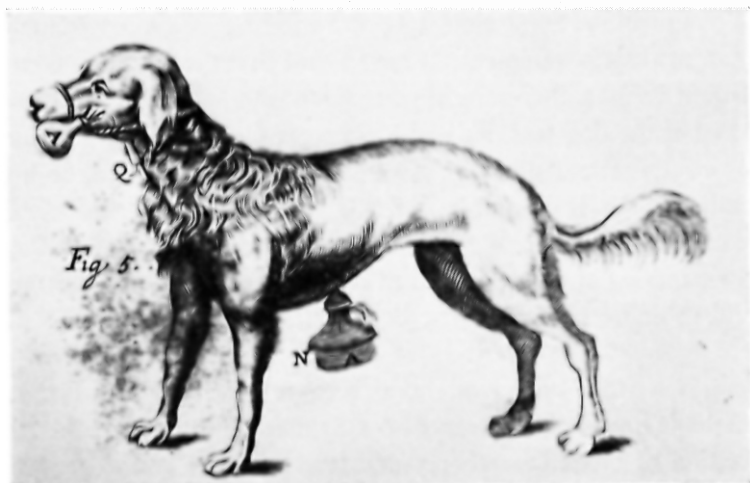


FIG. 1. *Illustration from De Graaf in 1664 showing a method for studying the secretion of the pancreas and salivary glands.*

thirty years they tested many diets to determine those best for forming new blood. In the course of these studies they discovered that liver was best for the formation of new blood.³ Thus liver became the staff of life for anemic people. The Nobel prize was awarded for this discovery in 1934. Today it is recognized as the most valuable meat that can be eaten by either men or dogs. The dog has given a wealth of information about the regeneration of blood and the value of special diets. Today manufacturers use carloads of liver for the extraction of its valuable blood-forming constituents.

The dog has played an important part in making about half the basic discoveries underlying the science of nutrition. For a recognition that proteins differ in quality we have to turn the pages of

history back to 1816. In that year, the great French physiologist, Magendie, reported that dogs could be kept in health upon a meat diet, but failed if fed gelatin alone.⁴ In this same study he observed that some dogs developed a cataract over the eye. This was probably the first evidence that diet could influence the eyes.

Likewise, a quarter of a century before vitamin B₁ was discovered in the course of feeding rice to chickens, the symptoms arising from a lack of this vitamin were carefully described in dogs by Forster in 1873.⁵ Forster was attempting to feed dogs a diet low in salt when he nearly discovered a vitamin. In modern times, the recognition of the importance of nicotinic acid (now called Niacin) in preventing pellagra was made possible by the knowledge that dogs get the disease called "black tongue" when fed the diet producing pellagra in man.⁶ Similar examples can be drawn from many other phases of nutrition.

The processes by which food is converted into bone and muscle are so nearly alike in dog and man that it would be very difficult to cite genuine differences. The dog is able to digest and utilize the same foods as man. In addition, the dog takes pleasure in many foods, such as overripe meats, not relished by modern civilized man. As far as anyone knows today, the dog has the same nutritional requirements as man, except that man develops scurvy if his diet is deficient in vitamin C, while the dog does not seem to need this vitamin. Therefore, in most cases, the dog should be fed like man.

But man seldom knows how to feed himself in order to remain healthy and live a long life, so he cannot hope to feed his dog without some friendly advice.

WHEN DOGS FEED THEMSELVES

In the wild state, the dog could doubtless do a good job in balancing his diet. When the farm dog catches a rabbit, he devours it entirely; even the head and fur may be eaten. A dog can be maintained in just as good condition upon a modern diet of dry feeds; instead of the bones of the rabbit, such a diet provides calcium and phosphorus in the form of bone meal. The proteins of the muscles of the rabbit

are replaced by protein in the form of meatscraps, milk products, or soy beans. In place of the plant products found in the stomach of the rabbit, the dry feed provides carbohydrates in the form of corn or wheat products. The vitamins of the liver of the rabbit are replaced by cod-liver oil or by concentrates mixed with the dry feed.

Since there is much misunderstanding about the digestion and utilization of these food constituents by dogs, each will be considered in more detail.

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CHAPTER II

CARBOHYDRATES FOR DOGS

WHEN THE biochemist uses the term carbohydrate, he thinks of a special class of substances found in foods such as cane sugar, starch, and milk sugar or lactose. From early times men have fed dogs bread, which is about half carbohydrate, and dogs can live for long periods on bread alone, especially upon whole grain breads. In some countries, Ireland for example, large amounts of potatoes (about one-fifth starch) are commonly fed to dogs.

Dogs can make use of the same carbohydrates as man, and there is no evidence that they develop any specific disease as a result of eating them. If, however, dogs are given a diet containing little but carbohydrates, such as a diet of candy or potatoes, they will ultimately suffer just as a child would under similar conditions. Such a diet lacks vitamins, protein, and minerals. Likewise, if a dog is fed largely upon potatoes, with a little meat, it will break down from both vitamin and mineral needs.

In the interests of economy the diet of the dog should consist of half or more of carbohydrates. In general, starch eaten by a dog is handled by the body just as it is by the body of man, with the single exception of changes in the stomach. The saliva of man contains an enzyme which starts digestion when food is chewed, and this action continues in the stomach until it is stopped by the acid of the gastric juice. The digestion of starch is resumed after it has left the stomach and passed into the small intestine. The saliva of the dog does not contain this enzyme; consequently the digestion of starch takes place only in the small intestine.

As a result of the digestion occurring when starch and sugar are mixed with pancreatic juice in the small intestine, glucose is formed.

This is a simple sugar which passes from the intestine into the blood stream. Excess sugar is stored in the liver and muscles in the form of glycogen until it is needed to furnish fuel for the body.

Claims have been made that a dog that works hard should be fed corn sugar or glucose, for more rapid absorption. There is no evidence for this. A well-fed dog has starch or sugar enough in its intestine to provide glucose for about six hours after each meal. As the meal is digested, first in the stomach and then in the intestine, glucose and amino acids pass into the blood stream. The glucose is then changed into reserve fuel for the body. Part of this reserve is the store of fat. Another part is the remarkable substance known as glycogen.

Glycogen was first discovered through the labors of the French physiologist, Claude Bernard (1813-1889).¹ He first fed a dog for seven days upon a diet rich in starch and sugar, and then took blood samples from both the large veins leading to, and coming from, the liver. After the dog was fed meat for some time, however, sugar was found only in the blood coming from the liver. Hence, Bernard concluded that the liver must be the storehouse for blood sugar. Later the substance called glycogen was isolated from liver. It has many properties like starch, except that it turns red instead of blue when treated with iodine. This glycogen is easily changed to glucose.

Whole books have been written about glycogen. Most of the studies on it have been made with dogs. In a well-fed dog from a fifth to half of the glycogen is found in the liver and an equal amount in the muscles. A considerable amount is also found in the bones and skin, with a small amount in the heart. The following percentages of glycogen are found in the tissues of a normal dog:

Liver	4-17
Muscle	0.7-3.7
Bones	0.2-1.8
Skin	0.1-1.6
Heart	0.1-1.2

When a dog is forced to exercise very hard, it starts burning fuel, and this fuel is furnished partly by glycogen.

Long ago, Pflüger² found that a dog fed largely carbohydrates had

about 16 per cent of glycogen in its liver, while one fed meat had 7 per cent. Both reserves are probably adequate.

Claims have also been made that adding malt products, such as diastase, to a dog feed improves the digestion of starch. The addition of malt is an attempt to make good the lack of starch-digesting enzymes in the saliva of the dog. Malt may speed the digestion of starch slightly, but in the end matters little, because the pancreatic juice of a healthy dog can handle the job without assistance.

The importance of the pancreas of the dog for the digestion of starch, as well as the great ability of the dog to utilize starch, is shown in the studies of Beazell³ and others. They fed normal dogs a mixture containing 62 per cent of starch. On this diet no starch was excreted in the feces. After the pancreatic duct was cut, however, so that no secretion from the pancreas entered the intestine, the feces contained 18 to 39 per cent of starch. If diastatic enzymes were fed to help digest the starch, this fecal loss was partly prevented. These results are surprising in showing the extensive disappearance of starch from the intestine even after its digestion by the pancreatic juice is interrupted.

For many years the question of the digestion of raw starch by dogs has been debated. Men and dogs can digest some raw starch, but they usually develop diarrhea if they eat much of it. This is due to the passage of considerable amounts of the raw starch into the large intestine. Here it is fermented, with the evolution of gas. Every small boy has had this experience after eating raw potatoes or poorly baked pancakes. Many animals can digest raw starch as well as cooked; the white rat and the common farm animals, for example, make good use of raw starch.

Many farm dogs eat raw starch when they steal feed from the chickens, and seem to suffer no ill effects. The probable reason is that dogs exercise considerably and eat many other foods, and as a result the undigested raw starch causes no trouble.

As a rule, starch should be well cooked for dogs. In the Far North the corn meal fed to sled dogs is well boiled to form mush. Likewise, wheat flour must be boiled or baked. Corn and wheat flakes, as well as shredded wheat, are commonly used in dog feeds, because these are cooked in preparing breakfast foods for human consumption.

The Feeding of Bread and Sugar to Dogs

As early as 1816 the great French physiologist, Magendie (1783-1855), observed that dogs could be kept for long periods upon bread and water.⁴ Such dogs lived longer if the bread was made from whole grains, such as wheat or rye. Today we realize that these whole grain breads are much richer in vitamins and in certain minerals, such as iron, than white bread is.

Much can be learned about the feeding of dogs from these classical studies of Magendie.⁵ A brief report of his work was printed in 1816, and an extensive one in 1841. The object of his studies was to determine whether or not animals could live upon a diet of gelatin alone. He soon found that they could not. He attempted to feed a dog only sugar and water. After a single week upon this diet the dog failed to eat well; at the end of a month the animal died. The eyes had developed ulcerations. Today we recognize this as an early description of vitamin deficiency. It usually took two to three weeks to develop this eye condition on the diet of sugar and water. Magendie did this one experiment three times with three different dogs. He also tried other dogs upon diets of other single substances, such as olive oil and water. In all cases he "observed the excrements" and concluded that these foods were digested and absorbed.

A hundred years ago it was well recognized that animals could live well for long periods upon milk. The chemists of that day knew that milk contained a protein called casein, fat in the form of cream, and inorganic salts. For this reason the British chemist, Prout, claimed this was the ideal diet for an animal.

Magendie tried to make an imitation milk by mixing starch, lard, sugar, and salt; but the dogs failed. We now know that such diets lacked protein and vitamins. These early trials, however, led to the use of the "synthetic diets" which in modern times have proved so useful in teaching us the needs of the dog for vitamins.

Five years after the death of Magendie there appeared a great German book (Bischoff and Voit, 1860)⁶ devoted throughout its three hundred pages to the nutrition of the dog. Much of this book de-

scribed experiments to determine the amount of meat needed to maintain a dog in good health. Some attempts were made to keep a dog upon rye bread alone. They found that this was difficult. In one balance study they fed the dog slightly less than two pounds of bread daily. After such feeding about 16 per cent of the ingested solids were recovered in the feces; in another trial only 12 per cent could be recovered. This demonstrates that the dog was able to utilize at least 84 to 88 per cent of the dry bread. The feces from the bread diet were slightly acid, and gave a test for starch with iodine, indicating that a small fraction of the starch was being excreted.

When dogs were fed only lean meat they often defecated but once a week; on a diet of bread they did so one or more times a day. The fecal solids appeared to be related to the amount of starch ingested, as is shown by the following brief table from Bischoff and Voit:

FOOD GIVEN THE DOG (in grams)			SOLIDS IN THE FECES (in grams)
<i>Meat</i>	<i>Starch</i>	<i>Fat</i>	
2,000	260	—	22
500	250	250	15 — plus 11% fat
176	229	—	15
—	450	—	22
—	221	—	11

The feces were neutral when sugars such as sucrose were fed. Long feeding on glucose produced "slimy" excreta. Lactose (milk sugar) feeding gave the dog diarrhea.

In 1871 another German, Gustav Meyer,⁷ reported other studies with bread. He found that more fecal nitrogen resulted from bread feeding than from feeding the same amount of protein as meat. He concluded that the acid feces resulting from bread feeding were caused by some fermentation in the large intestine. He thought that some organic acids were formed, and that these stimulated peristalsis. About 12 per cent of the solids of bread passed through the dog without absorption, and about 10 to 20 per cent of the nitrogen of the bread was recovered from the feces.

Feces after bread feeding tended to be softer and carry more water. After a dog ate bread it took about twenty hours for the residue to be

excreted. In balance studies with men this same author found that dark pumpnickel gave twice as much residue in the feces as lighter rye breads. Meyer realized that the bran content was important.

An early work by Donders, a Dutch physician (1818-1889), had shown that dogs and men cannot utilize bran as sheep can, but the Germans soon found that some of this bran could be digested if it were partly decomposed by boiling with acid or alkali. Today the Germans produce sugar by boiling the cellulose of wood with acid in this same manner. In earlier studies the Danish physician, Panum (1820-1885), had found that dogs could utilize only 75 per cent of black bread, which is rich in bran, but 85 per cent of white bread, which is poor.

The amount of cellulose is of considerable importance in considering diets for dogs. Not only do dogs fail to utilize this substance, but about the time of the last world war the Germans found that other nutrients in the diet were lost if too much cellulose was eaten in the bread.

In summary, we can conclude that bread and other carbohydrates are excellent food for dogs, but that neither men nor dogs can live upon bread alone. Some popular dog feeds make use of the stale bread from bakeries. This is ground after it is returned from the stores, and is then baked to a light brown. This is a good use for such bread, but part of the vitamins are probably destroyed by the toasting, since well toasted bread may lose half of its vitamin B₁.

Rieder⁸ fed starch alone to dogs in balance trials. When 119 grams of dry starch and 11 grams of fat were fed, the feces contained about 6 grams of dry matter. Thus about 95 per cent of the starch appeared to have been digested and absorbed. The fecal nitrogen during starch feeding was somewhat higher than when the dog was fasted.

Various attempts have been made to feed dogs considerable amounts of sugar in order to see if the body mechanism would fail to handle it and force its excretion into the urine. Hofmeister⁹ found that this could be done. He established "assimilation boundary" values for the different sugars; if these were exceeded the sugar passed into the urine.

His table shows wide differences among different sugars:

<i>Sugar</i>	<i>Weight of Dog in Kg.</i>	<i>Assimilation Boundary in Grams per Kg. of Live Weight</i>
Sucrose	2.8	3.6
Glucose	2.6	1.9-2.5
Lactose	2.5	0.4-0.8
Galactose	2.6-3.6	0.2-0.4

A surplus of starch is excreted in the feces rather than in the urine of the dog. But, if a dog is fasted and then fed large amounts of starch, the starch appears in the urine as glucose. As much as 10 per cent of the starch can be recovered as urinary glucose. In one case sugar was detected in the urine two to four hours after feeding starch.

The reason for this effect of fasting seems to be a lowering of the sugar boundary, since there is no evidence that digestion and absorption rates increase after a period of fasting. After fasting, even the level for glucose is lowered to about one-third of its normal level.

Several attempts have been made to determine if the feeding of carbohydrates with meat lowers the tendency toward intestinal putrefaction. Krauss ¹⁰ fed dogs meat with and without glucose. He analyzed the urine for ethereal sulfates, but could get no evidence that carbohydrates modified either the putrefaction or the digestion and absorption of meat by the dog. Munk ¹¹ also failed to get evidence for a specific effect of carbohydrates.

The common assertion that starch leads to skin diseases probably goes back to experiences before the discovery of the vitamins. In 1893 Rosenheim ¹² attempted to keep dogs on mixtures of meat, 25, fat, 25, and rice, 120 grams. The dogs gradually perished because the diets lacked most of the common vitamins as well as important inorganic elements like calcium. There is no sound evidence that starch produces skin diseases in dogs. Little is known about these skin troubles, and no one has been able to produce them at will by dietary or any other means.

Dogs were used by Mann ^{13, 14} and others to develop diets for human patients in which the large intestine had become functionless. After the colon and part of the ileum of experimental dogs were removed, various diets were given to determine which were best absorbed in the small intestine. All sugars except lactose were well absorbed. Lactose in a 4 per cent solution passed through the intestine

rather rapidly. Raw starch did the same and was therefore not well utilized. Rice and glucose were well absorbed in the small intestine. Of course, with the colon removed, these dogs were far from normal.

Roseboom and Patton¹⁵ rendered dogs diabetic by injecting phlorhizin. They then fed raw starch and obtained nearly quantitative recovery of glucose in the urine. In this case the dogs must have converted the raw starch into glucose.

At various periods in the course of five years the author has undertaken chemical balance studies with dogs to determine the percentage of starch recoverable from the excreta under various conditions. Starch in various forms was fed: raw and cooked corn starch, corn meal before and after cooking, wheat cooked in various ways, and corn flakes before and after toasting. The experiments indicate that raw and cooked starch tend to disappear from the gastro-intestinal tract at about the same rate. However, if starch is not well cooked, dogs tend to develop marked diarrhea after a few days upon the diet. If corn meal is fed in large amounts after it is cooked by blowing live steam through it, and then dried, the feces remain well formed, but if the corn meal is only slightly cooked, diarrhea ensues. One of the early authors claims that old corn gave a meal that would cause little diarrhea (Dinks and others).¹⁶

Likewise, if wheat is baked in an oven for three quarters of an hour at about 300° F., it still produces watery feces in many dogs. Well-baked bread or biscuits of wheat flour cause no disturbance. Raw corn flakes tend to produce diarrhea, but toasted ones do not.

The apparent digestibility of raw starch is probably due to its passage into the large intestine and fermentation by bacteria. Thus it does not reappear in the feces although it has not been digested and absorbed in the small intestine like cooked starch.

Small amounts of raw starch, such as that contained in the minor constituents of dog feeds, are well tolerated. Thus wheat germ, which contains some starch, can be fed at levels up to 8 per cent without trouble.

Many dry dog feeds are approximately half corn flakes, wheat flakes, or shredded wheat. These are all well utilized by the dog. Some dog feeds contain oatmeal and similar products. Small amounts

probably have little effect. The dog will tolerate large amounts if it is cooked into a gruel. Such gruels have been used in both laboratories and kennels.

The dog will not only thrive upon diets containing 50 per cent of cooked starch, but can also be maintained for long periods upon diets containing this amount of cane sugar in place of the starch. Thus the dog utilizes both starch and sugar. Under such conditions the remainder of the diet must be well selected.

Among the carbohydrates, the only one that behaves in an exceptional manner in the course of assimilation by the dog is lactose, or milk sugar. Fresh milk has about 5 per cent of lactose. Dry skim milk, which is incorporated in many good dog feeds, is about half lactose. Very often diarrhea is produced if a dog is fed a dry feed containing 5 per cent of skim milk, and this is supplemented with additional milk. This does no harm but is the result of giving the dog too much milk sugar.

Scientists have long known that milk sugar behaves within the body differently from other sugars. Pflüger² reviewed the many attempts made to determine whether lactose could be changed into glycogen within the body of the dog. He could find no good evidence that it was so changed, although he knew the dog's body made use of this sugar. When lactose is injected into a dog it passes out of the body in the urine.

In the studies of Deuel and Chambers,¹⁷ when dogs were made diabetic by the injection of phlorhizin, most sugars fed were excreted unchanged into the urine in the course of about five hours. Lactose, however, was only about half accounted for in such excretion. Furthermore, it appeared in the urine more slowly than the other sugars.

Likewise, Lusk calls attention to the failure of lactose, in contrast to other sugars, to increase the basal metabolism after it is eaten. He attributes this to the slow digestion of lactose and its probable fermentation before absorption from the intestine.

Older evidence indicated that the intestine lacks enzymes for breaking down lactose in large amounts. This enzyme is called lactase. It seems to appear in the intestinal tract if an animal is fed milk for some time. Cajori¹⁸ has recently reviewed this matter and

concludes that there is enough of this enzyme for splitting the lactose. However, he provides some evidence that the body might be able to handle lactose even if it were absorbed into the blood, since the liver of the dog has a small amount of the enzyme. Much remains to be learned about the sugar, lactose. Because of the great volume of milk drunk by man it is an important sugar in the human diet as well as in the ration of the dog.

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CHAPTER III

FAT IN THE DIET OF DOGS

FOR MORE than a hundred years students of nutrition have fed various fats to determine whether the dog can utilize them. All these studies have shown that the dog makes good use of fat when it does not comprise more than a third of the diet by weight. More than 90 per cent of all common fats, such as lard and tallow, are digested and absorbed by dogs. Dogs make good use of such fats as lard, olive oil, beef tallow, and cod liver oil. If a dog is too fat, it should be restricted in the amount eaten. If a dog is too thin, however, one of the best ways to make it more plump is to add about 10 per cent of a fat such as lard to the diet.

Dogs Can Use Lard

The statement is often made that dogs should not be fed some specific fat, such as lard. There is no basis for this in the scientific literature. In fact, some students of nutrition have used as much as 20 per cent of lard in diets fed to dogs over periods of many years.

Dogs are usually very fond of fats. If the components of a dry feed, such as beef scrap, corn flakes, or dry skim milk, are set before dogs in separate pans, and if lard is placed in another container, the hungry dog will usually eat the lard even before the beef scrap.

Most dry dog feeds are usually kept low in fat because it tends to become rancid. For this reason, if a dog becomes too thin, it is a good practice for his owner to add some fat such as mutton tallow or lard. Lard has more than twice as many available calories per unit weight as the usual dry feed, so it is really not an expensive fat to use. For large kennels tallow is somewhat cheaper and just as satisfactory.

Rats develop certain skin diseases when some fats are lacking in the diet. No one has shown a similar disease in dogs, but there is some

evidence that man must have these essential fatty acids. For this reason it is possible that the dog may also need them.

A Chinese student, Ling,¹ kept dogs upon a diet of only 0.5 per cent fat for a period of six months, with no ill effects. Possibly storage played some part; or the essential fatty acids may have been present in the small amount of fat.

At any rate, no harm is done if small amounts of some of the fats found in both plant and animal products are included in the diet of the dog. These essential fatty acids are probably adequate in most dry dog feeds, but more can be added in the form of a little lard, corn oil, or linseed oil. If linseed oil is fed to a dog, even in small amounts, the raw oil should be used; boiled oil may be toxic because of its lead and manganese.

The body fat of a dog is composed of both the fat given in the feed and that built by the dog from carbohydrates. Thus, if a dog is fed a very soft fat like linseed oil, the body fat of the dog becomes soft; while if the dog makes its own fat from the starch and sugar of the diet, his body fat is very hard.

When a dog goes without food its body first burns the glycogen of the liver. After that, the body fat and the proteins of the muscle are consumed. As long as any body fat remains, about nine parts of it are used for one part of protein.

The Digestion and Absorption of Fat by the Dog

Fat is a substance unique in the animal body. It is insoluble in water. In most processes the animal body deals with water solutions. In the case of fat, the body must handle fine emulsions, like the cream in milk before it rises to the surface. A close study of the dog for more than a century has given us much of our basic knowledge about the fate of fat in the body.

Usually, a dog eats fat along with its other food. The more fat there is in the food the longer the food remains in the stomach. This is the reason that "fried foods" are said to be "hard to digest." The fat in the stomach may even cause some bile and fluid from the intestine to flow back into the stomach. Cannon² found also that the movements of the stomach were slowed down by the presence of fat.

Fats usually pass from the stomach at a rate that will permit digestion in the small intestine. Thus, after a meal rich in fat there is no great accumulation in the intestine (Frank).³ The fat eaten by the dog is formed into an emulsion by the bile and split into free fatty acids and glycerine in the small intestine. During the war everyone has become aware of this reaction owing to publicity showing that fats yield about a tenth of their weight as glycerine when they are made into soaps.

When a dog is given a normal meal of a dry mixed feed low in fat, most of this has left the stomach at the end of six hours. On the other hand, Cannon noted that dogs fed a third of a pound of fat mixed with other foods still retained two-thirds of this fat in the stomach at the end of five hours. A small residue of fat was found in the stomach even after twenty-one hours.

As fatty acids are absorbed and pass through the walls of the intestine they are combined with glycerine again and thus become true fats. In the form of small droplets this fat is suspended in the lymph. Here it is carried like mud particles in a stream along the lymph vessel called the thoracic duct. Finally, this lymph flows into the blood of the dog at a point where the lymph vessel joins one of the veins at the base of the neck on the left side. In this way fat finds its way into the body of the dog. It is then either deposited as a reserve or burned for fuel.

Studies with dogs in 1826 first showed that lymph was the channel by which fat passed from the intestinal walls into the blood. These early experiments were made by Tiedemann and Gmelin⁴ in an attempt to win a prize offered in France for the best work describing digestion. In the course of their work they tied the bile ducts of dogs so that no bile could flow into the intestine. These dogs developed jaundice because bile was forced back into the blood. No fat was found in the lymph, because it could not be digested in the intestine. Without bile in the intestine there was much putrefaction. They even observed that dogs with jaundice developed blood that clotted slowly. It took more than a hundred years after their time until Americans found that some vitamins were not absorbed without bile. One of these vitamins was essential for blood clotting, namely vitamin K.

Even the lipstick of a hundred years ago served the scientists. The dye used in it at that time was called alkanet. They stained fat with this red dye. When this fat was fed to animals they could trace it as it left the intestine and flowed through the lymph.

The dog has probably been the most important animal used in studying bile. In the middle of the past century many debates were held concerning whether or not a dog could live if the bile was drained to the outside of the body, when it was lost and not available for digestion in the intestine. In some cases dogs died in a few days after this operation. One Frenchman claimed he kept such a dog alive for five years. His dog probably saved its life by finding a way of introducing bile into its intestine. Dogs secrete about 20 cc. of bile per kilogram of body weight each twenty-four hours. A rabbit secretes about seven times this much.

Bile is therefore important in the digestion of fat by the dog. Its other important functions are providing for the absorption of fat-soluble vitamins from the intestine and the prevention of putrefaction.

Body Fats of Dogs

In general, young puppies have bodies that are rich in fats. This is obvious to every observer and established by the analyses of Thomas.⁵ Strange as it seems today, one of the great problems of physiology a century ago was the origin of this body fat. Farmers knew that swine were fattened by feeding them liberally with grains. These grains were rich in starch, which was changed into lard by the body of the pig. The physiologists of the time, however, decided that protein of the diet was changed into body fat. This led to many misconceptions, such as the common idea that feeding diets rich in protein make cows give more milk fat.

The dog has contributed much to our knowledge of body fats. As early as 1868 Radziejewski⁶ fed dogs some oils of low melting point. The body fats of these dogs became softer as a result of this oil feeding. Later work has shown that an animal such as the dog deposits some food-fat in body stores. Swine do the same, but no one has ever

been able to feed a sheep so that its tallow will become softer and not stick to the dishes of the housewife.

One of the best examples of the effect of feeding fat upon the body fat of the dog was provided by Lebedef.⁷ He fasted two dogs until they were thin; one was then fed a diet rich in linseed oil and the other was given food rich in mutton tallow. The dogs were killed and their body fats studied. That from the dog fed linseed oil was liquid near the freezing point of water, while the fat from the dog fed mutton tallow was solid at 50° C. The latter figure is given for the body fat of a normal dog.

In other studies dogs have been fed soaps and also the fatty acids made by treating soap with a mineral acid such as hydrochloric. Dogs can even make some use of these fatty acids but could probably not be kept upon them indefinitely in place of fats.

The common idea of a century ago that protein was the major source of fat in the body arose from observations that the livers of animals suffering from phosphorus poisoning became "fatty." It was assumed that protein was changed to fat. One of the Germans who dominated the whole field of thought was Voit.⁸ He fed dogs meat and then analyzed the excreta for carbon and nitrogen. He could account for all the nitrogen in the urine and feces, but some of the carbon seemed to remain in the body. He concluded that this was used for forming fat.

Finally, the matter was concluded by a celebrated polemic written by Pflüger⁹ in 1892. He showed that the dog had behaved properly but that the chemists had erred in their analyses. Fifty years have elapsed. We now realize that the major sources of fat for storage in the animal body are the fats and carbohydrates in the food. A little may be made from protein.

The purpose of fat in the body of the dog is to act as insulation, to form a reserve of food, and to help anchor such organs as the kidneys. As a rule it is probably better to keep a dog from becoming very fat. Probably the greatest evil in over-feeding either men or animals is the deposition of excess body fat. It shortens the span of life.

Thin Versus Fat Bodies

Dogs, like men, can go for long periods without food if they have water. Hawk ¹⁰ kept his Collie dog, Oskar, for 117 days without food. On the 101st day the dog could still jump from its cage. Other dogs could not do so well, but learned to fast after an initial experience. Thus a fox terrier lost 46 per cent of its weight and was near collapse after fifteen days. It was refed. In a second trial it was able to fast for thirty days.

If dogs are kept thin and hungry, the quality of the diet must be good. This is illustrated in the methods used by Dr. W. T. James ¹¹ and the author to study the effect of feeding puppies a diet low in calories. The ration used consisted of alfalfa meal, 1; dry yeast, 10; tomato pomace, 5; bone meal, 1; salt, 1; limestone, 2; wheat germ meal, 5; meat scrap, 30; dry liver, 10; shredded wheat, 18; dry skim milk, 10.

Puppies were fed this diet from the time of weaning until they were about thirteen months old. Only enough of the diet was given each day to permit slight growth or to hold the body weight stationary. These puppies passed through a cold winter in an unheated kennel. They remained in excellent physical condition. They showed no signs of trouble from an epidemic of bronchial disease that swept the kennel. They were immunized against distemper without trouble. They were always extremely active and happy because they hoped a full meal was around the corner.

When they were thirteen months old, and allowed all the feed they wished, they ate ravenously for about a month. Each day they ate twice as much as the usual dog of their weight. Both the male and female in this study were sexually normal. The female gave birth to normal pups. The only effect upon these dogs of spending a year on the border line of starvation was that they were slightly smaller than normal. Apparently the skeleton could never attain the same size that it would have if growth had been more rapid.

This experiment indicates that there is no danger in keeping dogs reasonably hungry and thin if the diet is well designed. In fact, such dogs may be more resistant to disease.

Melting Point and the Utilization of Fats

Voit ¹² found that the utilization of fat was about the same whether he fed a dog 100 grams per day or 350 grams. In fact, the higher levels appeared to be slightly better utilized, with a loss of only about 1 per cent. The dog can digest relatively hard fats, such as mutton tallow, which melts at 53° C. Seven to 11 per cent of this fat may be excreted in the feces while only 1 to 3 per cent of a soft one, such as butter or lard, is lost. The literature in this field has been well summarized by Lyman.¹³

As much as 30 per cent by weight of the food of the dog can be fat, although this level is probably high. For regular feeding 10 to 20 per cent is the preferred level. Such levels have been used during many years in the studies with dogs at Yale (McCay).¹⁴ Hoffman ¹⁵ found a 32 kg. dog could tolerate as much as 300 gms. of lard per day.

Rancid fats are often eaten by dogs. Small amounts probably do little damage. The dog seems to enjoy them, in contrast to his master. The danger from the continuous feeding of rancid fats lies in the destruction of vitamins. Rancid lard or cod liver oil will destroy vitamins E and A in a few weeks if these fats are mixed with a diet and left in a warm room. Rancidity development and vitamin destruction are very rapid if mixed diets contain iron or copper.

Dorothy Whipple ¹⁶ fed dogs a diet containing 25 per cent of lard made rancid by blowing hot air through it. The first symptom of injury was the severe loss of hair from all parts of the body. A rash soon spread over the body and ulcers developed. This was accompanied by a loss of appetite. After a period of constipation there was severe diarrhea, and the dogs died. Neither the eyes nor mouths of the dogs became sore. Control dogs fed the same diet with the same amount of good lard suffered no ill effects.

Many substances are added to fats to check rancidity. Some of these, such as oat flour have been patented. Gum guaiacol is also added to lard in an amount equal to one part per thousand. As a rule these may help, but cannot replace, cool, dry storage.

The part of rancid fat that injures dogs is probably some decomposition product other than free fatty acids. In 1894 Frank ¹⁷ found

that dogs could be fed free fatty acids. These tended to leave the stomach very rapidly. Nine hours after feeding 200 grams of fatty acids, he found 81 per cent had left the stomach, while after thirteen hours the stomach still contained 87 per cent of an equal weight of true fat. He believed that free fatty acids cause some injury to the stomach, although Munk had fed a dog 2,000 grams over a period of two weeks with no apparent injury.

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CHAPTER IV

PROTEINS FOR DOGS

PROTEIN, in the thinking of the biochemist, means the nitrogen compounds that represent the chief part of egg white, meat, and cottage cheese. The chemist thinks especially of the white of the egg because it is quite pure protein. Every cell in the animal body contains protein.

Most proteins are first created in plants, and stored in the seeds and leaves. Young, growing plants, such as the pasture grasses, are very rich in protein. Dogs, like men, get their supply of protein from eating either plant or animal foods. Thus the dog may eat bread or corn meal for a plant protein. At the same time the dog may eat meat, milk, or eggs and get animal proteins.

As a rule, animal proteins are more complete. However, those from plant foods, such as soy beans and peanuts, are also very good. It is possible to rear and maintain most animals upon vegetarian diets if these are well selected. Few such attempts have been made with dogs.

Inasmuch as foxes and dogs seem very similar in their nutrition, it is probable that they are alike in the digestion and absorption of proteins from different sources. Smith ¹ has given the following values for the digestion of proteins by foxes:

<i>Diet</i>	<i>Per Cent Protein Digested</i>
Horsemeat (frozen)	91
Meat scrap	86
Fish meal	88
Liver meal	88
Blood meal	78
Soy bean meal	86
Linseed meal	81

Dogs can pass through their whole life cycle in good health without fresh meat or raw bones. In such cases the feed mixtures have usually contained meat meal and some dry milk products as well as dry

bone meal. In one study the author placed two Scottie bitches upon a dry feed at the time of breeding. They were carried through the gestation and lactation periods without trouble. The puppies were weaned and reared upon the same dry mixture. All nine became sound dogs and were marketed for pets when nearly grown.

In a later experiment Cairn Terrier pups were reared without fresh meat until about six months old. They were then offered meat, but they refused it until they had played with it for some hours. Such pups develop excellent teeth. If the diet contains enough calcium and phosphorous, the dog does not need fresh bones. There is no proof that the gnawing of bones is essential for the development of teeth. Perhaps the pups fed on the meal mixtures described above chewed their pens enough to cleanse the teeth.

The cooking of meat for dogs is a waste of time from the point of view of nutrition. Cooking tends to destroy vitamins. In fact, the meat meals commonly used in dog feeds are often so overheated in processing that they are devoid of the important vitamin B₁ (thiamin). Recently, in a digestion trial of meat meals made by our students, the dog refused to eat and became badly constipated. A small supplement of vitamin B₁ renewed his appetite immediately, and he became normal. This dog's diet contained 30 per cent of meat meal. Rats and hamsters fed the same diet at the same time showed the same vitamin B₁ deficiency. Even in the processing of canned meats for dog feeds more than two-thirds of the thiamin (vitamin B₁) may be lost by heating for an hour at 240° F.² The loss during the first hour of heating is much more severe than during the second.

Over a century ago Magendie³ found that dogs could be kept alive for long periods upon fresh bones; but if the bones were boiled, the dogs died within a couple of months.

Dogs can be kept upon meat alone for long periods. Early workers found that the amount of meat needed to keep a dog was 4 to 5 per cent of its live weight. Over long periods such dogs had to be fed bones also, since meat is deficient in calcium. Muscle meat is low in fat soluble vitamins, but can almost meet the needs of the dog. Of course, the dog usually comes to grief if the vitamin intake is lowered by feeding potatoes with only a little meat.

In the usual mixed dog feed, protein is provided by dry meat products, cereals like corn flakes, soy-bean meal, dry yeast, wheat germ, and dry milk products.

Basic Discoveries about Protein Were Made with Dogs

Studies with dogs led to the basic ideas underlying our present knowledge of the science of nutrition. If these are understood, the science will have been mastered.

The first great discoveries with dogs resulted from attempts to duplicate human diseases resulting from eating too much gelatin. Gelatin was first discovered about three hundred years ago by a Frenchman named Papin.⁴ Soon after he invented the pressure cooker while experimenting in the laboratory of Robert Boyle in London, he used the cooker for boiling bones. In this way he produced gelatin, and wrote a book upon the subject. Because of gelatin's great volume, he thought he had found a way of making a lot of food from a few bones. This idea persisted until about the year 1800, when the modern science of analytical chemistry began.

In the meantime, gelatin was extensively used during periods of meat shortage. Because of human troubles that developed in France from eating too much gelatin and too little of other foodstuffs, the French physiologist Magendie⁵ ran extensive feeding trials with dogs. After a few days of feeding gelatin alone to dogs, he found that they preferred to die rather than eat more. The first report of this work appeared in 1816, and the last in 1841.

These great studies, in addition to giving information about gelatin, showed that dogs must get protein in their food, and that they cannot build body proteins from the nitrogen of the air as leguminous plants can. They indicated that dogs could live much longer upon breads from whole grains than upon those made from refined flour. They proved that proteins differed in quality, since a dog could live for long periods upon meat alone, but died if forced to eat only gelatin. Magendie died without learning why his dogs fed on gelatin had failed, while those given meat had thrived.

The first real clue to this mystery resulted from the labors of a Swiss physician named Escher⁶ in 1876. By his time the chemists had found

that proteins were great structures built from many different substances called amino acids. The great physiologist Hermann told Escher about sixty-five years ago that proteins resembled the words in a book, because one could take the twenty-six letters of the alphabet and combine these into thousands of different words. The substances of which proteins were built were called **AMINO ACIDS**. Today the chemist knows there are about the same number of these as there are letters. To each of them he gives a name such as tyrosine or cystine. These amino acids can be built into thousands of different proteins, such as the casein in cottage cheese; the white of the egg, called albumin, the red protein of blood, called hemoglobin; the gluten of wheat flour; and thousands of others. The alphabet of the protein chemist, then, is his amino acid collection. In the bottles in his laboratory they all look much like sugar. Under the microscope, however, each has differently shaped crystals.

Before the time of Escher the chemists had found that they could take proteins apart into the pieces called amino acids either by boiling them with acids and alkalies or by letting them digest in the stomach or in the gastric juice of an animal.

Escher thought that the reason gelatin could not serve the dog might be that gelatin lacked some essential parts, so that the dog lacked the building stones for making its own body proteins from gelatin. The chemist had already found that many proteins would yield the amino acid tyrosine when broken down, but that gelatin would not.

Six attempts were made by Escher to keep a dog upon a diet in which the protein was supplied by gelatin with and without tyrosine. In all cases Escher failed, but he did find that gelatin was better with tyrosine than without. This gave the great clue to the shortcomings of gelatin in providing protein to replace the wear in the dog's body. Those amino acids which the body cannot make and which the dog must have in its food were gradually termed the "essential" ones. If a protein contains a liberal amount of all of them it is said to be "complete."

After Escher, the next great step forward in the study of the pro-

tein needs of dogs was made by Kaufmann ⁷ in 1905. He found that a dog could remain in nitrogen balance if gelatin replaced as much as a fifth of a higher quality protein. Before this time Loewi ⁸ had been able to keep a dog in balance with proteins digested by means of enzymes. To further remedy the deficiencies of gelatin, Kaufmann fed his dogs not only the amino acid tyrosine, as Escher had done, but he also fed tryptophane and cystine. For a time the dogs thrived and remained in balance, but then they died. Kaufmann's supply of dogs must have been exhausted, since he completed his studies on himself.

All of these early studies were confused because the diets probably lacked vitamins. The dogs were condemned, even though the proteins were complete. Gelatin was probably blamed for its own deficiencies in amino acids and the lack of vitamins in the diet. The attempts to maintain dogs on the products of split proteins were also failures because the science of nutrition was not far enough advanced in the field of vitamins.

The more complete a protein is, the less of it is needed to maintain a dog in good health; or "in nitrogen equilibrium," as the biochemist says. The most complete proteins are those from milk, meat, soy beans, peanuts, and yeast. The incomplete ones are those from white flour, gelatin, and refined corn meal.

The latest work of Rose and Rice ⁹ now indicates that, for dogs, proteins must contain ten of the twenty-two well-recognized amino acids. In other words, the body of the dog can probably make twelve amino acids for building its protein, while it must have ten provided in the protein of the diet. These ten are tryptophane, lysine, histidine, phenylalanine, leucine, isoleucine, threonine, methionine, valine, and arginine. It is probable that the body of the dog can make some arginine. In the growing pup, however, the body may not make it rapidly enough to supply the needs of the muscles and tissues that are increasing rapidly in size, if we can assume that a pup behaves like a white rat. In other words, arginine proves to be a "bottleneck" in the protein industry of the growing pup.

The names of the amino acids may seem strange to the novice, but

to the biochemist they are even more useful than the street names in his home town. They help him find his way around in the science of nutrition.

The Utilization of Plant and Animal Proteins

As the result of many balance studies, the author has found that the dog digests and absorbs about four-fifths of the protein in the usual mixed feed. About one-fifth of the protein is excreted in the feces of the dog. This is due in part to a failure to utilize plant proteins completely and in part to the changes produced in meat proteins by heating to high temperatures. Furthermore, many of the meat-meal proteins used in dog feeds contain fibrous tissue that resists digestion and are thus lost from the body of the dog.

Raw meat is probably the best digested protein. Long ago students found that a dog might defecate only once a week if only meat were fed. This was due to the very complete digestion of the meat and the excretion of the nitrogenous end products in the urine. The feces of such dogs contained about 5 per cent of nitrogen. This probably originated from the waste cells shed by the gastro-intestinal tract.

Under normal conditions, a dog needs about one-twentieth of its weight in meat to maintain its body. Early scientists thought they could determine the need of the dog's body for protein by measuring the nitrogen of the urine during fasting. When they fed this amount of nitrogen in the form of protein, however, they could not maintain the dog. In other words, there was some wastage when the muscle meat from an animal like the cow was converted into the muscles of the dog.

The dog makes equally good use of meat whether it is fed once or three times daily, according to Munk (1894).¹⁰ Meat also seems to be well digested whether swallowed in chunks or finely ground.

The relative completeness of the utilization of protein can be judged by balance studies in which the amount of food eaten and the dry feces are weighed for a given time period. For complete information the urine, feces, and food are all analyzed.

As a refinement of this method, the rate at which a food protein is utilized can be determined by feeding a test meal of a known amount

of some substance such as meat, then analyzing the urine for nitrogen, sulfur, and phosphorus at regular intervals such as one, two, three, etc., hours after the meal. Leder ¹¹ used this method as early as 1881. He found that the peak of excretion for sulfur and phosphorus occurred during the second hour, while the nitrogen peak did not occur until the fourth. All had dropped to normal in twelve hours. His results were about the same whether he fed 500 or 1,000 grams of meat and his study indicated that dogs used raw and cooked meat equally well. Wolf ¹² used this method upon men in 1912. Their digestion rate seemed slower.

Mendel and Lewis ¹³ made use of this method in 1913 to compare proteins fed to dogs. In general, the diets fed by Mendel and Lewis were mixtures of meat (or other protein for testing), 225; lard, 35; sucrose, 70; bone ash, 5; and water, 325, expressed in grams. The rate of utilization of meat was about the same whether it was dried in vacuo, or fresh. Casein, egg albumin, edestin, and gliadin all gave about the same rates of digestion. On the other hand, soy-bean protein was considerably slower, and raw egg white even more so. When the egg white was coagulated, it behaved about like meat. In general, inert materials fed to the dog, such as filter paper, ground cork, or paraffin, slowed the rate of digestion and absorption. Other workers had found earlier that fat slowed the rate of excretion of the end products of protein digestion.

The Utilization of Plant Proteins by the Dog

The earliest books describing feeding practices in kennels record the use of plant products such as gruels made from oat meal, corn meal, and wheat meal products. Many of the earlier works contain unique observations, such as the tendency of fresh corn meal to produce diarrhea, while meal from corn more than a year old does not do so.

Early studies with bread indicated that the dog could live upon whole grain breads for long periods, although the body tended to be very thin. In 1904 Rockwood ¹⁴ compared various sources of plant proteins fed to dogs, and found that poorly cooked oatmeal gave a loss of 16 per cent in dry matter and 20 per cent in protein. The well

cooked product gave a loss of only 12 per cent in dry matter and 16 per cent in protein. He compared the protein from corn, called zein, with that from oats. Zein was poorly utilized, with a loss of 22 per cent in the feces. Recent studies indicate that the proteins of whole corn are of much better quality than zein, which is the alcohol soluble protein. Rats have been put through their whole life cycle with the chief source of protein coming from corn.

Mendel and Fine¹⁵ compared the utilization of proteins of plant



FIG. 2. *Reared upon a mixture without meat scrap. Most of the protein was soybean meal.*

origin. Some of their values for utilization were the following: gliadin from wheat, 94 per cent; autoclaved barley, 85 per cent; corn gluten, 90 per cent; soy-bean protein, 74 to 84 per cent. In a second study with soy beans the values ranged from 83 to 86 per cent. The utilization of the protein of white navy beans was about the same.

Practical diets for the maintenance and rearing of dogs can be devised so that they are satisfactory even when the protein is entirely of plant origin. Koehn¹⁶ lists such diets, and the author has had limited experience with them. Koehn notes the importance of cooking such diets, especially if they contain soy beans. The improvement of soy bean protein by limited heating was established by Hayward¹⁷ some years ago.

Cottonseed meal is one plant protein concentrate that seems toxic to dogs. Koehn states: "Dogs may appear healthy and thrive on

cooked rations containing cottonseed meal for long periods, but eventually they will die very suddenly."

Lelu¹⁸ compared dogs and swine in their utilization of plant proteins. He concluded that, in general, dogs used about two-thirds of the protein of peas, soy beans, and rye, in contrast to 85-95 per cent of milk proteins. Swine made better use of plant proteins than dogs.

Diets rich in gliadin will ultimately kill dogs, according to the findings of Melnick and Cowgill.¹⁹ The gliadin was prepared from wheat flour. The diets richest in gliadin contained 36 per cent of this protein. Inasmuch as rats were not affected similarly, they concluded that dogs were especially sensitive to this protein. There is no evidence of injury to dogs from feeding diets based upon wheat flour, so this injury must be something developed from using the isolated protein.

Eggs—Cooked and Raw

Since eggs are often fed to dogs, and since egg white is of interest in nutrition because it is a rich source of protein, the question of cooked versus raw eggs is often raised. As early as 1898 Steinitz found that the feeding of raw eggs was often followed by vomiting and diarrhea in dogs. Mendel and Lewis confirmed this observation in 1913.

A little later, Bateman²⁰ studied this peculiar effect of egg protein. He found that raw egg white fed to dogs was often found in the stools. At the same time the dogs suffered from diarrhea. In dogs weighing 12 to 15 pounds he found that a single egg produced no effect, but that two eggs caused the feces to soften, and four or five eggs caused marked diarrhea. When eggs were beaten with milk the effect was the same, but it was less marked when the eggs were fed with cracker meal and lard. The effect of the raw egg white was usually noticed after eight to twenty hours. Bateman was able to recover as much as 30 to 50 per cent of the raw egg white from the feces of the dog. Chemical balances showed that 95 per cent or more of the meat protein was digested and absorbed by the dog, but that only about half the egg white was so utilized. The nitrogen of the egg

yolk was much better utilized in the raw state than that of the white. In the case of a dog that could utilize only 50 to 60 per cent of raw egg white, the cooked was found to be 90 per cent utilized.

Rats, rabbits, and even man tend to show similar poor utilization of raw egg white. Bateman thought that this was due to the rapid rate at which raw egg white leaves the stomach and also to the difficulty of tryptic digestion. In recent times many studies of raw and cooked egg white have been made by Parsons and her colleagues.²¹ In 1927 Boas²² observed that rats suffered from sore skin, called dermatitis, when the protein of the diet was derived from raw egg white. Boas thought that this indicated a toxic property of raw egg white which was not manifested if the wheat starch of the diet was replaced by corn starch. Parsons and her associates found that in rats this dermatitis from feeding raw egg white was prevented by including certain levels of yeast or dried liver in the diet.

The beginning of the solution of the mystery of raw egg white started with the discovery of a new vitamin by a Dutchman named Kögl²³ in 1937. He christened his new vitamin "biotin." He made it from egg yolk. Several workers found that rats developed sore skins when their diet lacked this vitamin, just as they did when fed raw egg white.

From studies with chickens, it was soon found that animals fed raw egg white really were deficient in this vitamin, biotin. The raw egg white in the intestinal tract seized the supply of this vitamin. As the egg white was excreted the biotin was lost. Later, a substance was actually isolated from egg white that had this unique property of combining with the vitamin. This substance was called "avidin."

When heated, egg white no longer ties up the vitamin. No one knows why boiled egg white is digested normally by the dog while the raw acts so differently. As early as 1905, Russian workers observed that raw egg white started leaving the stomach almost as soon as swallowed. As early as an hour and a half after swallowing, the raw material was well along in the small intestine. In contrast, boiled egg white remained in the stomach for two to three hours, until well digested.

In more recent times, workers at the Mayo Clinic in searching for

low residue diets have noted the contrast between cooked and raw eggs. After dogs were fed meat or cooked eggs, the residue came through the intestine in about four and a half hours. Raw egg appeared very rapidly, however. In many ways raw egg white passes through the intestine at the rate of lactose, and both produce diarrhea (French and Cowgill).²⁴

The only other raw substance of special interest among protein rich foods is fish. When raw fish is fed to foxes in large amounts, they produce a deficiency in vitamin B₁. The fish seems to have the same action in seizing the supply of vitamin B₁ as egg white does in the case of biotin. Likewise, the feeding of raw fish to brook trout causes this species to die of vitamin B₁ deficiency. This can be corrected by feeding large amounts of this vitamin, or by cooking the fish. Whether or not dogs suffer in this same way from feeding on raw fish is unknown. Since dogs are very similar to foxes in their nutrition, it is likely that they would suffer in the same way if kept for long periods upon diets rich in raw fish. Possibly such a condition is known among sled dogs but has never come to our attention.

Protein Level in the Diet

No good data are available to show the level of high quality protein needed for growth and maintenance.

Early studies with dogs were reviewed carefully by Chittenden²⁵ in 1907. Most of these were made by gradually replacing the meat in the diet of a dog by either rice or a mixture of rice and lard. Thus the dog was changed from a diet rich in protein and adequate in vitamins to one low in protein and very deficient. The outcome was inevitably failure. Even in 1907, however, Chittenden drew the correct conclusion that this failure was due to essentials other than proteins.

The dog probably needs a minimum of 12 to 14 per cent of good protein in its diet. In the case of meat scrap of low grade or plant proteins, the level should probably be 20 per cent, to allow for the losses, with a utilizable level of about 15 per cent. Both our experience and that of Koehn¹⁶ indicate that puppies grow well upon diets containing 20 per cent of protein, with part of this provided by animal or soy-bean products.

Putrefaction and Intestinal Gases

Early workers gave much attention to putrefaction in relation to proteins because they believed many ills resulted from the absorption of toxic products produced in the intestine through the action of bacteria upon the proteins. Special products, such as indican and ethereal sulfates, were known to exist in the urine after they were produced through intestinal putrefaction. Various attempts were made to measure these as a reflection of the diet. Munk,²⁶ for example, in 1894 tried to determine if glucose fed with meat would decrease the excretion of the toxic products. He could get no evidence of the modification of putrefaction by carbohydrates.

Some substances, such as fish meal, are usually supposed to create bad odors in the excreta of dogs, although odor is difficult to measure. Large amounts of beans, even soy-bean meal, lead to the formation of gas. If fat is not digested, as when the supply of bile is cut off in the dog, there is marked putrefaction. Alvarez²⁷ has summarized the little that is known in this field. Early work with dogs was described by Maly²⁸ in 1881. Dogs were fed known diets, killed, and the intestinal gases analyzed by methods available sixty years ago. In general, plant foods produced more gas than animal ones, such as meat. However, hydrogen sulfide, which has a bad odor, was produced only from meat. Most of the gas of the intestinal tract, even after the feeding of beans, proved to be carbon dioxide. Some must be sulfide, however. Some claim has been made that the outer husk of beans is responsible for this gas production, inasmuch as beans thoroughly cooked and passed through a coarse sieve do not produce flatulence.

A number of early attempts were made to learn if dogs were able to use forms of nitrogen other than those of protein, such as asparagin. All of these indicated the dog could not, and was different in this respect from cattle and sheep.

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CHAPTER V

MINERAL REQUIREMENTS OF DOGS

NEARLY TWO hundred years ago physiologists fed bones to determine how much the dog utilized. Today we realize that a dog needs the same inorganic elements to build its body as do the higher animals. The more common of these are sulfur, calcium, phosphorus, magnesium, sodium, potassium, chlorine, iron, iodine, silicon, manganese, copper, and fluorine. Some of these are needed in only small amounts; in large amounts such elements as copper, iodine, and fluorine are poisons.

For the most part the student of nutrition, in preparing a dog feed of natural feedstuffs, can neglect certain elements because they are present in adequate amounts in almost any mixture palatable enough for a dog to eat. The elements that can be neglected are potassium, sulfur, copper, fluorine, and silicon. Potassium is present in large amounts in meat, milk, and plant products. The requirement of the dog for this element is unknown, but is probably low. In some of the older experiments at Yale, the workers forgot to put potassium in their salt mixture.¹ The dogs remained in good health for many months upon a diet very low in this element.

Since most dog feeds contain meat scrap, there is little danger of a deficiency in the sulfur-containing amino acids. A deficiency might follow synthetic diets with the protein furnished by casein, but this is of interest only in the laboratory.

The copper requirements of a rat are supplied in excess if the feed contains five parts per million. The level for a dry dog feed is unknown, but can be assumed with reasonable certainty to be less than this.

The growing chick's need of manganese seems to be about 40 parts per million in dry feedstuffs. The requirements of no other species

are known. It is known, however, that this element is essential for reproduction in the mouse and rat. Schaible ² and his co-workers have prepared an excellent table of manganese levels in various feedstuffs. The following values are of interest to those preparing dog feeds: (values are in parts per million, p.p.m.) corn, 5; oats, 26 to 44; soy beans, 20 to 56; wheat, 24 to 37; bran, 96 to 105; meat scrap, 18; fish meal, 41; wheat germ meal, 160; skim milk, 0.4; soy-bean meal, 30; dried yeast, 2; alfalfa leaves, 63 to 82; bone meal, 13; limestone, 20 to 1140; rock phosphate, 1250.

Salt

The salt requirements of the dog have never been established.^{3, 4, 5, 6} Forster ⁷ attempted to determine them about fifty years ago, but his results are questionable, because his dogs undoubtedly were suffering from vitamin deficiencies. In human beings, the salt consumed daily varies from 1 to 7 grams between individuals. To give a dog a similar amount of salt, each pound of dry feed must contain 0.1 to 0.7 per cent of sodium chloride.

On diets very rich in potassium, such as those composed largely of potatoes, the dog would need to be fed a high level of salt, because of the loss of sodium from the body when the diet is rich in potassium. Thus, the author maintained a dog upon a diet consisting largely of cooked, dried potatoes for a period of six weeks. The diet was well balanced in all respects, and in this case the salt level was raised to 2 per cent. The dog drank more water than usual but remained in excellent health. It is probably safe to assume that a dry feed should contain somewhat less than 0.5 per cent of salt. Since many of the substances commonly used in dog feeds are already rich in salt, it may not be necessary to add any to an ordinary diet. On a straight meat diet a dog probably needs very little salt; but when the calories are largely of plant origin, as they are in most modern dry dog feeds, there is a real salt need.

Both sodium and potassium are closely interrelated in their action in the body. Allers and Crandall ⁸ were able to get puppies to grow after removal of the adrenals if they kept the diet low in potassium and relatively high in sodium.

Friends of the author who have dog teams in the Far North say that they give their dogs no salt during the working season because they pull better without it. The feed for these dogs consists of boiled corn-meal mush with some fat, such as lard, bear grease, or tallow from the moose. From time to time such dogs are given bones or fish.

Iodine

Before the days of the World War I, when many people were not getting enough iodine in their food, goitres were as common in dogs as they were in people.

In the area around Cleveland, Ohio, Marine and Lenhart⁹ found that 90 per cent of the dogs showed hyperplasia of the thyroid, which

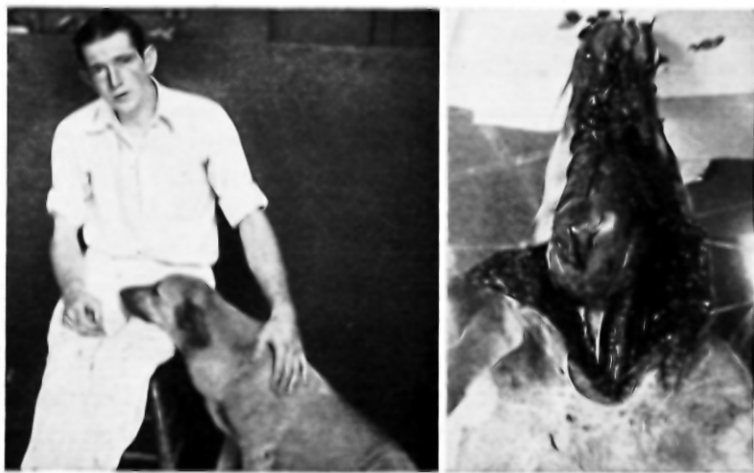


FIG. 3. *Enlarged thyroid in an old dog.*

could be prevented by iodine in the diet. These authors extended some of Halstead's experiments made in 1888. Halstead removed part of the thyroid gland from a bitch before she was bred. At the time of birth the thyroids of the puppies were ten to twenty times the normal size. Marine and Lenhart found they could prevent this condition in the puppies if iodine were fed the mother and too much of her gland were not removed. In general, animals suffering from

iodine deficiency had poor hair coats, anemia, and deficient calcification of bones. They also usually had enlarged thyroids with prominent lymph glands, thymus, and spleen.

In cases of border-line geographical areas, where the iodine supply is slightly deficient, animals may have enlarged thyroids at birth. In the course of a few weeks this condition may disappear.

Most pets getting table scraps have no need for additional iodine. High-priced salt mixtures making special claims for the form of iodine they contain, such as "organic," are not justified, since tincture of iodine, potassium iodide, or iodized salt are inexpensive sources.

Today one sees very few goitres among dogs. This probably indicates that the ordinary dog is getting iodized salt in the scraps from the family table. In kennels there may be more interest in seeing that iodized salt goes into the dog feed. A requirement of 100 micrograms of iodine per kilogram of feed, or half this amount per pound, is probably a reasonable estimate for normal dogs. During gestation and lactation this requirement is higher. The best way to meet this requirement is to add a drop of Lugol's solution or of tincture of iodine to the bitches' drinking water once or twice a week.

Iron

Iron was discovered as a part of blood about the time George Washington was born. The dog has been used in studying blood formation and iron assimilation more than any other animal. Nearly a hundred years ago studies were made on the effect of diet upon the formation of blood in dogs. As early as 1849 Verdeil¹⁰ fed one dog for twenty days on bread and potatoes, and another on meat. At the end of the study he killed both and analyzed their blood. He found nearly twice as much iron in the blood of the dog fed meat as in the one fed bread and potatoes.

During the last half of the 19th century many attempts were made to determine the relative utilization of iron fed as one of its salts, like iron oxide, and iron fed in organic combination, such as occurs in liver or eggs. Both the organic and inorganic forms were utilized by dogs. Most of the iron of the body was found to be built into the hemoglobin of the blood, but every cell had its share. Some of the organs,

such as the liver, were the chief storehouses for iron, although the kidneys, spleen, and muscles were found to have considerable amounts. Iron was found to leave the body chiefly through the intestinal tract rather than through the kidneys. In this respect it resembles calcium and manganese. This confused early workers, because they depended upon urinary iron to tell whether or not iron had been absorbed from the intestine. But urinary iron affords no criterion in this case, because iron is taken from the intestine and then thrown back into it for excretion.

The body of the normal dog is about 7 per cent blood by weight. Thus, a 14-pound dog has about one pound of blood. Normally this blood has 10 to 16 per cent of hemoglobin. This hemoglobin in the dog contains 16 per cent of nitrogen, 0.39 per cent of sulfur, and 0.3 per cent of iron.

The dog and man seem alike in their iron metabolism. Many, if not most, of the advances in our knowledge of blood formation in man and the treatment of the anemias must be credited to the dog.

The daily requirement of iron for man is usually assumed to be 5 to 10 milligrams. An ordinary dog probably needs about one-fifth of this amount. Fresh meat has about 15 milligrams of iron per pound and dried meat about four times this amount. A dry dog feed containing 20 per cent meat scrap would then supply about four times as much iron as the dog needed if no other source were available.

More Iron During Gestation

During gestation a bitch may need somewhat more iron in her feed, since puppies at birth contain about 79 milligrams of iron per kilogram of live weight. No one has found it possible to increase the iron in the milk of an animal during lactation, but Lintzel¹¹ was able to increase the hemoglobin and liver iron of puppies by adding a small amount of iron citrate to the milk. Young pigs can be saved from anemia by swabbing the teats of the sow with iron salts. This is not injurious to normal animals and may save anemic puppies.

At the time of weaning, Lintzel found puppies had about 24 milligrams of iron per kilogram of body weight. This shows the loss in the stores within the body during the nursing period. This is a part

of normal physiology, and trouble does not follow unless some special condition promotes anemia.

The form of iron for feeding to animals seems to matter little. Iron oxide, iron citrate, and the more common forms used for human anemias are satisfactory. In human medicine, it is well known that some iron salts may cause disturbances in the stomach. Two excellent sources of iron, as well as all the common vitamins, are liver and egg yolk. These sources are too expensive for kennel feeding but can be used for pets. Dogs are usually very fond of liver, either raw or cooked, but they usually care little for the dried product that is used in many dog feeds. In time, improved processes for drying liver will probably add to its value. Crude molasses is a moderately good source of iron, but dogs do not usually relish it.

Magnesium Requirements of Dogs

Since 1803 magnesium has been recognized as one of the common constituents of bone. Like calcium, it is combined with phosphate. About 1870 Papillon¹² attempted to force animals to make their bones from aluminum instead of calcium and magnesium. He fed one rat a diet furnishing calcium and aluminum, and another rat a diet furnishing magnesium and aluminum. The rat fed calcium developed tetany and died, while the one getting magnesium remained normal for a couple of months, until it was killed. The early work indicated that the lack of magnesium played some part in the development of tetany, but the observation was not extended.

In recent times, magnesium as a dietary constituent has attracted much attention,¹³ since animals develop a number of typical symptoms, including tetany, and die if this element is deficient in the diet. The animals studied thus far are chiefly the rat and the calf, but a few experiments have been made on the dog.

Since most dog feeds consisting of natural ingredients are well supplied with magnesium, it is not of interest at the present time in practical feeding. Diets producing a deficiency of this element in dogs and rats contain about two parts per million of magnesium. On a diet of casein, starch, butter fat, mineral mixture, and vitamin concentrates that are all prepared to be low in magnesium, dogs develop

characteristic symptoms, including skin troubles, reddening of definite areas, and a spreading of the toes so that the weight rests upon the metatarsus. In rats, under similar conditions, some of the teeth loosen and the gums change. Dogs upon such diets may die in five or more weeks (Hoobler).¹⁴

When there is such a deficiency, the magnesium of the blood plasma drops from about 2 milligrams per cent to less than one. At the same time the blood calcium may also drop slightly from its normal value of 10 to 12 milligrams. During this period the loss of magnesium through the feces decreases, but that in the urine changes little. The dog usually dies after one or more attacks of convulsions.

Greenberg and Tufts¹⁵ found that the minimum level of magnesium for a rat upon a diet containing 0.87 per cent of calcium was 50 milligrams per kilogram of feed. If, however, the calcium level of their diet was increased to 1.6 per cent, the need for magnesium also increased, and 130 milligrams per kilogram proved a minimum level. Severe calcification of the kidneys developed on the high calcium-low magnesium diets. In experiments on young girls, there was little storage of magnesium upon diets allowing 6 to 12 milligrams per kilogram of body weight.

In rats, the requirement for magnesium is increased during lactation, but this has not been established for dogs.

Cow's milk is exceptionally low in magnesium; it contains only 0.01 per cent. The deficiency seems to explain the tetany of calves reared upon an exclusive diet of milk. Rats and swine, however, have been reared upon milk supplemented only with copper, iron, and manganese. It is likely that for most animals there is a considerable excess of magnesium in milk, judging from studies of minimum requirements. Herbivorous species may have special requirements during growth.

Magnesium at moderate levels does not appear to injure animals. With diets adequate in phosphorus, farm animals have been fed as much as 0.5 per cent of magnesium in the form of dolomitic limestone, with no apparent injury. This would be about a hundred times as much as needed.

Calcium and Phosphorus for the Dog

The important part played by the dog in discoveries concerning rickets will be traced briefly in the section dealing with vitamin D. In 1866 Roloff ¹⁶ produced rickets in puppies by feeding them mixtures of meat, starch, sugar, and oil. With calcium of some form added to the diet, the dogs seemed normal. Without it they appeared to develop rickets. He concluded that the development of rickets depended upon the size of the breed, the rapidity of growth, and the degree of deficiency of calcium in the diet.

In 1880 E. Voit ¹⁷ produced rickets in dogs by feeding a mixture of meat and lard. He found that the bones of these dogs failed to calcify, were low in ash, and high in water. His paper provides a good review of the literature of the period but makes little advance in knowledge.

As early as 1890 attempts were made by Beraz ¹⁸ to determine whether the teeth of the dog are modified by diets low in calcium. He found no evidence for changes. He indicated, however, the usefulness of the dog in dental research, because teeth can be pulled at intervals to determine the effect of specific diets over a considerable period of time. Little use has been made of this technique.

Very detailed studies of the structural changes in the bones of puppies that developed rickets on a diet of horse meat and lard were made in 1898 by Miwa and Stoeltzner.¹⁹ They made no advance in nutrition.

In 1908 Aron and Sebaue ²⁰ determined the amount of calcium in a dog's body and estimated the requirements of the dog for calcium. They found that the body of the dog contained a little less than 1 per cent of calcium and reasoned that it would take about 10 grams of this element for each increase of a kilogram in body weight. They estimated that about 60 per cent of the calcium from bone meal could be retained. In their dogs even the brains were low in calcium if this were deficient in the diet. The different bones in the body of the dog seemed to vary widely in their deficiency in calcium. The fibula of the dog fed a calcium rich diet yielded 29 per cent ash, and the scapula, 25 per cent. In fibula of the dog fed a calcium deficient diet had only

12 per cent ash, and the scapula less than 8 per cent. These values were for fresh bones.

The interest in nutrition that arose with the discovery of the vitamins during the early years of the present century stimulated research studies with dogs. In 1921 Findlay²¹ and others ran many calcium analyses of the tissues of dogs suffering with rickets. In general, they found little decrease in the tissue calcium, even when the bones of puppies were depleted by a diet deficient in this element. The calcium in the blood of puppies decreased from about 15 mg. per cent at eleven weeks of age to 12 mg. per cent at seventeen weeks. Today these constant values for tissues are not surprising because the function of the bones in serving as a reservoir of this element is well appreciated. Findlay was one of the first to claim that the feeding of oatmeal to puppies produced rickets more promptly than a diet composed mostly of bread.

Mellanby's papers²² of 1921 should be read by all students of mineral metabolism in relation to rickets, because of their many illustrations of dogs and X-ray photographs. The whole outlook in the field of calcium and phosphorus metabolism was changed by the discovery of vitamin D and the effect of sunlight in curing rickets.

Phosphorus and Rickets

The importance of phosphorus in the formation of the bones of animals has been recognized for a century and a half because bones contained this element in fairly constant amount. This element, however, assumed a minor position in nutrition because the diets fed dogs usually contained some meat rich in phosphorus. For the same reason, phosphorus is even today of little interest in the feeding of dogs under practical conditions.

Diets poor in phosphorus were devised by Lipschütz²³ in 1909. These consisted of mixtures of rice, sugar, egg albumen, fat, and salt mixture. The salt mixture had a composition similar to the ash of dog's milk. For balance studies some dogs were fed this mixture, and others the same diet supplemented by sodium and potassium phosphates. A third group was given milk to supply phosphorus.

The growth rates were best for the milk, and poorest for the low

phosphorus diets. At the end of the seventh week, the first pup failed upon the diet low in P. This failure was probably partly due to vitamin deficiencies. The bones were poorly calcified. The balance studies showed a daily fecal excretion of about 70 mg. from a 1,200 gram dog, except for the one fed milk. In the latter, the value was about twice this level. The excretion of P in the urine of the dog given the low P diet was only 12 mg. daily, while the urine of the dogs fed milk or phosphates reflected the diet.

Schmorl²⁴ found that when dogs were fed low P diets the bones failed to deposit calcium and phosphorus normally. His work was histological.

More recently, Jones²⁵ and others have made use of diets deficient in phosphorus to study this form of rickets. Jones has employed the fibrin of blood as a source of protein low in phosphorus for similar studies with rats.

Retention of Calcium and Phosphorus

Most forms of calcium seem to be well utilized by the body of animals, although some forms, such as that in broccoli, seem better utilized than others, as that of spinach. In the phosphorus compounds found in plant foods, however, there is a greater difference. The common method of producing rickets in rats is to feed diets rich in corn meal and high in calcium; since much of the phosphorus in corn meal is unavailable, an unfavorable ratio is thus created. Little attention has been given to the utilization of the phosphorus of plants by dogs, because the meat products of the usual dog feed, as well as the bone-meal supplements, provide a good supply of this element.

From early balance studies with children, there was clear evidence that the calcium and phosphorus were poorly retained in cases of rickets. Shohl and his co-workers²⁶ found that dogs on a good diet could retain as much as 77 per cent of the dietary calcium and about 34 per cent of the phosphorus. Dogs suffering from rickets would utilize much less of both of these elements. A normal dog had 10 milligrams per cent of calcium in its blood serum, while one with rickets had only 6 to 8.

In Morgan's studies,²⁷ the normal diet contained 0.42 to 0.56 per

cent of calcium and 0.48 and 0.61 per cent of phosphorus. This is considered adequate for most farm animals. Morgan's dogs retained about half of the calcium and one-fourth of the phosphorus. She confirmed the findings of most earlier workers, inasmuch as about a third of the phosphorus and most of the calcium were excreted from the body by way of the feces.

In the usual dog feed, bone meal provides most of the calcium, although skim milk and alfalfa-leaf meal make some addition. Bone meal can be fed at 1 or 2 per cent levels. This is adequate for growing puppies of the smaller breeds, but in the larger ones, bones and milk should probably be used in addition to a stock diet. As a rule, even puppies do not relish bone meal. If it is fed in a separate dish, they will seldom touch it. Bone meal also provides adequately for the magnesium and fluorine needs of the dog.

Dogs can be fed large amounts of ground bone. Early workers kept dogs for long periods upon a diet of fresh bones. In recent times, some of the canned dog feeds have contained as much as 15 per cent of ash, when calculated on a dry basis. This was probably derived largely from ground bone.

The gastric juice is very important in rendering calcium salts suitable for absorption and deposition in bone. If the stomach of growing puppies does not function, the bones will be fragile, weak, and deficient in ossification. Bussabarger²⁸ and others concluded that this failure was due to lack of acid to make calcium salts, such as those in bone, soluble; the absence of the reservoir function of the stomach, thus permitting food to pass through the intestine too rapidly; and, finally, the "acid tide" which decreases calcium retention.

The hard, white, dry excreta of dogs eating large amounts of bone have been observed by everyone. Bone ash has been fed to dogs to produce such excreta. Bone ash is made by burning bones in air until they are white. Etzinger²⁹ reviewed the history of such studies in 1874. In recent times, large amounts of bone ash have been fed by Steel³⁰ as well as Lothrop.³¹ They used it to make fecal collections easy when the diets studied tended to produce diarrhea. A gram of bone ash per kilogram of live weight seems enough to harden the excreta.

Lothrop ran four balance studies with dogs fed the above level of bone ash as a supplement to a diet of meat, 150 g.; cracker meal, 40 g.; lard, 30 g.; and water, 350 g. The weight of the dry feces excreted per day increased from 4 to 14 grams, but the fecal nitrogen increased only slightly. *In vitro* studies indicated that the enzymes of the body were little affected by bone ash. These studies need repetition to determine the effect of bone ash upon the loss of vitamins caused possibly by adsorption. Bone ash is usually too expensive for use in commercial dog feeds, even if this practice were justified.

Low grade meat scrap is usually high in bone. At times, the uninitiated want to know if the phosphorus injures the dog. There is no evidence for such injury. If such meat scrap is used in a dry dog feed at a level of 20 per cent, the bone meal added will amount to only about 7 per cent on a dry basis.

In general, one can conclude that the dog, like other species, probably needs a ratio of calcium to phosphorus of approximately 1:1. About 0.5 per cent or more of each of these elements in the diet is probably adequate.

Calcium and Phosphorus for Reproduction

An adequate amount of calcium and phosphorus must be fed to females during reproduction. In general, young animals are born with bodies low in calcium. During the nursing period the mother provides the calcium for the bones of her young in the form of milk. When the diet of the female is too low in calcium, she draws heavily upon her own bones in order to secrete milk and build this calcium into the bones of the puppies. A good source of vitamin D is also essential for the female.

One of the few attempts to determine the calcium balance in dogs during gestation and lactation was made by Dibbelt³² in 1910. In an initial study he allowed the female, daily 200 g. of rice, 100 g. of horse meat, 30 g. of lard, and 5 g. each of NaCl and KCl. Part of the puppies were allowed a gram of dicalcium phosphate per day. His chief observation was the slowness of eruption of teeth when the diet lacked calcium.

In a second study, the female lost several grams of calcium from her body during the course of lactation. The balance was complicated by the eating of excreta by the bitch. This instinct has long been recognized as a method for keeping the puppies clean. It may also serve as a means of conserving mineral sources, such as calcium, that are not utilized by the puppies. The eating of excreta may also be a means of conserving vitamins or, possibly, of acquiring additional supplies created by bacteria in the large intestine.

Mellanby³³ found that the diet of the mother created in the body of the puppy a storage lasting for nearly a year. One female was fed well and another badly during gestation and lactation. The puppies of both were allowed a good diet for four months after weaning. Both were then fed a diet to produce rickets. The puppies from the well-fed mother were more resistant to developing the disease.

Toverud³⁴ has provided an interesting balance sheet for three elements during the period of gestation and lactation. Essential data from these balances are included in the following table:

STATUS OF THE DOG LILEMOR AT THE END OF GESTATION AND AT
THE END OF LACTATION

(Ca, P, vitamin A and D deficiency)

	Ca Gm.	P. Gm.	Mg. Gm.
Total intake during gestation	10.5	20.4	8.9
Loss through urine and feces	16.0	33.8	7.8
Total loss through 4 fetus	9.4	5.8	0.3
Total loss during gestation	25.4	39.6	8.1
Balance at the end of gestation	-14.9	-19.2	+0.8
Intake through food during lactation	7.3	12.1	4.2
Intake through feces from the puppies during lactation	4.0	2.7	0.8
Total intake during lactation	11.3	14.9	5.0
Loss through urine and feces	10.0	13.2	2.6
Loss through secreted milk	30.9	20.6	1.4
Total loss during lactation	40.9	33.8	4.0
Balance at the end of lactation not counting gestation	-29.6	-18.9	+0.9
Balance at the end of lactation counting gestation	-44.5	-38.1	+1.7

The values give some idea of the magnitude of the losses when the basal diet consisted of meat, 50 g.; milk powder, 10 g.; lemon juice, 5 cc.; marmite, 5 g.; salt, 3 g.; iron, 0.1 g.; and cocofat, 10-40 g. In addition to this basal diet fed each day, each dog was allowed to eat what it wished of a gruel made of wheat and rye flours with cocofat.

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CHAPTER VI

VITAMINS FOR DOGS

DOGS NEED most of the recognized vitamins, with the exception of vitamin C. Dogs never get scurvy from lack of this vitamin. In this respect dogs differ from men. Many people waste their efforts feeding dogs vitamin C in the form of orange juice or tomato juice. Of course, these juices are not entirely wasted on the dog since they provide some other vitamins.

The four vitamins of most importance in the practical feeding of dogs are vitamins A, D, B₁ (thiamin), and niacin. The dog played an important role in the discovery and isolation of each of these vitamins.

The first evidence that dogs needed vitamin A was given in the report of Magendie ¹ in 1812. He described the sore eyes that developed when his dogs were fed special diets such as those containing sugar. Sore eyes are now recognized as one of the symptoms of a diet too low in this vitamin. The author has observed that puppies tend to get sore eyes if the diet of the mother is not adequate in vitamin A early in the lactation period. If the bitch is fed cod liver oil, the vitamin passes into the milk and thence into the bodies of the pups, whose eyes become normal in a few days. This eye condition is called xerophthalmia by the nutrition student. In the early days it was recognized as a condition in which the eyeball became dry. This was followed by an infection. In late stages the eyeball looked as if it had burst, with a stream of yellow matter flowing from it. We know now that there is also a partial loss of vision even when there is some vitamin A in the diet. This is called night blindness because higher animals cannot see so well in dim light when they are kept upon a diet too low in vitamin A.

Vitamin A is known to influence many other activities in the bodies

of animals. Without it growth ceases, and reproduction also fails. Mellanby,² in England, has also found that young dogs fed a diet deficient in vitamin A, become deaf owing to changes in the nerves that connect the ear and the brain. The growth of the ear bones of these young dogs was also modified. The remainder of the diet seemed important in these conditions, since the condition was more marked on a cereal than upon a diet of potatoes.

No one knows what other diseases in dogs may be related to vitamin A deficiency. Even the teeth of dogs suffer if the diet is low in vitamin A. The zone where the gums cover the lower teeth opens and infections develop. The proper functioning of the kidneys seems to depend on this vitamin (Herrin).³ French researchers discovered that the fat from the lungs of dogs was as rich as butter in this vitamin. In cattle it is known that the colostrum, which is first taken by every young animal at birth, is many times richer in vitamin A than normal milk. This may also be true in the dog. Hence, liberal supplies of vitamin A are probably needed during both gestation and lactation.

Young pups at the time of birth have a very poor store of vitamin A in the liver.⁴ The reason for this is unknown. It indicates the importance of a rich supply in the colostrum during the first few days of life, if the puppy is to make a good start and not fail. The author has tested the livers of a number of puppies killed at birth. None possessed a liver rich in vitamin A.

EVERY DOG OWNER SHOULD WATCH THE EYES OF HIS DOGS. If they contain "matter," allow a little extra vitamin A. At the same time, the eyes must be washed with boric acid if they are quite sore.

The first well designed modern experiment showing the need of the dog for vitamin A was that of Steenbock and others.⁵ The picture of their dog has now become familiar to nutrition students.

Most dogs receive vitamin A either from meats, such as liver, or from yellow plant materials, such as carrots, lettuce, corn meal, or tomatoes. The true vitamin A found in liver, such as that seen in cod-liver oil, is colorless. The yellow material of carrots, called carotene, is converted in the body of the dog into true vitamin A.

Several factors seem to govern the absorption of vitamin A or

carotene from the intestinal tract. The flow of bile must be normal for the absorption of this vitamin as well as of the other fat soluble ones. Furthermore, the absorption and utilization of carotene seems to depend upon the presence of another fat soluble vitamin, namely vitamin E. Without the latter, vitamin A may be poorly absorbed and utilized. Fortunately, carrots contain both carotene and vitamin E, although other products such as wheat germ are richer in the latter.

Most good dog feeds contain vitamin A in the form of carotene. This is added in the form of dried grass, alfalfa meal, yellow corn meal, or tomato pomace. In addition, most dog feed manufacturers spray their feed with a known amount of cod-liver oil concentrate. It is likely that the vitamin A from the cod-liver oil is largely wasted, because of rapid oxidation, when the feed remains in a warm room for a few days. Dog feed manufacturers should put this cod-liver oil into their feeds in the form of pellets made by mixing some non-destructive substance, such as dicalcium phosphate, with the oil and then coating the pelleted mixture with sugar or some inert protective coating. These pellets should then be mixed into the feed as raisins are in bread. The safest practice today is for the kennel owner to feed his dogs small amounts of cod-liver oil every week or two. If cod-liver oil is unobtainable, good substitutes are cheap organ meats, such as liver and kidneys, or ground carrots.

Little is known about the loss of vitamins in the baking of the biscuit or kibbled types of dog feeds. Rice and others⁶ found that the loss in baking biscuits for human use is about 10 per cent of their vitamin A. The biscuits were baked for twenty minutes at 450° F., since they contained 14 per cent of fat, they cannot be more than a guide to changes in low-fat dog biscuits made of cheap flour and corn meal. They found the greatest loss in pie crust with its content of 37 per cent of fat. From the experience of those manufacturing dry tablets for the drug industry, the loss of vitamin A from biscuits is probably very marked, because they are left in a warm room with a porous surface facilitating oxidation before they are sold.

Cod-liver oil should be stored in a cool place.⁷ In a warm room it loses its vitamin A and becomes rancid. These rancid products are

injurious to the dog inasmuch as they produce certain types of skin diseases.

Feedstuffs rich in carotene, such as alfalfa meal, tend to lose this, because of oxidation, if they are stored in a warm room. A good grade of alfalfa meal should be rich green instead of a brownish color. A number of substances, such as oat flour, have been patented for prevention of rancidity of fats. No one knows if these are useful in dog feeds.

Workers in Arizona ⁸ have found that dogs can utilize the carotene of carrots as readily as that from cod-liver oil. At the date of their studies they did not appreciate the importance of vitamin E in the utilization of vitamin A. This interrelationship makes difficult to evaluate the requirements for vitamin A that have been established in the past.

How Much Vitamin A Does the Dog Need?

Only a few attempts have been made to determine the vitamin A needs of dogs. This may vary between breeds, and nothing is known about such variation. The common use of a relatively standard animal, such as the white rat, tends to make workers think of a species as uniform. They forget the great variation between breeds of dogs. The available evidence, however, indicates that dogs need about the same amount of vitamin A as do other animals. Fröhring,⁹ in his earlier study with thirty-one pups, found a need for 200 to 700 U.S.P. units per kilogram of body weight.

On the basis of depletion of the liver, Crim and Short ¹⁰ found a need for 25 to 50 Int. Units per kilogram per day. They, as well as others who have used their technique, assume a relatively constant loss from the liver per day, while it is likely that the daily loss decreases as the liver is depleted of its supply. In general, these authors concluded that each pound of dog feed should have 635 units of vitamin A. They also believe that the dog needs 6 to 8 gamma * of true vitamin A or 24 to 30 gamma of beta carotene per kilogram per day.

Vitamin B₁ or Thiamin

The dog owner is likely to detect the need of additional supplies of

* A gamma equals a millionth of a gram, or a microgram.

vitamin B₁ for his pet through the loss of appetite and a failure to excrete regularly. Many other factors, however, such as overfeeding and lack of exercise, may produce the same symptoms. As early as 1893 Rosenheim ¹¹ noticed such conditions when he fed his dogs mixtures made largely of rice. These dogs not only showed the usual symptoms of vitamin B₁ deficiency but also developed sore skins. The feeding of liberal supplies of meat brought the dogs back to health.

The average dog gets vitamin B₁ from many sources. The first of these is probably meat. Pork contains about seven times as much of this vitamin as beef. The modern dog, eating table scraps of whole wheat bread, gets a good supply. Modern fortified flour has increased the amount even in white bread. Oatmeal is a good source. This has long been fed in kennels as part of a gruel.

The usual mixed dog feed provides its vitamin B₁ through additions of small amounts of brewers' yeast and wheat germ. Some contain whole wheat products that are good sources if they have not been heated too much. The meat meals cannot be relied upon unless they are carefully dried. Otherwise they contain little. In normal times the dog owner can give additional allowances of this vitamin by feeding cheap meat such as kidneys.

The beginning of extensive studies showing the importance of vitamin B₁ in the maintenance of appetite was made by Karr ¹² about 1920. Although his diets were probably deficient in many vitamins as well as potassium, they showed the importance of such foodstuffs as yeast, milk, and tomatoes in stimulating the appetite. He ascribed this correctly to vitamin B₁.

Cowgill ^{13, 14, 15} soon extended the study of Karr and ascribed the loss of appetite to a deficiency of vitamin B₁. He made use of the method used by Voegtlin in 1919 to destroy the vitamin B₁ in a dog's diet and still leave it fairly complete. This was done by autolaving meat in accordance with the standard practice long in use for destroying this vitamin in test diets. Cowgill also produced hind-leg paralysis in his dogs.

Every student who has worked in a laboratory such as that at Yale, where the vitamin B₁ needs of dogs were studied extensively, has a

lasting memory of the paralyzed hind legs that ultimately result from a lack of this vitamin. Such students can never forget their own misery in observing the spasms and twitchings of the legs of these dogs. Neither can they forget the miraculous recovery when such dogs were fed concentrates of vitamin B₁, such as yeast, or injected with sources of this vitamin. Improvement comes in a few hours. Recovery is only a matter of days if the condition has not gone too far.

The need for vitamin B₁ increases in proportion to the carbohydrates burned in the body. Thus an animal such as a rat needs about a third more of this vitamin when exercising. It is probable that a hunting dog subjected to hard exercise needs twice or several times as much. Pigeons kept in a cold room suffer from a need of this vitamin sooner than when warm. Here again more fuel is burned. Dogs kept in cold kennels may need more, since they are consuming more fuel within their bodies.

Most dog feeds are low in fat. This also increases the need for vitamin B₁, in contrast to diets well supplied with fat. Arnold and Elvehjem¹⁶ suggest that the need of the dog is supplied by about 1 γ of vitamin B₁ per gram of fat-free food. Only about a third as much was needed on a fat rich diet. Growing pups seem to need no more vitamin B₁ than adults. The milk of the bitch is relatively rich in fat; which probably keeps the puppy's requirement at a low level during the first three weeks of life.

Cowgill, in his studies on dogs, has given much attention to vitamin B₁. His many papers afford a good introduction to the literature for those wishing to do research in this field. Levison,¹⁷ in 1936, attempted to follow some of the blood and urine constituents as the vitamin B₁ deficiency in dogs grew progressively worse. He distinguished a "latent" and a "manifest" period in the development of the diseased condition. He noted that the water of the urine, as well as the salt excretion, decreased. The percentage of such constituents of the urine as the urea increased. The reserve alkali in the blood of his deficient dogs tended to be low. The urine was neutral instead of alkaline. In the last period the ammonia of the urine increased to as much as 1 per cent. The blood-sugar level seemed to fluctuate more widely in the deficient dogs. The hemoglobin and lymphocytes of

the blood tended to decrease. This author did not run controls with food intakes restricted to the amount eaten by the vitamin-deficient dogs. Hence his results may have been due to partial fasting.

Thiamin and Infections

An adequate intake of vitamin B₁ seems important in protecting dogs against certain types of bacterial infection. Rose¹⁸ found that vitamin B₁-deficient dogs succumbed to staphylococcus aureus much more readily than dogs adequately fed. The loss in body weight after the infection was much more marked in the dogs lacking vitamin B₁.

Vitamin B₁ is lost from the body both in the feces and urine. Light and others¹⁹ have studied this loss in both the rat and dog, although their studies on the dog were limited to two terriers. Upon a diet low in vitamin B₁ each dog excreted 20 to 80 gamma of the vitamin in the urine. When these dogs were injected with a daily supplement of 500 gamma of the vitamin, they excreted 80 to 212 gamma in the urine. When 2,000 gamma were injected, the urinary excretion amounted to 400 to 1,000 gamma. In other words, beyond the needs for the body, about one-fourth of this vitamin is excreted in the feces; one-fourth, in the urine; and half, in an unknown form. As a rule, this vitamin is lost from the body relatively rapidly. Little is known, however, about the many factors that may modify this loss, such as exercise and other dietary factors.

Even in white rats there are inherited differences in the need for vitamin B₁. One strain may need much more than another. This may also be true for dogs, but this problem has not been studied.

Per unit of body weight, Cowgill found that the mouse needed the most of this vitamin and the dog the least. Cowgill set 15 as the number of international units of vitamin B₁ that should be in 100 calories of food for man. He assumed one milligram of the crystalline vitamin B₁ (thiamin) was equal to 200 to 500 Int. Units.

Collazo²⁰ has found a greatly increased elimination of fat from the kidneys in dogs suffering from vitamin B₁ deficiency. He believes that this accounts for the loss in body weight as well as the loss of appetite and ultimate death.

Some claims have been made that running fits in dogs can be

checked by feeding them vitamin B₁. Recent data of Arnold and Elvehjem ²¹ indicate that these fits can be checked by feeding 10 per cent of casein or some other protein that will furnish lysine.

Vitamin D and Rickets

Rickets in dogs has long been a familiar experience to the kennel owner who rears puppies in the winter time, especially if these puppies belong to one of the larger breeds. Usually, such litters are kept inside a dark barn or basement. Shortly after weaning the puppies show the typical bowlegs of the disease. Such puppies are often "pot bellied" because of round worms.

To prevent rickets, the female should be given a good diet containing either bones or bone meal. At all times she should be given a kennel that allows a period each day in the sunshine. Furthermore, her diet should be supplemented regularly with either cod-liver oil or an irradiated product such as yeast or evaporated milk. In spite of these precautions the puppies may tend toward rickets shortly after weaning, in their fourth week.

Even before weaning, puppies can be given a little cod-liver oil from a medicine dropper. In the third or fourth week they can be treated for round worms. The author has done this many times, using ethylene tetrachloride, and has never lost a pup. In the course of weaning, the puppies can be fed irradiated evaporated milk and a little cod-liver oil. As they learn to eat solid food, they can be given irradiated yeast. Usually, a good grade of meal-feed contains irradiated yeast and 1 to 2 per cent of bone meal. Finally, puppies should be exposed to the sunlight for a period each day, if this is possible.

Sunlight acts upon the exposed areas of the body, such as the nose and lips. Furthermore, it is likely that it acts upon certain compounds resembling fats which are present in the hair of the dog. When the dog licks its hair it probably is getting some vitamin D, especially if it has been sleeping out of doors in the sunshine.

The larger the breed of dog, the more subject it is to rickets. A breed with heavy bones, such as the Great Dane, is very liable to this trouble because it grows rapidly and is rather difficult to feed. The owner often courts trouble by trying to feed the dog only a muscle

meat like hamburger, a diet lacking both calcium and vitamin D, and the dog therefore fails to develop a good skeleton.

In mild rickets the leg bones are bowed, and in extreme cases the legs become badly deformed. The ribs are "beaded," and the chest is malformed. Even the head bones may be abnormal in shape, with the jaws badly undershot. Such puppies should be destroyed. The teeth also suffer; the permanent teeth, especially, are slow to erupt.

The studies of Morgan ²² indicate the needs of medium-sized dogs for vitamin D. In a private communication she states: "We have never used less than 1 gram of standard cod liver oil per kilogram of body weight of young dog per day. Actually we have found severe rickets occurring on young shepherd dogs when given as much as two grams per kilogram per day." "In terms of the present international units of vitamin D, our dogs never receive less than 80-100 units per kilogram per day. Young dogs are given about 50 grams of dry feed per kilogram per day. Therefore in terms of actual feed our dogs receive from 1.7 to 2 I.U. of vitamin D per gram of dry feed per day. The quantity of dry feed eaten by the adult dog is about $\frac{1}{3}$ this amount and the amount of vitamin D may be correspondingly less, or it may be omitted altogether. I believe there is little logic in providing vitamin D per pound of dog feed without discrimination for the adult and young or pregnant and lactating females. For the latter group one to two units per gram of feed is necessary. For the former perhaps none need be given. The amount of sun exposure of the dogs must also be taken into account. The figures which I have quoted are for kennel grown animals with very little outdoor life or exercise."

Arnold and Elvehjem ²³ estimated that each pound of canned dog feed should have 10 to 13 U.S.P. units of vitamin D. This is somewhat higher than Morgan's estimate. The Fleischman Laboratories ²⁴ found that a Fox Terrier needed only 28 units per kilogram of body weight per day, while a Dane needed more than ten times this much. In both cases the calcium-phosphorus ratio was 2.1:1.

Dogs seem able to tolerate much higher doses of vitamin D without injury. I. E. Steck and colleagues ²⁵ fed as much as 20,000 units of vitamin D per kilogram of body weight per day with no obvious injury to the dog. However, most experiments of this type

need to be examined carefully, since the whole life span should be given consideration.

The Dog Showed the Way to Prevent Rickets in Children

No animal has played a more important part than the dog in promoting child welfare during the past hundred years. Many of the basic discoveries teaching men how to prevent rickets in children and domestic animals came from research with dogs.

Rickets in dogs has long been studied by physicians in the hope of learning better methods of treating human cases. Thus we find reports by Guerin in the medical literature of France more than a hundred years ago. He divided a litter of puppies into two groups of four each. One group was fed meat and the other the milk of the mother. Those fed meats developed rickets, while the others did not.

One of the clues to the development of rickets in dogs fed upon meat was found by Bischoff ²⁶ in 1867. He ran a series of chemical balances upon a dog fed only meat. After a time such dogs tended to lose more phosphorus from their bodies than they consumed in their food. When this happens to any element, the animal must ultimately die from the loss.

About 1875 a serious attempt to understand this strange disease was made by F. Roloff, the director of the veterinary school in Berlin.²⁷ Realizing that calcium and several other factors were involved, he fed dogs mixtures of meat, starch, sugar, and fat, with and without calcium; and then killed the dogs and analyzed their bones. Only 44 per cent of ash was found in the bones of the dog deprived of calcium, and 58 per cent in those of the dog that was given this element. He tried many other substances instead of calcium phosphate, such as potassium, magnesium, and sodium salts, but the bones were always poorly calcified and poor in ash unless the diet contained calcium. If a dog developed rickets, its life could be saved, but its bones were often permanently misshapen.

In general, Roloff concluded that calcium held the key to rickets, but he realized that many other factors were involved. The rapidly growing dog was more liable to develop the disease, as was also the dog with large, heavy bones, because it needed much more calcium.

In some of his dogs he found poor teeth as well as poor bones, but he did not pay much attention to the development of teeth. The drawings accompanying Roloff's papers are well worth study today.

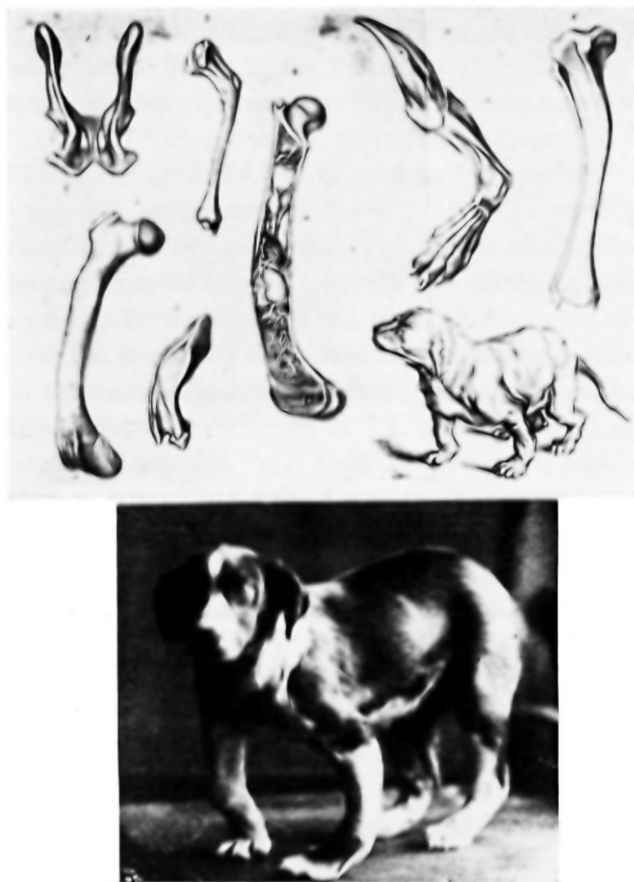


FIG. 4. *Some early German illustrations of rickets in dogs.*

In addition to the importance of calcium and phosphorus in preventing rickets, the value of some organic substance found in cod-liver oil was appreciated.

Early writers described rickets in puppies, lambs, calves, and even porcupines. From very early times cod-liver oil was eaten by Green-

landers and Laplanders. It was also used as a remedy for rickets and tuberculosis. This early form of cod-liver oil was not very pleasant to the taste, because it was made by letting the liver rot in a barrel and skimming the oil from the top. About 1853 the steam process was introduced by Möller, and the quality of the oil improved.

In general, early workers thought that the whole of the cod-liver oil was valuable. They discouraged chemists from attempting to isolate specific compounds, such as the vitamins.

Cod-liver oil was used about a hundred years ago in a limited way in feeding farm animals. When, about 1880, it was fed together with bones to lions in the London Zoo, it made the rearing of young cubs possible; before this time all had died with rickets. Today lion cubs are so easily reared that they are worth only about twenty-five dollars.

By the time of the last World War the use of cod-liver oil for the treatment of rickets in both dogs and children was well established. The best proof of its value, however, came from feeding it to children in the hospitals of Vienna during the post-war period of poor nutrition.

The following list indicates the years in which the more important discoveries concerning vitamin D were made:

- 1913. Vitamin A was recognized by Mendel and McCollum. Cod-liver oil and butter were found to be rich in this factor.
- 1920. Professor Hopkins in England found that vitamin A was destroyed by blowing hot air through butter.
- 1921. Dr. Mellanby found that cod-liver oil was very effective in preventing rickets in dogs.
- 1923. Dr. Chick and others showed that cod-liver oil was a specific in the treatment of rickets among the children of Vienna.
- 1920-21. Shipley and Park suggested the "line test" for measuring vitamin D in foods.
- 1922. Professor McCollum found that cod-liver oil was rich in vitamin D and butter relatively poor, while both were rich in vitamin A.
- 1922. Professor McCollum destroyed the vitamin A in cod liver oil by blowing hot air through it. The vitamin D remained.

1923. English workers found that the irradiation of rats with ultra-violet light produced vitamin D in their livers.
1924. Americans found that certain foods became good sources of vitamin D if they were irradiated.
1927. Bills found that most fish liver contains vitamin D. The amount varied from none in sturgeon liver to 40,000 international units per gram in the liver of the blue-fin tuna.
1930. Massengale and Nussmeier found that vitamin D from irradiated ergosterol did not work as well for chickens as that from cod liver oil.

More than eight different forms of vitamin D are known today, and the number is still increasing. Ruigh²⁸ has prepared one of the newest from soy-bean oil. He has christened this "7-dehydrocampesterol." Its potency is about 4,000,000 units per gram. This is about one-tenth the potency of the best vitamin D from irradiated ergosterol.

Fortunately, dogs seem to make nearly equal use of all forms of vitamin D. In this respect chickens and birds seem to differ, since they do not use that from irradiated yeast as well as that from cod-liver oil and that from cholesterol, known as 7-dehydro-cholesterol.

In general, manufacturers of dog feeds use either a concentrate from fish-liver oil, such as that containing 3,000 units of vitamin A and 400 units of vitamin D per gram, or they use an irradiated dry yeast of the type containing 9,000 units of vitamin D per gram. Such dry yeast is usually used at the rate of about a pound per ton of dry feed. The manufacturer of this yeast recommends 2 to 4 pounds per ton. This is an excess for the average dog.

In general, most dogs are very fond of cod-liver oil, but it tends to become rancid easily. Thus it may lose first its vitamin A and then its vitamin D. Feeds containing cod-liver oil, or the oil itself, should always be stored in a cool place if possible. Dogs seem indifferent to the flavor of yeast. They will not consume yeast if it is offered to them separately, but the flavor of the meat meal in the usual mixed feed probably masks the taste of yeast.

The problem of adequately mixing small amounts of ingredients, such as yeast, is usually met by preparing a combination of dry yeast with some other common ingredient, such as soy-bean meal. This mix-

ture may consist of one ounce of dry yeast and fifteen of meal. It can then be used for different animal feeds. Where dog feeds exclusively are made, other constituents of the diet can be pre-mixed with the irradiated yeast, such as brewers' yeast. Patents have been issued for the use of dyes to stain such ingredients as yeast to insure good distribution. Rosenberg (1942)²⁹ has presented good summaries of patents concerning vitamins and their concentrates.

The Destruction of Vitamin D in Mixed Feeds

Until recent times little attention was given to the loss of vitamin D in mixed feedstuffs. From the method originally used to differentiate this vitamin from its associate, vitamin A, its stability against oxidation was recognized. Hopkins, in 1920, had found that blowing hot air through butter destroyed its vitamin A. McCollum and his associates, in 1922, proved that vitamin D was a separate substance, because hot air could be blown through cod-liver oil with the destruction of vitamin A and the preservation of vitamin D. Vitamin D was therefore commonly called the heat-stable vitamin.

In time, however, the loss of vitamin D during the storage of chicken feeds was recognized. Fritz and others³⁰ measured the retention of the original vitamin-D potency of cod-liver oil after storage for different time intervals with different substances, some of which are common ingredients of dog feeds. When mixed with materials with a lot of surface, such as Fuller's earth, because of the fineness of the powder the vitamin D disappeared in one week. (Fuller's earth is a yellowish, claylike material used for such purposes as decolorizing oils.) After a month had passed all of the vitamin D was destroyed if the oil was combined with calcium carbonate, certain mineral mixtures, sugar, and dried whey. Lactose was not as destructive as cane sugar, but four-fifths of the vitamin had been lost after two months when the oil was in contact with this sugar.

On the other hand, after six months in contact with ground yellow corn, distillers solubles, liver meal, soy-bean meal, and dry skim milk, two-thirds or more of the original potency of the oil remained. In general, in the case of mixed poultry feeds, the losses in the course of six months ranged from none to about 50 per cent. Feeds con-

taining charcoal tended to lose vitamin D very rapidly, although this was not always true. The same authors made a limited study with different sources of vitamin D, such as cod-liver oil, tuna-liver oil, the non-saponified fraction of cod-liver oil, activated ergosterol, D-activated animal sterols, and activated 7-dehydro-cholesterol. The source of vitamin D did not seem to matter so far as its rate of destruction was concerned.

In pre-mixing an oil with a carrier such as corn meal, there was complete destruction after one month if the corn meal also was combined with 10 per cent of calcium carbonate, 25 per cent of mineral mixture, or 50 per cent of dried whey. In contrast, soy-bean meal tended to protect the vitamin D, and there was much less destruction even when the above ingredients were added in the same manner as they were to corn meal.

The destruction of vitamin D seems to be due to oxidation, and the oxidation is in turn accelerated by rancid fats. Coating the vitamin with some protective material, such as calcium stearate or mineral oil, helped preserve it. Antioxidants, such as oatmeal flour and hydroquinone, also retarded the destruction of the vitamin D, although sodium thiosulfate was ineffective.

Sterol Metabolism in Dogs

The biochemist struggled with the problems of the sterols long before he realized they would have any importance as vitamin D. More than a hundred years ago chemists learned to isolate from either gall stones or the brain the common sterol found in animals. This was known as cholesterol. The chemist usually found it in that part of fat which could not be made into soap by boiling with lye. This fraction he called the "non-saponifiable." Cholesterol can also be made from other substances within the bodies of animals. Of course, it also occurs in the food of animals that eat meat, or especially, brains or nerves. In recent times cholesterol has been prepared from such tissues as brain, and then converted into one form of vitamin D.

Plant sterols have also been known for more than a hundred years. They differ from those found in animals. One of the best known plant sterols is ergosterol, the form commonly found in yeast. If yeast is

used in feeding dogs, ergosterol is converted into the source of vitamin D when irradiated with ultra-violet light.

In general, plant sterols are not well absorbed by dogs. Ergosterol is poorly absorbed before it is treated with ultra-violet light, but is well absorbed after this treatment.

Animal sterols are easily absorbed. About ten years ago Schoenheimer³¹ fed mixtures of cholesterol and ergosterol to dogs. The cholesterol passed into the blood stream by the usual channel of the thoracic duct, but the ergosterol was absorbed only in traces. Thus the animal sterol passed from the intestine into the lymph and then into the blood, while the plant sterol was excreted.

Bile has long been recognized as an essential agent in the absorption of sterols, and neither sterol would have been absorbed from the intestine if the bile had not been present to form an emulsion. Fats also seem to be needed for the absorption of sterols.

The secretion of the stomach and pancreas of dogs is devoid of sterols. That of the intestine contains beta-cholestanol. Thus the intestine is constantly both absorbing sterols from the food and secreting a special one which is not reabsorbed.

One of the old methods for studying such problems consisted in cutting the intestine in two, just as one cuts a piece of garden hose when it wears out in one spot and the remainder is still sound. The intestine is sewed together as the good pieces of garden hose are united. The segment corresponding to the bad spot in the garden hose is bent like a horseshoe, with the open ends sewed to the abdominal wall. Such a segment, called a Thiry fistula after the Belgian physician, J. H. Thiry (1817-1897), who developed it, secretes its normal quota of juices which can be removed from the open ends for study.

Using this method, Schoenheimer³¹ found that the sterol beta-cholestanol tended to accumulate in the isolated segment. The small intestine thus acts like the kidneys in producing a secretion that is partly taken back like an "Indian gift." The part not taken back, the special sterol, beta-cholestanol, passes down into the large intestine, where it is partly changed by the action of bacteria before it is excreted.

There may be some loss of ergosterol in feces by conversion to coprosterol. In chickens, Klein and Russell ³² found this to vary from 26 to 43 per cent, since they were able to recover this much from the feces of those fed ergosterol.

Injury from Large Amounts of Vitamin D

Large amounts of vitamin D have been fed to many animals, including dogs. In general, it seems to take a thousand times as much to injure an animal as it does to protect it from rickets. Of course this margin may not be as wide as it seems, because such studies have usually been run for relatively short periods and not throughout life.

Compared with other animals, cats seem most sensitive to large doses of vitamin D and chickens, least. Dogs are intermediate (Taylor et al). ³³

Use of Vitamin D by the Body

Vitamin D is readily absorbed by dogs. Ten hours after irradiated ergosterol is fed it can be detected in the blood and organs. The lungs of the dog seem to inactivate the vitamin D.

In general, vitamin D increases the absorption of calcium from the intestine. During rickets the feces tend to become more alkaline than normal. The reverse is true when vitamin D is fed.

The parathyroids are small glands that look like small islands of tissue in the thyroid of the dog. When these glands are cut out, the dog is subject to convulsions owing to the lowering of the calcium in the blood. If such dogs are fed vitamin D, the blood calcium level is increased and convulsions are prevented.

The effect of the injection of large amounts of viosterol into the circulation of dogs is seen in the calcium values for the tissues found by Reed and co-workers. ³⁴

No consistent deposition in the tissues of the animals was found. Each individual seemed to vary in selecting the site of calcium deposition.

Freeman and Farmer ³⁵ fed dogs and rabbits sub-toxic amounts of irradiated ergosterol for ten weeks and followed this with toxic doses of 11,800 units per kilogram of body weight. The toxic doses

CALCIUM IN MG. PER 100 GM. DRIED TISSUE. RANGE AND MEAN.

TISSUE	NORMAL		"ERGOSTEROLIZED"	
	<i>Range</i>	<i>Mean</i>	<i>Range</i>	<i>Mean</i>
Adrenal	22-68	38	390-800	596
Aorta	37-118	64	173-730	272
Brain	24-202	55	1,125-1,526	1,317
Rt. vent.	13-87	28	581-1,008	708
L. vent.	12-38	18	513-1,094	767
Kidney	29-177	56	354-1,112	816
Liver	10-28	18	512-990	790
Lung	42-221	89	555-1,143	865
Muscle	12-59	18	409-930	699
Skin	13-42	—	73-344	152
Spleen	7-32	14	682-1,198	925
Thyroid	40-263	101	243-802	554

increased the calcium and phosphorus of the blood and decreased the phosphatase.

Vitamin D Stimulates Basal Metabolism

Reed ³⁶ found that when five dogs were injected with large doses of vitamin D in the form of irradiated ergosterol, the basal metabolism increased. The body tended to consume its store of fats. Even in doses as low as 0.3 cc. daily of 100 X viosterol per kilogram of body weight, this stimulation took place. The rise in different experiments varied from as low as 15 per cent to a high value of 85 per cent. The basal remained high for about five days after the last injection. In these studies the calcium in the blood of the dog rose from the normal value of 10 mg. per 100 cc. to a peak that more than doubled this value. More calcium appeared in the urine, and there was some evidence of injury to the kidneys.

Rachitogenic Substances

Some of the pioneer work on rickets in dogs was performed in England by the Mellanbys.^{37, 38} These reports should be read by anyone studying rickets in dogs because detailed discussions of the changes in the bones are given. Before the time that vitamin D could be distinguished from vitamin A, the Mellanbys came to the conclusion that certain dietary constituents, such as oat meal, promoted rickets

by preventing the calcification of bones. In general, their diets were made of cooked cereals with small supplements of skim milk, fats, and yeast. In some of these diets meat was used to induce the dogs to consume large amounts of cereal or bread.

A typical rickets-producing diet consisted of bread, *ad lib.*; skim milk, 175–250 cc.; yeast, 5–10 grams; orange juice, 5 cc.; salt, 1–2 grams; and linseed oil, 10 grams. At the time, dogs were thought to be subject to scurvy if they did not get vitamin C in some form such as orange juice. Today it is believed that there is no substance in cereals that promotes rickets. The effect the Mellanbys observed was probably due to the unavailable form of phosphorus found in certain cereals. Furthermore, they found that dogs that ate sparingly of the diet did not develop rickets. Rickets is now recognized as a disease of rapidly growing animals. One that fails to eat enough to grow rapidly escapes. No hypothesis of a rickets-producing substance in the diet is needed to explain these phenomena.

The miscellaneous observations made by Mellanby in the course of his study of rickets may afford clues to the cause of other diseases in dogs. He found, for example, that dogs fed butter made a rapid recovery from mange, and that a diet producing rickets made dogs very susceptible to anaesthetics like ether and chloroform. The heart seemed to have been changed. Dogs on the low calcium diets commonly developed tetany. This could be checked by feeding whole milk or whey.

Vitamin D and the Development of Teeth

The teeth of growing puppies have been studied by Mrs. M. Mellanby.³⁹ She found that if the diet of the mother contained cod liver oil, the time of eruption of the first teeth varied from twenty-three to thirty days. But if olive oil were used in the diet, it took about five days longer, ranging from twenty-seven to thirty-nine days.

The shedding of the first teeth was also delayed by about thirty-eight days if the diet contained olive oil. The average age at shedding was as follows:

Incisors	116 to 136 days
Canines	138 to 160 days
Molars	139 to 157 days.

In general, diets deficient in vitamin D led to poor teeth. The effect did not show up in the first, or "baby," teeth because the mother built these from her own bones. If the diet of the mother contained an adequate amount of vitamin D, there was a favorable effect upon the puppy well after the weaning period. A few of these dogs were kept on the experimental diet for eight years.

Niacin or Nicotinic Acid

Niacin or nicotinic acid is the fourth vitamin of some interest to dog owners. The name "Niacin" was adopted for this vitamin because people tended to confuse the older term of nicotinic acid with the nicotine of tobacco. Nicotine is very poisonous, while nicotinic acid is not. Niacin is the substance in the diet which is essential for the prevention of the disease called black tongue in dogs and pellagra in man. Few dog owners have any experience with this disease if their dogs are given a good mixed diet or if the table scraps contain whole wheat bread, which is very rich in this vitamin.

Black tongue as a disease of the dog is chiefly interesting because it made the discovery of the value of niacin in the prevention of pellagra possible. The early description of this disease and the symptoms that characterize it were discussed by Wheeler and others⁴⁰ in 1922. Their article includes a good bibliography of the literature in the veterinary field as well as some discussions by veterinarians of the relation of black tongue in dogs to pellagra in man. In America black tongue began to be recognized as a deficiency disease about 1916.

Much was written about pellagra during the first two decades of the present century. The disease was known to be related to the diet, since it was most prevalent in areas where the people ate large amounts of corn meal. For about two centuries medical writers attributed the disease to some poison contained in corn, similar to the ergot found in spoiled rye.

About 1917 Chittenden and Underhill⁴¹ attempted to maintain dogs on diets of boiled peas, cracker meal, and cottonseed oil. These dogs developed black tongue but were cured when fed meat. These authors were interested in the utilization of various protein mixtures; hence they did not follow this lead further at the time. Furthermore,

other workers repeated these studies with rats, not realizing that this species gets no disease like pellagra.

As the years passed, experience with cases of human pellagra indicated that the disease was due to the lack of some vitamin present in meat, milk, eggs, and leafy vegetables. Yeast was also used in treating the disease. The field was confused, however, because constant attempts were made to evaluate the potency of yeast by rat tests. There was no correlation between the response of the rat and the pellagra patients to different yeasts.

In early years great efforts were made to isolate from corn the so-called poisonous substance which was supposed to cause pellagra. Later, attempts were made to concentrate a vitamin that would prevent it. The philosophy of the age had changed.

Underhill and Mendel⁴² extended their observations and published good pictures of black-tongue disease in 1928. They found that a diet of pork liver prevented the disease. In this same year Goldberger and Wheeler⁴³ described their experience in producing the disease in dogs. They fed a diet of white corn meal, 300; Farina, 90; white rice, 40; cowpeas, 20; lard, 23; cod-liver oil, 14; cottonseed oil, 20; calcium carbonate, 4; salt, 14; gelatin, 66; and tomato juice, 166. To recondition their dogs, they fed a mixture of Graham flour, 380; fresh beef, 350; whole dry milk, 60; butter, 21; cod-liver oil, 9; dry brewers yeast, 15; salt, 6; calcium carbonate, 9; and bone meal, 6. Today we recognize the first three substances and yeast as good sources of niacin. They described the disease in great detail. The veterinarians had called it many different names, such as Stuttgart dog epizootic, *Typhus des Hundes*, gastroenteritis hemorrhagica, southern canine plague, and sore mouth of dogs. The factor in meat which prevented black tongue was now called the P-P factor because it "prevented pellagra."

Birch,⁴⁴ in 1937, provided good evidence that the rat did not need this factor, while the dog did. The dog was thus shown to be a suitable test animal. Furthermore, Birch found that the P-P factor of liver concentrate was different from any of the known vitamins, such as B₁, B₆, or riboflavine.

Finally, in 1937 Elvehjem and his associates⁴⁵ isolated the amide

of nicotinic acid from liver fractions that were potent in curing black tongue in dogs. They also proved that nicotinic acid, which had long been known to chemists, was a specific in curing or preventing black tongue in dogs.

This work was soon confirmed. Human pellagra was also successfully treated with this organic compound, which had rested, unused, on the shelves of the organic chemist for many years.

In determining the dog's requirement of nicotinic acid, Sebrell ⁴⁶ and others have used a basal diet of white maize meal, 400; cowpeas, 50; casein, 60; sucrose, 32; cottonseed oil, 30; cod-liver oil, 15; sodium chloride, 10; calcium carbonate, 3. The corn meal and cowpeas of this diet were cooked before the other ingredients were added. After black tongue was produced upon such a diet in dogs weighing 10 to 20 pounds, it could be cured by 20 to 60 milligrams of nicotinic acid. A semi-weekly dose of 10 milligrams of nicotinic acid was sufficient to prevent black tongue during a period of six months. This seemed to be about three times the requirement. Since a gram of nicotinic acid costs only twelve cents, this would be the cost of supplying this vitamin to an ordinary dog for one year. However, most diets containing meat are probably already adequate in this essential.

Cats as well as dogs must have nicotinic acid in their diet or they develop a disease like pellagra.⁴⁷ The other species that must have this vitamin are swine and monkeys.

Dogs suffering from vitamin A deficiency may show the same conditions of the mouth as those that have black tongue from a lack of nicotinic acid. This caused much confusion after Chittenden and Underhill described their cure of black tongue by substances rich in vitamin A or carotene, while Goldberger and others needed another vitamin to cure black tongue in their dogs.

This mystery has been solved by three bacteriologists—Smith, Persons, and Harvey.⁴⁸ When dogs suffer from either deficiency, the mouth becomes a good host for large numbers of micro-organisms that are normally present on the teeth in small numbers. Under normal conditions the tissues of the mouth do not become infected by these bacteria. Since the mouth looks the same and really is the same, whether the tissues lose their resistance from a lack of either

of the vitamins, confusion resulted because a cure resulted in two different laboratories by two different vitamins.

Other Water Soluble Vitamins

Riboflavin is needed by dogs. Sebrell and others ⁴⁹ in 1937 injected riboflavin into a dog suffering with what they called "yellow liver." This dog survived while others died. This disease was produced by feeding a mixture of corn meal, 400; cowpeas, 50; casein, 60; sugar, 32; cottonseed oil, 30; cod-liver oil, 15; NaCl, 10; and CaCo₃, 3.

Street and Cowgill ⁵⁰ found that dogs collapsed suddenly if fed a diet lacking in riboflavin for periods varying from 107 to 235 days. They kept one dog in good health for 500 days with a daily allowance of 25 γ of riboflavin per kilogram of body weight. Few real symptoms of this deficiency were detected. In only one case did they find the "yellow liver."

Axelrod and others ⁵¹ found that a level of 100 γ of riboflavin per 100 grams of feed would permit fair growth in puppies, but these dogs failed in a few weeks unless this level were increased to 400 γ per grams of feed. They concluded that 200 γ per gram of feed was about the minimum. In acute deficiencies the blood level was 0.30–0.38 γ per cc. while the normal value had a range of 0.46 to 0.49 γ .

If the diet of the dog contains some meat, milk, dry yeast, or other dairy products, the needs for riboflavin are usually supplied.

Another vitamin needed by the dog is vitamin B₆ or pyridoxin. This vitamin is supplied in the usual diet by wheat germ, yeast, and egg yolk. Good sources are fish, liver, legumes, milk, and whole wheat. Without this vitamin, growing puppies become very anemic. Iron will not cure this anemia, but a concentrate of this vitamin will do so. Fouts and others ^{52, 53} studied this anemia. Street and others ⁵⁴ found that the heart failed to function properly as this anemia developed. Some degenerative changes were also found in the nerves of dogs suffering from a deficiency of vitamin B₆. McKibben and others ⁵⁵ found that it was needed at a low level for growth, with a higher level needed to prevent anemia. Sixty micrograms per kilogram of body weight per day allowed enough to prevent anemia.

No evidence has been found that the dog develops the severe sores

of the skin and nose that one finds in the rat lacking this vitamin.

Dogs also need pantothenic acid and possibly several other factors existing in liver. McKibbin and others⁵⁶ found pantothenic acid essential for growth.

By feeding various levels of pantothenic acid as a supplement to an otherwise complete diet for the dog, Schaefer and others⁵⁷ found that a growing puppy needed about 100 γ of pantothenic acid per kilogram per day. They found that during pantothenic acid deficiency the non-protein nitrogen, glucose, and chlorides of the blood are abnormally low. For producing pantothenic acid deficiency they fed a diet composed of sucrose, 66 per cent; acid washed casein, 19 per cent; cottonseed oil, 8 per cent; cod-liver oil, 3 per cent; and salt mixture, 4 per cent. As vitamin supplements they fed twice weekly in water solution an estimated allowance per kilogram of body weight per day the following: vitamin B₁, 100 γ ; riboflavine, 100 γ ; nicotinic acid, 2 mg.; pyridoxine HCl, 60 γ ; and choline HCl, 50 mg. Puppies started on such a diet at weaning broke down in three to four weeks.

Today the evidence seems adequate that dogs need most of the water soluble vitamins and several others that are in process of being defined.

Dogs Do not Need Vitamin C

From all available evidence, dogs do not need vitamin C and suffer from no disease resembling scurvy in man and guinea pigs. Innes⁵⁸ fed dogs a diet completely deficient in vitamin C. In five months this diet produced no ill effect in puppies. On the same diet guinea pigs died in twenty-five days. At the end of five months there was ample vitamin C in the livers of the dogs to protect guinea pigs against scurvy. These experiments accord with others in indicating that dogs can synthesize vitamin C within their bodies.

Imbalance among Vitamins of the B Complex

Evidence for imbalance among vitamins is scarce. Mrs. Morgan, however, who⁵⁹ studied special cases of imbalance in four groups of pure-bred cocker spaniels, came to the following conclusions:

1. "Dogs require one or more of the vitamins of the B complex in addition to thiamin, riboflavin, pyridoxin, nicotinic acid and pantothenic acid."

2. "Young dogs which receive none of the filtrate fraction, that is, no nicotinic acid, pantothenic acid or so-far unidentified factors, survive, grow moderately well but exhibit gradual depigmentation of hair, lack of activity and elderly behavior."

3. "The administration of nicotinic acid or pantothenic acid alone to animals receiving ample amounts of all necessary vitamins except those of the 'filtrate fraction' results in their gradual loss of neuromuscular control and sometimes sudden death."

4. "Attention should be given to the possible danger of the administration of large amounts of certain vitamins such as nicotinic acid to persons subsisting on diets having multiple deficiencies. Fortification of foods with those vitamins such as thiamin or nicotinic acid which are available in large quantities may precipitate conditions worse than the subacute deficiency state produced by the usual diet balanced in its inadequacies. Improvement in all directions equally is essential."

Vitamins E and K

Vitamin E was first recognized as a fat soluble vitamin essential for reproduction in the rat. Small amounts of this vitamin were found in liver and lettuce, but wheat germ oil was recognized as an excellent source. Finally, this vitamin was isolated and synthesized under the name of "tocopherol." Today it is manufactured by the organic chemist in the synthetic form. It is also prepared in concentrated solutions very cheaply by special distillation methods.

Little evidence has accumulated that this vitamin is essential for reproduction in the dog. In fact, it seems needed for this purpose only by the rat, mouse, and, possibly, the chicken.

As years have passed, evidence has accumulated that this vitamin is an important factor in the preservation of the muscles. This activity was discovered by accident when Swedish workers first found that guinea pigs and rabbits died with degenerated muscles if they were fed moderate doses of cod-liver oil. After many years of work in a

number of countries, this so-called "toxicity" of cod-liver oil was recognized as a destruction of the vitamin E in the diet. When cod-liver oil comes in contact with vitamin E for a few days in a warm room, the vitamin is destroyed. Thus animals exhibit paralysis and die because the diet lacks vitamin E.

These paralyses can be prevented easily by feeding an excess of vitamin E. For example, a rabbit on a normal diet will die in five to ten weeks if fed a small dose of cod-liver oil daily. If the diet contains about 10 per cent of wheat germ the rabbit will thrive indefinitely.

Anderson ⁶⁰ produced what appeared to be a vitamin E deficiency in puppies by maintaining their mothers for long periods upon mineralized evaporated milk. The symptoms of the degenerated muscles were similar to those described for guinea pigs and rabbits. The puppies recovered if fed some pure alpha-tocopherol before the condition was too far advanced.

If the dog's intestinal tract is deprived of bile by means of a fistula, the dog develops dystrophy of the muscles that is probably due to the failure to absorb vitamin E from the diet. This was observed by Warner and Brinkhaus ⁶¹ in 1939.

Many kennels feel that feeding wheat germ or wheat-germ oil improves reproductivity in animals. Inasmuch as wheat germ seems to play an important part under certain conditions in herbivorous animals, and since this product is a good source of vitamin B₁, it may be considered a useful addition to the diet of the dog.

No known disease has been recognized in dogs as a result of vitamin K deficiency. However, this vitamin is essential for chickens, rats, dogs, and men. As time passes, it may help solve some of the problems in nutritional diseases of dogs. Evidence today indicates that vitamin K is the organic compound known as 2-methyl-3-phytyl-1, 4-naphthoquinone. Alfalfa leaf meal is rich in this compound. It is readily extracted as an oil by the usual fat solvents. Interestingly enough, this vitamin seems to be formed as the result of bacterial action. This was first discovered in fish meals that had been acted upon by bacteria. Perhaps this explains the dog's love for meats that are rather too ripe for human consumption.

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CHAPTER VII

MODERN DOG FEEDS

THE DOGS of this country are, as a whole, probably better fed than the children, and this is particularly true of dogs kept in kennels where good mixed feeds are used. Two classes of dogs are often poorly fed—those pampered by the rich, and those living in the families of the poor. In both cases, the dogs are apt to suffer because they tend to dine on food of their own selection. The pampered dog of the wealthy is likely to be allowed his choice of delicacies, while the dog of the poor family often supplements his diet from the garbage pail.

FORMULAS FOR DOG FEEDS

The dog books of fifty or more years ago often gave directions for preparing feeds for kennels. At that time it was a common practice to boil mixtures, or single meals such as corn meal or oatmeal, with meat, and then feed this mush. During this period the average house dog was fed table scraps as he often is now. Today, in emergencies, dogs can be kept for long periods upon corn-meal mush, cooked oatmeal, or cooked whole-wheat flour. Such simple feeds should be supplemented with about 1 per cent of limestone or, better yet, bone meal. Ground carrots or some green vegetable, such as spinach or lettuce, would have to be fed at intervals to furnish vitamin A. Puppies would probably grow poorly under such conditions, and the female would have trouble in reproduction.

Dogs can live upon vegetarian diets. Three puppies were, shortly after weaning, placed by the author upon the following mixture, expressed in pounds: corn flakes, 30.5; wheat flakes, 30.0; soy-bean meal, 20; wheat germ, 5; tomato pomace, 3; dried yeast, 3; alfalfa meal, 1; bone meal, 2; salt, 0.5; and dried whey, 5. The growth rate

of these puppies was somewhat slower than when they were fed the usual mixed ration containing cod-liver oil and meat scrap. However, they withstood a severe winter, grew moderately, and remained in good health.

Today it is possible to prepare in large amounts good mixtures of dry feeds capable of satisfying all nutritional requirements of the dog. As a whole, the formulas of the best mixtures are very similar because the number of special ingredients available in large amounts is limited. These are well known and used by the feed-mixing industry. As a rule, this feed-mixing industry assembles the ingredients of mixtures but does not produce them.

In making a dog feed formula only a meal will be considered since this is readily converted into pellets, and since essentially the same ingredients can be used for a biscuit if the flaked cereals are replaced by flour.

Certain general requirements are placed upon all dog feeds. Usually, the feed must be uniform, so that it looks the same to the master each time he shops for the dog. If the feed contains black specks of iron or charcoal at one time and not at another, the purchaser usually thinks that the iron or charcoal is dirt. If it contains flakes of oatmeal one week and none the next, the formula may have been changed. The dog's master usually consults his own sense of smell and not that of the dog in judging a feed.

Packaging is of much importance. If the feed is rich in fat—an unusual characteristic of a dog feed—the package must have an inner lining to prevent staining of the package. A few years ago a manufacturer produced a feed relatively rich in fat because it was based upon a special breakfast food treated with fat. Packaging this product was a matter of considerable expense because of this ingredient, although the fat made the feed far more attractive to the dog.

The directions upon packages should be written with originality and care. These are of real educational importance, since they can teach vital lessons for feeding and care of the dog to maintain optimum health. Usually, these directions are little but hackneyed phrases.

Unless a dog producer owns a very large kennel, he usually cannot afford to mix his own feed. The ingredients come from many differ-

ent parts of the nation, and it is economical to assemble them only in large amounts.

A typical dry dog feed formula, sold in large volume and entirely satisfactory for feeding the dog from the time it is weaned, has the following composition:

	<i>Per cent</i>
Corn and wheat flakes	55.215
Meat meals	20.0
Soy-bean meal	5.0
Dry skim milk or dry whey	4.0
Wheat germ	5.0
Tomato pomace	2.5
Dry yeast	2.0
Fish meal	2.0
Cheese meal	2.0
Alfalfa meal	1.0
Bone meal	1.0
Salt	0.2
Cod-liver oil concentrate	0.035
Irradiated yeast	0.05

On mixtures of this type dogs have been put through their whole life cycle by the author. Scotch terrier bitches were bred and placed upon this diet and given no additional feed supplements during lactation. Their puppies were weaned, started upon the same diet, and reared to adult size with no other feedstuffs. This indicates the adequacy of the diet.

Such mixtures are probably more complex than necessary and it is probable that dogs would do equally well upon simplified modifications of them.

A simpler mixture that has proven equally good in shorter trials is the following:

	<i>Per cent</i>
Corn flakes	50.0
Meat meal	10.0
Liver meal	5.0
Soy-bean meal	15.0
Dry whey	5.0
Wheat germ	5.0
Tomato pomace	2.5
Dry yeast (Mixed with irradiated 1:30)	3.0

	<i>Per cent</i>
Cheese meal	2.0
Bone meal	1.0
Salt	0.5
Alfalfa meal or dried grass meal	1.0

At weekly intervals a supplement of cod-liver oil was mixed in the feed to insure adequate vitamin A for the growing puppies and lactating bitches.

A comparative trial of several months was given the following mixtures:

	A	B	C
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Corn flakes	36	36	36
Wheat flakes	20	20	20
Meat meal	10	5	0
Liver meal	10	10	10
Soy-bean meal	5	10	15
Skim milk	4	4	4
Wheat germ	4	4	4
Tomato pomace	2.5	2.5	2.5
Dry yeast	2.0	2.0	2.0
Fish meal	2.0	2.0	2.0
Cheese meal	2.0	2.0	2.0
Alfalfa meal	0.5	0.5	0.5
Bone meal	1.0	1.0	1.0
Salt	0.2	0.2	0.2
Cod-liver oil	0.8	0.8	0.8

No differences were found although animals were not put through the whole cycle of reproduction. Any of the three mixtures could probably have been sold by a manufacturer with equally satisfactory results.

Mistakes of Manufacturers

In general the mistakes found in formulas submitted to our laboratory for criticism fall into four classes, as follows:

(1) The manufacturer is paying a high price for some special ingredient sold him on the basis of claims having no foundation. For example, a chemist was producing an organic form of iodine mixed with mercury, which he thought made the dog digest its feed better.

He had no evidence for this, but was nevertheless having the mixture sold at a high price. Our laboratory tests proved his claims unjustified.

(2) Too much starch in the form of raw cereals is included in the mixture. One manufacturer was producing the following mixture: Alfalfa meal, 2.5; beet pulp, 2.5; beef meal, 15; fish meal, 2.5; liver meal, 3.0; soy-bean flour, 5; flaked oatmeal, 5.0; low-grade flour, 5; wheat germ, 5; corn proteins, 14; corn flakes, 15; wheat flakes, 15; milk by-products, 5; molasses, 2.5; oyster shell, 1.5; iodized salt, 0.5; oil of anise, 0.012; and garlic meal, 0.012. This mixture is needlessly complex, containing too much raw starch and too many special high-priced products when cheaper ones would do equally well. For example, this mixture contains oil of anise, garlic meal, special milk by-products, and special corn proteins that cannot be justified either by experience or testing. It contains raw starch in the oatmeal, the wheat flour, and the wheat germ. Farm dogs getting plenty of exercise might tolerate this mixture just as they might do quite well on a laying mash for hens. Other dogs, especially pets in cities, might develop diarrhea or other troubles from the uncooked starch.

(3) The mixture is too low in vitamins. In such cases the yeast, dry skim milk, wheat germ, and liver meal are used at levels that are too low in order to save money on these ingredients.

(4) Poor grades of ingredients are used. The alfalfa-leaf meal may be a dull greenish brown in color, the dry yeast full of starch or impurities, the meat meal low in protein or the liver meal low in vitamin A. The use of such ingredients is usually due to the failure of a beginner in the production of mixed feed stuffs to appreciate quality in the ingredients.

Specification for Dog Feeds

Writing the specifications for a dog feed so that they can be easily measured in a laboratory is impossible today, for the following reasons: The fundamental knowledge concerning the needs of dogs in terms of protein, vitamins, minerals, fats, and fiber have not been determined with adequate consideration of many special factors such as the activity of the dog, the breed, and the conditions of its life.

In no other species is there variability comparable to that found in the dog. Stockard ¹ has given an excellent review of this field and has shown that man has created the many breeds because of the different ideas he held concerning his ideal pet. Thus we have adult dogs that range in weight from two to two hundred pounds. Furthermore, some of these dogs spend part of their lives under conditions of severe exercise, such as that allowed the hunting dog, while others sleep in city apartments. In spite of the great differences in breeds little good evidence has been offered thus far to show differences in nutritional requirements.

The nutritional requirements of most dogs are undoubtedly covered by the formulas previously shown. For the large breeds there is probably an extra requirement for vitamin D as well as for additional calcium and phosphorus during growth. The vitamin D can be fed in the form of extra allowances of irradiated yeast or concentrates of the vitamin. Extra bone meal or fresh bones can be fed to cover the mineral requirement during the period of very rapid growth.

Most researchers have done little work on pure breeds of dogs. Tests have usually been made on dogs taken from the pound. Some of these have been described as "pure bred mongrels." If these represent crosses of many breeds results may be applicable to the average American dog. The future will undoubtedly see more research on pure breeds.

Three sources of evidence now indicate that dogs differ in the chemical transformations within their bodies. Biochemists have long known that Dalmatian coach hounds differ from other dogs in excreting uric acid as an end product of purines rather than allantoin, the usual end product in the dog. In recent years Morris ² and, later, Brand ³ have given much study to a strain of Irish terrier that excretes the amino acid cystine. Finally the tendency of large breeds to develop rickets more readily than the smaller ones has been discussed elsewhere (p. 61).

Most of the testing of mixtures such as those described previously has been done by the author and his associates with registered terriers of two pure breeds, namely Scotch and Cairn. For comparison a considerable amount of work has also been done with three other breeds

—the Saluki, the German Shepherd, and the Bassett Hound—descendants of dogs brought to us from Stockard's laboratory by Dr. W. T. James.

Mixtures of Widely Different Ingredients

To determine whether dogs would break down in a kennel when confined to very different rations, four groups of Cairn Terriers were fed for four months on four very different diets. No differences developed. The following mixtures, H, I, D and C, were used:

	H	I	D	C
Dry skim milk	6.0	6.0	6.0	5.0
Beef scrap (65%)	30.0	10.0	—	16.0
Pork scrap	—	10.0	20.0	—
Shredded wheat	39.0	—	—	—
Bran	5.0	4.0	—	—
Wheat germ	5.0	—	2.0	4.0
Corn flakes	—	12.7	27.7	20.0
Wheat flakes	—	—	—	15.0
Peanut meal	—	—	—	5.0
Corn Meal (Cooked-Dried)	—	—	27.0	21.8
Sugar	—	10.0	—	—
Potatoes (Cooked-Dried)	—	24.0	—	—
Dry yeast	2.0	5.0	2.0	2.0
Beef tallow	—	—	10.0	—
Lard	—	10.0	—	—
Alfalfa leaf meal	2.0	—	1.0	0.5
Fish meal	—	—	—	2.0
Cheese meal	—	—	—	2.0
Tomato pomace	2.5	5.0	3.0	2.5
Dry liver	5.0	—	—	3.0
Salt	0.5	1.3	0.3	0.2
Ground limestone	1.0	1.0	—	—
Bone meal	2.0	1.0	1.0	1.0

No details are given concerning these studies; they are mentioned merely to show that dogs can live very satisfactorily upon ingredients from very different sources if the special nature of these products is considered. Thus, much of the starch of diet I comes from potatoes. In this case the salt level was increased as well as some of the other sources of special nutrients such as the tomato pomace and

dry yeast. A weekly allowance of cod-liver oil was fed to each dog separately.

Any of these mixtures would probably have proved satisfactory for marketing commercially. Only "H" was on the market at the time these tests were made. Such mixtures illustrate the possibility of producing dog feeds from local ingredients combined with satisfactory supplements. Prejudice and superstition have kept many manufacturers from stepping outside the usual channels in developing dog feeds.

Home Mixed Rations of Commercial Ingredients

Several mixtures have been described by Koehn ⁴ for mixing at home. These are shown in the following table:

	1	2	3	4
Yellow corn meal	35	58	46	55
Wheat bran	10	—	—	—
Wheat shorts	20	20	20	20
Meat scrap	10	20	—	10
Fish meal	10	—	—	—
Dry skim milk or dry buttermilk	10	—	—	—
Alfalfa leaf meal	2	—	—	—
Bone meal	2	—	2.5	—
Salt	1	1	1	1
Sardine oil	1	1	1	1
Peanut meal	—	—	29	12
Limestone	—	—	0.5	1

He believes that no. 1 is best for reproduction, but that the others are satisfactory if supplemented with milk. He recommends cooking these mixtures by baking in the oven or boiling in the form of a mush. Under ordinary conditions the cost of the labor and of cooking these rations would not be justified except in very large kennels. Koehn finds that these mixtures can be fed raw, but that the ingredients are then less well utilized and diarrhea is more frequent.

The Chemical Composition of Commercial Dog Rations

The usual dry dog feed, in terms of the chemist, contains protein, 22-24 per cent; fat, 3-4 per cent; and fiber, 4-6 per cent. Such analyses

tell little about the real value of the feed, since the protein level may be modified by varying amounts of low grade proteins. Furthermore, these analyses tell nothing about the vitamins.

Biscuit Types of Feeds

A considerable tonnage of dog biscuits is sold. Biscuits have the same advantage in feeding as pellets; they are clean to handle and many dogs enjoy chewing them.

Such biscuits are prepared by mixing the ingredients into a dough and baking them. Thus, the ingredients, especially those of plant origin containing starch, and even the raw meat, are cooked in one step. Cheap meals from grains can be used. Fresh horse meat or meat meals can be included in the original dough. In such products the raw material, such as corn meal or wheat flour, is processed in one step into a dog feed. In the usual meal or pellet feed the wheat or corn is first flaked, then toasted, and then mixed into the dog feed.

The chief disadvantage of the biscuit or kibbled feeds is that the vitamin concentrates, such as cod-liver oil and yeast, are exposed to the temperatures of baking. Destruction probably ranges from ten to thirty per cent for thiamin and vitamin A. Perhaps this could be largely prevented by mixing these vitamin concentrates into the dough in the form of coated pellets, although this is not done today.

A typical biscuit type of feed is composed of the following, in pounds: finely ground corn meal, 43; wheat gray shorts, 20; meat scraps, 10; powdered skim milk, 10; soybean oil meal, 5; peanut oil meal, 5; alfalfa leaf meal, 2; bone meal, 2; iodized salt, 2; dry brewers' yeast, 1; and fish oil, $\frac{1}{8}$. After being mixed in a dough, these are baked into a biscuit.

One prominent manufacturer uses raw horse meat instead of the meat meal. This merely means adjustment in the water. Likewise, waste eggs from hatcheries or waste dairy products can be used.

As a rule, the dry dog feeds are too low in fat. For comparison, the canned dog feeds, which usually contain 25-30 per cent of dry matter, can be calculated to a dry basis. They usually have 8 or more per cent of fat. This is about twice the fat level, on a dry basis, of the usual biscuits or dry feed mixtures.

The Maintenance of Dogs Upon Dry Feeds

The usual house dog weighing 12 to 14 pounds needs a third of a pound of dry feed per day. In kennels a very close estimate of the needs of the dogs can be made if 1 pound of feed is allowed for every 36 pounds of dogs. Of course, this estimate assumes summer weather or heated kennels, and is accurate to within about 5 per cent, even for dogs of very different sizes. For example, in the author's kennel at one time were the following:

1 farm dog weighing 40 pounds

7 small puppies weighing 2 to 4 pounds each

6 puppies nearly grown, weighing 12 to 15 pounds each

2 adult males weighing 14 to 19 pounds

3 adults from special experiments, weighing 12 to 18 pounds

5 grown bitches weighing 10 to 14 pounds

The total weight was 286 pounds. The daily requirement for dry feed was regularly between 7.75 and 8 pounds. This amounted to 2.71 pounds of feed per 100 pounds of live weight.

During the winter months, when these same dogs were living in unheated quarters with temperatures well below freezing, the daily feed requirement increased to 250 grams, or more than half a pound, for each 14-pound dog. These values are for the usual commercial mixtures described previously. About three-fourths of such mixtures are utilized. For estimating the utilizable energy values one may assume 3 calories per gram.

Maintenance tests were run for about one year by Dr. James at Cornell with three breeds, namely the Saluki, the Basset Hound, and the German Shepherd. They were housed during the winter in heated kennels with outside runs. Little difference was found in the maintenance needs of these different breeds.

When individuals were allowed all the feed they wished per day the Basset Hounds ate least. This breed is sluggish. The more nervous individuals within a breed such as the Saluki or German Shepherd tended to consume the most feed.

The Future of Dry Dog Feeds

Dry dog feeds of the future will improve with better manufacturing methods for the ingredients. Much attention needs to be given to cereals in order to produce starch in the form best utilized by the dog. Proteins of plant origin, including those from yeast, may ultimately be so treated that they will have the same flavor appeal as fresh meat. Better processing of meat scrap at lower temperatures will inevitably improve this ingredient. This seems to be the promising field of the future rather than to attempt to devise separate rations for different breeds of dogs. The dog's nutritional requirements seem to be far more uniform than one might expect; hence, stress should be placed upon better ingredients and probably simpler mixtures.

For economy of storage space and transportation dog feeds will in the future probably be pressed into hard cakes the size of paving bricks for the purchaser of small amounts. The kennel owner may buy his feeds in larger blocks, like those used on farms for feeding salt.

To save vitamins, they will probably be included in future dog feeds in the form of well coated tablets mixed through the feed like raisins in cake. This form is badly needed for the fat soluble vitamins, since they are readily oxidized when sprayed on feed and mixed with many catalysts, such as iron. Fat soluble vitamins are quite stable if mixed with some inert material like dicalcium phosphate and then coated with sugar. The future will probably see great improvements in these coatings; for example, some water insoluble protein, such as zein, may be combined with the usual coating of sugar. Machinery for these operations is available in the drug industries but is unknown in the feed mill. On the other hand, the feed mill has good machinery for making pellets, an operation not used in the drug industry. Further, pellets are made at 1 per cent of the cost of making tablets.

As knowledge develops better methods will be found to protect essential vitamins and also to prevent unfavorable changes in feeds, such as the rancidity of fats caused by storage in warm rooms.

Canned Dog Feeds

As the meat-packing and breakfast-food industries in America grew, there followed the manufacture of dog feeds. The meat industry early came to appreciate that waste meats could be mixed with other ingredients and canned as a dog feed. This pleased the housewife because she needed merely to open a can to feed her dog with the same ease with which she opened a few more cans to feed her family. The cost of such feeds was relatively high when calculated to a dry basis, but they possessed the advantages of ease of feeding. Furthermore, they were very palatable to the dog. For some unknown reason, cooked meats remain very palatable to both dogs and men, while meats dried at high temperatures in large part lose their palatability. Furthermore, many other ingredients, such as fats and vitamin concentrates as well as plant materials, could be mixed in canned feeds.

Not only meats produced for man, but such products as horse meat, were canned as dog feeds. The dog does not share the prejudices of man, and enjoys his juicy steak whether it comes from a horse or a steer.

In the horse-meat industry the slaughter of a 1,000-pound horse would yield the following in pounds: muscle, 450; edible bone, 260; kidneys, 4; tongue, 4; spleen, 3; fat, 8; tripe and glands, 4; lungs, 14; hearts and cheek meats, 4.

The cost of canning such meat in 1940 could be broken down as follows, in cents: materials canned, 0.82; cans, 0.70; labels, 0.50; factory overhead, 0.18. This means that a pound can of good dog feed costs about two and one-third cents at the factory. When the consumer pays about four times this amount, he is assuming the additional costs of advertising, shipping, and selling.

The table on page 96 shows a typical canned dog feed and the cost of ingredients at the factory.

This represents a high-grade mixture established by usage and a moderate amount of empirical testing. Such feeds probably contain more protein than the average dog needs. Furthermore, they probably contain more ingredients than are needed for a complete

<i>Ingredient</i>	<i>Weight in pounds</i>	<i>Cost per lb. (Cents)</i>	<i>Dry Wt.</i>
Meat	200	3.5	50
Bone	100	1.5	70
By-products	20	2.0	5
Cracked barley	24	1.5	22
Cracked wheat	10	1.5	9
Wheat bran	10	1.0	9
Skim milk	7	5.5	7
Carrots	18	1.5	2
Dry yeast	4	11.5	4
Salt	0.08	—	—
Cod-liver oil	0.75	—	—
Soybean meal	84	1.5	76
Wheat germ	10.5	3.0	9

diet. Before the canning of dog feeds was stopped by the war, there was a growing practice, among the better producers, of increasing the vitamin B₁ as this synthetic vitamin became available at less than a dollar per gram.

Ingredients of Canned Dog Feeds

As the dog feed business proved profitable many attempts were made by certain unscrupulous manufacturers to widen the profit margin by the use of low-grade ingredients. This operated against the interests of both the consumer and the manufacturer of a high-grade product.

Some attempts at control were made, but none proved very satisfactory. The American Veterinary Association established under the active leadership of Dr. M. L. Morris a committee for the certification of reliable products. This committee made a good start but had to struggle with two great difficulties, the backwardness of the industry and the lack of adequate technical tests for the evaluation of feeds.

The committee attempted to establish the value of feeds upon the basis of some simple observations with dogs and by the use of rats as experimental animals. They really needed extensive facilities to evaluate feeds upon the basis of dog studies covering long periods of time and involving growth, reproduction, biochemical and special physiological tests. The basic problem was essentially that which now faces

physicians in evaluating borderline nutritional deficiencies in man. Tests, such as those involving the study of the circulation in the eye by means of the slit lamp, are slowly being evolved for human use. They will ultimately be available for similar studies with dogs. Only then will it be possible to evaluate feed mixtures more effectively.

The Chemical Composition of Canned Dog Feeds

A few state agencies have made attempts to evaluate canned dog feeds by conventional analytical procedures. These are somewhat useful for measuring the fiber, fat, and protein but tell nothing of the quality of ingredients used in the can of feed or the nature of the vitamins and minerals. Even the protein values may be very misleading because the dog makes excellent use of most meat proteins, while it uses only about three-fourths of the proteins from plant sources or those subjected to high temperature in the course of drying.

The following table shows some of the extreme values found in the analysis of dog feeds by the state of North Dakota.⁵

DOG FEED ANALYSES IN PERCENTAGE

	NINE GOOD FEEDS		EIGHT POOR FEEDS	
	<i>Extreme</i>	<i>Mean</i>	<i>Extreme</i>	<i>Mean</i>
Protein	10-18	13	5-12	8
Fat	3-7	5	1-5	2
Fiber	0.4-1	0.6	0.5-1	0.9
Water	60-72	70	70-80	75

The state of Kentucky, in an attempt to control commercial feeds, has had numerous samples analyzed and has published the results of part of these analyses.⁶ The analyses give the name of the manufacturers and the trade name of the product. The data are interesting in showing the range of ash in canned dog feeds as claimed by the producer. This varies from 1 to 5 per cent on a wet basis. On a dry basis this would range from about 3 to 15 per cent. In most animal feeding 4 or 5 per cent of ash is considered adequate. These values indicate great differences in the amount of ground bone included in different canned dog feeds.

Some dog feed manufacturers in Kentucky attempted to block the publication of the amount of water in the various canned feeds so

that the consumer would not appreciate how much water he was buying. This court action was still pending in 1938. Producers would undoubtedly be glad to reduce the amount of water in canned feeds and include more food value in a can, because they appreciate that their customer buys only a cent's worth of feed in an eight-cent can. However, the reduction of the water content is difficult if much meat is used, since meat itself is about 70% water.

The consumer usually has had little guidance and has been confused by the claims of the advertisers attempting to capture his trade. Because of the great difficulty of checking the claims of advertising, little governmental control has been exercised. The veterinary service of the U.S. Food and Drug Administration has remained asleep, much to the injury of the ethical feed manufacturer and the consumer. The veterinarian has also been in a quandary. He also has had no guidance. As a result, his quarters have usually resembled a hybrid between the sampling room of a feed control laboratory and the feed shelves of a large pet shop. The poor veterinarian has had to respond to the whims of his patients, the dogs, and, still worse, the prejudices of their owners.

The future will undoubtedly see some protection for the consumer, which will arise from the demands of the manufacturers of high grade dog feeds, from the increase in knowledge of the veterinary profession concerning nutrition, and finally from the interest of the consumer in his own economy and the welfare of his pets.

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CHAPTER VIII

THE INGREDIENTS OF DOG FEEDS

Grains

HALF OF most dog feeds consist of some natural product from grain that provides well cooked starch. In meals or pelleted feeds this is usually provided by flakes of corn or wheat. Some feeds use shredded wheat or bread crumbs. In the early days of making dog feeds, there was an adequate supply of these cereals from the by-products of the manufacture of breakfast foods. These supplies finally proved inadequate. Today there are plants devoted largely to the manufacture of flaked cereals for dog feeds. Oatmeal is used to a limited extent.

The flaked cereals provide some protein as well as cheap carbohydrates. If they are by-products, they may also contribute salt and some vitamins to the final mixture. They determine the bulk and also the rapidity with which a feed absorbs water.

Many of these breakfast foods contain malt but there is no evidence that dogs like the flavor of this sweetening agent. In general, dogs like most of these processed cereals. Although individuals differ, the dog usually prefers the taste of wheat flakes rather than of corn flakes. In the mixed feed containing meat scrap this preference can be neglected.

The addition of glucose or molasses to most dog feeds provides utilizable carbohydrates. Some dogs like sweet substances and others do not. If carbohydrates in the form of sugar cost much more than starch they are probably not justified.

From balance studies we have found that the dog utilizes about 85 per cent of the dry matter of flaked materials such as corn flakes. Ninety-five per cent or more of the starch in these processed grains is utilized. Bernard and others¹ also found that foxes utilized 90 per cent or more of the starch of cooked cereals, but less of uncooked.

The toasting of these flaked products probably decreases the water-soluble vitamins. The protein is also decreased in value but the grain products are added primarily for the starch they contribute to the mixture.

Protein Concentrates

Meat meals, cheese meal, dry skim milk, dried buttermilk, soy-bean meal, dry brewers' yeast, fish meal, and wheat germ are ingredients contributing both protein and flavor to dog feeds.

The lower grades of meat meals containing 55 per cent of protein are not usually used in the better dog feeds if meals containing higher protein levels are available. Some producers take special care in collecting meat scraps from the shops in order to produce a high quality product for dog feed. Usually, most of the fat has been rendered from meat scrap. The high temperatures used lower the value of the protein and destroy most of the vitamin B₁.

In the Cornell laboratory the students put a test dog upon a diet in which only the meat scrap provided vitamin B₁. In the course of a few weeks the dog was constipated and ceased eating. A solution of crystalline vitamin B₁ was then fed the dog; there was marked recovery immediately. The meat scrap had not provided this vitamin. Meat scraps may have no horn, hoofs, and stomach contents, but may contain dried bone. The bone meal of dog feeds is usually decreased in amount if low grade meat scrap is used. If meat scrap contains more than 4.4 per cent of phosphorus it must be classed as tankage.

In general, beef products are preferred for dog feeds. There is no good evidence against using meals made from pork scraps. The author has run some feeding trials with such meals and found them equal to similar products from beef.

As a rule, the dog utilizes about three-fourths of the protein in meat scrap. Part of this protein is poorly utilized because it comes from fibrous tissues. Furthermore, its quality is usually impaired by the high temperatures used in rendering and drying.

Liver meals are added to dog feeds when available. Some of these are imported from South America. These may contain many ingredients, such as lungs, that lower their nutritive value. Some liver meals

are produced in America. Some of the companies that extract the anti-anemia factor for the drug trade dry the liver residues carefully. Since the anti-anemia factor is taken from liver by a single extraction with warm water, the residue is a rich source of protein, vitamin A, and many of the water soluble vitamins that are only partly removed with the first water extraction. In time, however, such residues will undoubtedly be used for human food, since they have so much value.

Blood meals are added to some dog feeds. Limited evidence indicates that the protein of these is poorly utilized. Fresh blood seems to be well digested, but it seems to suffer from heat treatment more than most meats. In recent trials with foxes, Smith ² found the following percentage digestibility of the protein: blood meal, 78; horsemeat, 91; meat scrap, 86; fish meal, 88; liver meal, 88; soy-bean meal, 86; and linseed meal, 81.

The meat scrap is the most palatable of the usual ingredients in a dog feed. Liver meal, however, is not relished. To man it tastes bitter. Next to meat scrap, the dog usually prefers the wheat or corn flakes. Dogs are also fond of small amounts of cheese and wheat germ. They also like dry skim milk, but care little about bone meal or dry yeast.

Dry skim milk, dry buttermilk, and dry whey have been tried experimentally and used in the manufacture of dog feeds. All are well tolerated. The dried whey is much lower in protein than the other ingredients. An excess of dry skim milk must be avoided, or the dog will develop diarrhea due to the lactose. Little trouble is experienced if the dry skim milk is kept at a level of 5 to 10 per cent. Dry milk products are valuable as sources of calcium, phosphorus, and water-soluble vitamins, especially riboflavin.

Soy-bean meal is a useful source of protein for the dog. From evidence with other species, the protein of this meal is improved by heating. Those who wish to process their own soy beans can bake them in an oven for about an hour at a low baking temperature and then grind them. Such products tend to become rancid in a few weeks, especially after they are ground, since the usual soy bean contains about a fifth of its weight in fat. Peanut meals are used in some dog feeds and are well tolerated.

Dry brewers' yeast is an excellent ingredient of many dog feeds.

About one pound of this product results from the brewing of 93 gallons of beer. As this product comes from the brewery it has a bitter taste from the hops. This is partly removed before the yeast is sold for making tablets or used in human foods to increase the vitamins and protein.

The yeast used in animal feeds is usually that which has undergone some bacterial action before drying. This often improves its flavor. Dry brewers' yeast should not be confused with the fresh yeast sold in cakes for bread-making. The fresh yeasts are alive, and the cakes contain about 70 per cent water and a considerable amount of starch.

Brewers' yeast is added to dog feeds to increase the water soluble vitamins; 20 to 40 pounds are added per ton of feed. Irradiated yeast is added in an amount of about a pound or less per ton, to furnish vitamin D.

The composition of brewers' yeast is shown in the following table:

<i>Chemical Composition</i>		<i>Ash Constituents</i> (% of ash)		<i>Vitamins</i> (in gamma — micrograms/g.)	
Moisture	8.9	Ca	9.0	Thiamin (B ₁)	150
Ash	8.7	P	16.3	Riboflavin	50
Fat	2.5	So ₃	15.0	Niacin	600
Crude fiber	7.9	Fe ₂ O ₂	0.3	Pantothenic acid	200
Glycogen	5.5	K ₂ O	26.0	Choline	2,500
Yeast gums	2.8			Filtrate factor	8-12 *
Pentoses	1.9			Pyridoxine (B ₆)	100
Carbohydrate	10.7				
Protein	49.5				

* Jukes-Lepkovsky units/g.

Yeast can be grown on carbohydrates from hydrolized wood, from the wastes from paper mills, and from many other sources of soluble carbohydrates. In time it may become a primary product of great importance as a feedstuff for animals and a food for man.

Wheat germ is a by-product in the milling of wheat for the production of white flour. For nearly a century attempts have been made to put it back into the flour, but most of it still finds its way into feeds for farm animals. It is a good source of water-soluble vitamins and vitamin E. The following shows its composition:

WHEAT GERM

<i>Chemical Composition</i>		<i>Mineral Analysis</i>	
Fat	11-14%	P	1.0%
Protein	25-35	Ca	0.05
Carbohydrates	36-48 *	Mg	0.3
Moisture	9	Fe	0.007
Ash	5		
Vitamins in Micrograms per gram:—		B ₁ — 26-50	Niacin — 34-66

* As sucrose and raffinase, not starch.

Dog feeds may use up to 10 per cent of wheat germ depending some upon its price and availability.

Fish meals are widely used in dog feeds, but usually in small amounts, such as 2 per cent, to provide flavor. Fish meals vary widely in quality, from white products dried carefully in vacuo to dark meals dried with much oxidation. Dogs vary widely in their taste for these meals. High levels are not often used in mixed feeds because they have the reputation of producing excreta of foul odor.

Vitamin Concentrates

The products added to the usual dog feed to contribute vitamins are yeast, wheat germ, cod-liver oil, alfalfa meal, and dried liver.

Cod-liver oil is usually added in the form of a concentrate, since large amounts tend to grow rancid. Other fish oils such as shark-liver oil are often used instead of cod-liver oil. Salmon oil has been used. The marrow oil from horse bones is sold to kennels, but this is added for its fat content rather than for vitamins.

Alfalfa meal is not relished by dogs, but in amounts of about 1 per cent it does not modify the flavor of the mixed feed very much. It is added as a source of carotene and vitamin K. Some manufacturers add dried grass for this purpose.

Tomato pomace is the residue from the manufacture of tomato juice. It provides some carotene and vitamin E and is a rich source of pectin, which regulates the water of the feces within limits and safeguards the dog from diarrhea and constipation under normal conditions. From analyses made by Dr. Kertesz of Geneva, tomato pomace contains about 4 per cent of pectin.

The fate of pectin in the intestinal tract of the dog seems to depend

upon other ingredients of the diet which probably modify bacterial decomposition. Thus Werch and Ivy ³ found that 90 per cent of the 20 grams of pectin added to a mixed diet disappeared from the intestine of the dog. In a fasting dog only 50 per cent of the pectin was decomposed.

About 0.5 per cent of iodized salt is added to most dog feeds, as well as 1 to 2 per cent of bone meal to provide calcium and phosphorus. Some manufacturers add limestone, charcoal, and special mineral mixtures containing trace elements like copper, manganese, and cobalt; but there is no good evidence for these latter additions. The world is waiting for a better bone meal that will be sterile but appeal to the tastes of the dog. Perhaps this is impossible without including the fats of bone. Such fats tend to mold easily. No good way of preserving them in mixed feeds is known.

Horse meat is often mixed with dry feeds. Smith ⁴ has summarized percentage values found in 16 analyses as follows:

	<i>Mean</i>	<i>Low</i>	<i>High</i>
Moisture	76.0	69.0	83.7
Crude protein	18.1	15.5	20.1
Fat	4.1	0.4	10.6
Ash	0.9	0.7	1.1

Many vegetables are fed to dogs. Among these, carrots are very useful since they are usually inexpensive. In the balance studies of Schlotthauer and Berryman ⁵ it was noted that carrots were not as well utilized as potatoes. In corresponding amounts vegetables are probably as well utilized by the dog as by man. The Japanese report feeding such plant foods as sweet potatoes, fermented beans, and rice to growing puppies without trouble.

From time to time claims are made for the addition of enzyme preparations to dog feeds for the purpose of improving the utilization of feed. There is no evidence that such enzymes are needed by the dog. Wells and others ⁶ have called attention to the high "factor of safety in the digestive mechanism of the dog."

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CHAPTER IX

TESTING DOG FEEDS

THE TESTING of commercial dog feeds has never been given attention comparable to the importance of the industry. As a whole, the industry has prospered and grown by spending little on research and

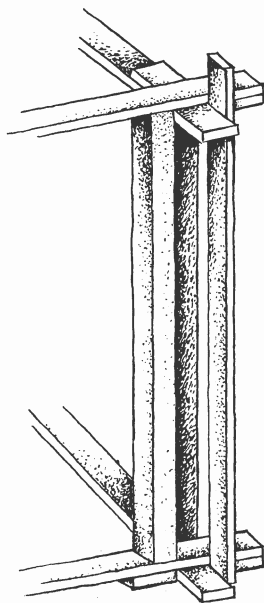


FIG. 5. *Corner construction of a movable pen that avoids the use of hooks or fasteners.*

large amounts on advertising. A few dog-feed manufacturers have maintained kennels and have supported continuous research in the field for many years. Little support has been given to this field of research by the government agencies because there has been no public demand for such action. Dog owners have never combined into

groups to demand that some public funds, such as license fees, be expended for studying the breeding, nutrition, and diseases of dogs.

Manufacturers often hesitate to embark upon research because they do not appreciate how much can be learned about their feeds by the use of simple techniques. Any industry that has a control laboratory for routine chemical work can improve its dog feeds through re-

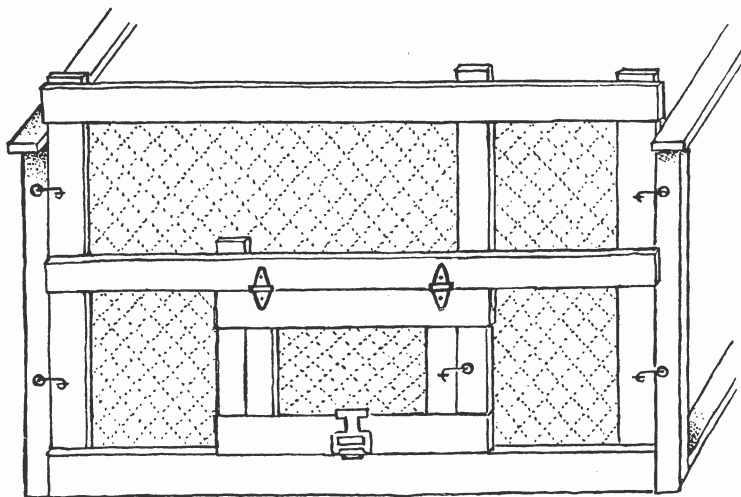


FIG. 6. *Front of a simple movable dog pen.*

search that can be conducted at moderate cost. Much can be learned from studies with a small kennel of dogs.

Only simple facilities need be provided. An old barn will serve for housing. A man capable of doing rough carpenter work can build feed bins, pens, and dog houses. For equipment, a large pan that will hold about 100 pounds is needed, and a hoe for mixing test batches of feed. Small batch mixers can be used. The author uses some old pans formerly employed for evaporating maple syrup. Three kinds of scales and balances are useful, such as a light laboratory balance that will weigh about 500 grams, a pair of scales for weighing dogs, and finally, some spring scales for weighing feed ingredients.

The person in charge must be capable of following directions accurately in both feeding the dogs and making mixtures. He should

also carefully observe the animals so that he may detect illness in its early stages.

Experiments should be designed by an expert. This needs to be done only a few times per year, since most studies will last for considerable periods of time.

The breed of dogs to be used can be chosen in relation to housing and the problems to be studied. If unheated quarters are employed,

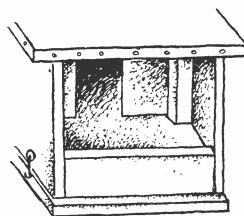
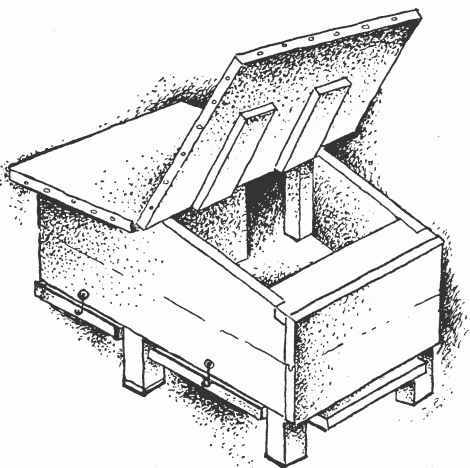


FIG. 7. *A dog house of good design.*

some of the long-haired breeds are useful. The smaller breeds, such as the Cocker Spaniel or Cairn Terrier, make good test animals. They need small quarters and little feed. For certain tests, such as the study of rickets, however, some of the large breeds may prove useful. After the initial investment is made, pure bred dogs are as cheap as mongrels for test animals.

Growth and Life Cycle Studies

The simplest test of the adequacy of a mixed diet is to start puppies at the time of weaning and feed them a test diet until they are grown. They are then bred and allowed to reproduce and take care of their puppies until the latter are ready for the same testing. Where

commercial formulas have been quite constant for several years, this is a simple and useful technique. Chief reliance must be placed upon the caretaker, who must never allow supplements in feeding.

Under such conditions puppies are usually weighed at weekly intervals. Growth curves are plotted from these weighings. Adults are weighed to insure the maintenance of their weights upon the diet.

Metabolism Studies

To determine the extent of the digestion of feed ingredients, dogs are confined for periods of about two weeks, so that the excreta can be collected. During this time the amount of the diet fed is kept constant during each day. Special cages may be used in such work, so that both the urine and feces can be collected. In many cases, however, only the feces need be saved for the chemist, since their amount and composition will give all the information needed. Under such conditions, almost any pen is suitable if it has a smooth floor to prevent loss of the excreta. The author has used linoleum and also smooth cement for pen floors in such studies. In France he found a pen built with a glazed tile flooring.

For short time studies lasting only two weeks there is usually enough reserve of vitamins in the body of the animal to carry it through. If longer trials are made, at least vitamin B₁ must be given as a supplement in order to keep the animal eating its daily food allotment, unless this vitamin is present in the feed tested.

In such tests the excreta are usually thrown away for the first four days. They are then preserved. Feces are usually covered with alcohol containing about 1 per cent of hydrochloric acid. Urine is usually preserved with a few ml. of chloroform and toluene. Both are stored in a cool place until analyzed. Feces are usually dried carefully and ground for analysis. Urine is analyzed directly. Under conditions where only the feces are collected, dogs may even be allowed to run for a couple of times daily on grass or ground where the excreta can be completely recovered.

An example of the use of such a method may be useful. A manufacturer decides to process soy beans for use in his dog feed. A bushel

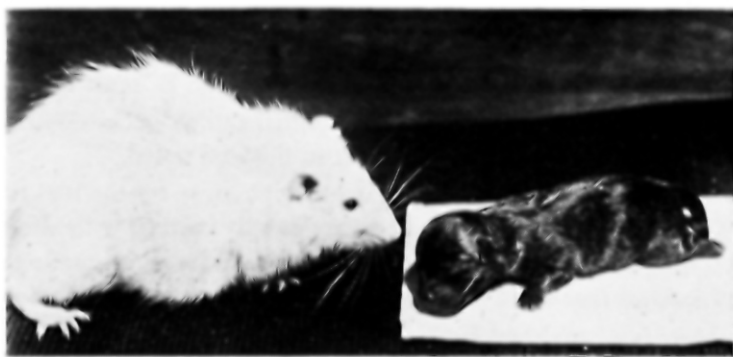
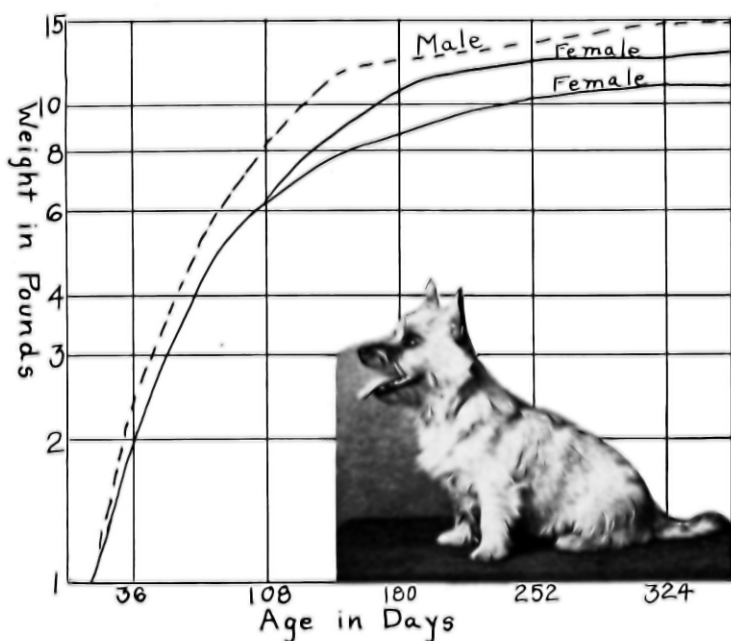


FIG. 8. Above: *Growth curves of Cairn Terriers.* Below: *The relative sizes of a Cairn Terrier at birth and an adult rat.*

of soy beans is divided into halves. One portion is heated in an oven for an hour at 280° F, the other half at 320° F. The bean samples are then ground.

A simple mixture is devised, such as the following, expressed in

pounds: Ground soy beans, 30; cod-liver oil, 2; dry yeast, 5; and cooked dry starch or rice, 63. About a pound of this mixture will be needed for each day's food for a 36 pound dog. One balance period of fourteen days is used for each sample of beans. The chemist analyzes the food ingested in terms of fats, protein, and carbohydrates. He also

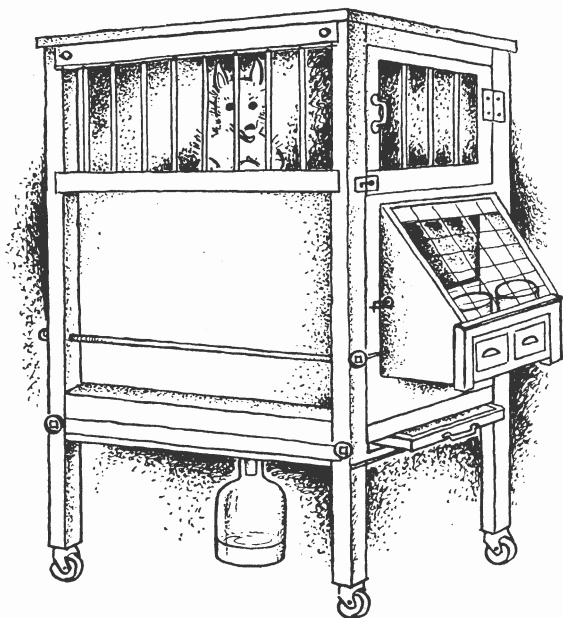


FIG. 9. *Metabolism cage for chemical balance studies.*

analyzes the dry feces. This gives a comparison of the effect of the two heat treatments upon the utilization of the chief components of the beans. If a more complete picture of the protein utilization is desired, the urine can be collected and analyzed for the last ten days.

Such technique is useful in comparing the utilization of different sources of protein, such as that of blood dried at various temperatures or of meat scraps from different sources. It may also be used to estimate the comparative utilization of dog feeds competing for the same market. Little is known about the digestion of nutrients by growing puppies of different breeds or by bitches during lactation and gestation.

Certain parts of the diet cannot be studied by this method of metabolism because of the fact that some elements such as calcium and iron, are excreted by way of the intestine. Protein, for example, can be tested by this method because most of that digested and absorbed leaves the body as the nitrogenous products of the urine. The relative use of the calcium of bone meal and some other source such as milk cannot be compared by this method, however, because there is no way of telling how much of the calcium is absorbed from the intestine and then thrown back into it for excretion. Therefore, to compare the use of calcium from different sources, some method must be used that measures storage.

IN ANY METABOLISM STUDIES, THE DATA SHOULD BE ASSEMBLED ON MIMEOGRAPHED SHEETS OF STANDARDIZED TYPE. This can be supplemented by notes of the workers, in the following form:—

TYPICAL DATA SHEET

Balance Trial No.

Date Run:	Species:
Diet Composition:	Diet Anal., Sample No:
Diet Analysis:	
Amount of diet fed daily:	
Remarks about the feed and reactions of animal to the diets:	
Feces—General Characteristics:	Fecal Anal., Sample No.
Method of preserving and preparing for analysis:	
Wet weight for period:	
Dry weight for period:	
Chemical composition:	
Urine—Characteristics:	
Method of preserving and storing:	
Volume for period:	
Chemical composition:	
Analytical methods employed with literature reference and modification:	
Name of person who ran the balance:	
Name of analysts:	
Remarks about the health, breed, and type of animal employed:	
Special observations made in the course of the experiment:	
Use back of sheet for daily records.	

Storage Methods

For studying the storage of some element such as calcium or phosphorus, young, growing animals are usually used because they are making use of such elements to build new bone. In making such storage tests, the level of the ingredient in the diet must be kept low. Otherwise, even a poorly utilized product will provide enough of the element to satisfy the need of the growing body. If bone meal and milk were to be compared as sources of calcium, for example, one diet might be prepared with this element at a level of 0.2 per cent, another at a level of 0.3 per cent, and still another at a level of 0.4 per cent. Puppies would be fed these diets for a given period, such as four to eight weeks or longer. At the end of the period the puppies could be killed and the bones analyzed for ash.

If X-ray equipment is available, the bones can be studied by this means at weekly intervals.

Such methods can be used for comparing bone meal and special products like dicalcium phosphate.

Similar methods can be used for evaluating proteins. In this case, levels are usually set at about 8 per cent, and the puppies must be sacrificed for analyses of their bodies.

Unscrupulous workers at times use such testing methods to make an inferior product appear superior in quality. This is done by setting levels so high that no differences are found; and one is declared to be as good as the other.

Palatability Testing

The nutrition students of the past century usually ascribed to poor palatability their failure to get animals to eat food. Palatability must be a real factor, because cats certainly prefer mice to hay, and cows, the reverse. In modern times, however, the recognition of the importance of vitamins in maintaining appetite for food has led to a general disregard of palatability. In the dog feed industries it is of great importance.

For comparing the relative taste preferences of dogs, a series of pans can be arranged in holders with a separate ingredient, or a mixture

of ingredients, in each. Known amounts are weighed into the pans. Either single dogs or groups can be allowed to choose. The dogs may be tested either after they have been given a meal or while they are

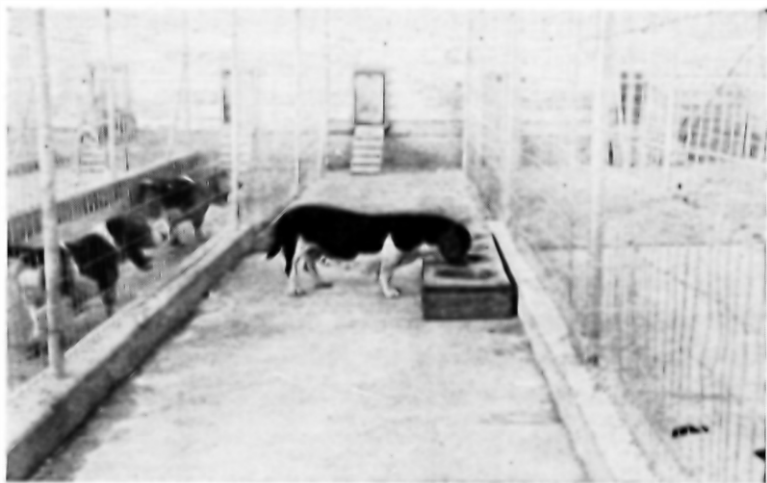


FIG. 10. *The dog will indicate which feed ingredients he prefers if given the chance.*

quite hungry. Much work of this type needs to be done to improve the palatability of feeds, and thus learn to compound feed mixtures of higher nutritive value that will be eaten readily.

Purified Diet Studies with Dogs

For more than a century dogs have been fed diets composed of purified ingredients. Voit ¹ described these many early attempts, such as that of Plosz who fed a mixture of sugar, starch, fat, and peptone in 1874. The modern form of these diets was established by von Hoeslin ² in 1882. To study the metabolism of iron, he fed diets of egg albumin, lard, starch, and a salt mixture designed to imitate the ash of milk. In part of his studies he anticipated, by adding cream, the modern improvement of adding vitamin supplements to such mixtures. His dogs died after a period upon such diets, probably because they lacked vitamins.

For about a quarter of a century, workers at Yale have made use of

synthetic diets for studies with dogs. In 1920 Karr³ reported work with dogs in which diets similar to the old German ones were used. His diet no. 1 was made by mixing the following, in terms of grams: Casein, 6.3; sucrose, 4.5; lard, 4.1; bone ash, 0.4; salt mixture, 0.2; and water, 2.5. This was the amount fed per kilogram of live weight; it furnished about 0.8 g. of N and 80 Calories. Various proteins were substituted for the casein. Karr used yeast, milk, and other supplements to supply vitamins. The salt mixture used by Karr contained: sodium chloride, 10 g.; calcium lactate, 4 g.; magnesium citrate, 4 g.; ferric citrate, 1 g.; and a few drops of iodine in potassium iodide solution. This salt mixture lacks potassium. Bone ash contains about 0.3 per cent of K. Therefore, his dogs must have existed on about 1 mg. of this element per kg. of live weight per day, except for that furnished as a contaminant in vitamin supplements.

Such salt mixtures continued in use at Yale until at least 1926. In the study of Williams⁴ reported in 1927, the bone ash was removed from the diet and the Karr mixture used. The potassium was therefore very low. Until 1926 Cowgill⁵ likewise ran many excellent feeding studies with these diets very low in this element. All of these results accidentally indicate that the dog can live for long periods upon synthetic diets containing very little potassium.

For many types of studies to evaluate proteins, fats, and inorganic elements as well as vitamins, the feeding of synthetic diets is an essential procedure. The great danger is that the diet may be incomplete. Thus additional variables enter the study and may confuse the results.

Analysis of Tissues

For the most part, the analysis of tissues of the body of the dog serves only limited purposes in developing better diets. Blood analyses, such as the determination of hemoglobin or the counting of the red cells, help in detecting certain anemias. For this purpose blood samples are easily taken from the ear vein of the dog. The methods are simple and the special pipets inexpensive if a colorimeter or microscope are available.

Some analyses involve larger samples of blood. These can be taken from the jugular vein without injury to the animal. If very large samples are required, they may be drawn directly from the ventricle of the heart.

At times, experimental dogs must be sacrificed for the study of tissues. By the use of liver samples and the simple colorimetric test for vitamin A with antimony trichloride, a worker with modest training in chemistry can determine roughly the amount of vitamin A that has been stored in the liver. This in turn may tell whether the diet is providing this vitamin in suitable amounts.

Due to the great progress that has been made in the microdetermination of vitamins, the analyses of many tissues will probably become of great importance in evaluating borderline deficiencies. The chief skill needed for such assays today is that of the bacteriologist, since the methods depend upon the growth of micro-organisms in many cases. In others, microchemical analyses are used.

In time, the biopsy method will undoubtedly find a use with dogs. This method consists of cutting a small piece of muscle from the living animal. The pain is slight, and there is no permanent injury. Such samples can be used for analysis.

The Rate of Digestion and Movement of Foods

When dogs must be sacrificed for some reason, they can, without suffering, render a last service to man and his pets. A dog dies very quickly and painlessly if 1 or 2 cc. of chloroform are injected into the jugular vein. Test meals of known weight and composition can be fed at definite periods before death. Immediately after death the lower end of the esophagus and various segments of the intestine can be tied off with pieces of string. The contents of these different portions can then be washed out into evaporating dishes or pans and dried. If they need to be preserved for some days, alcohol is added as soon as the contents are removed. Feed samples must be taken and dried under the same conditions.

Typical data from experiments in which the contents of the stomach and intestine in dry matter were determined were the following:

DOG	AMOUNT OF TEST	TIME AFTER	CONTENT IN PER CENT	
	MEAL IN GRAMS (Dry Basis)	FEEDING (Hrs.)	OF TEST MEAL <i>Intestine</i>	<i>Stomach</i>
Jock (Cairn)	74.5	3	17	79
Whiffy (Springer)	74.5	6	28	32
Gray (Cairn-Scotty)	140	6.5	16	52
Nig (Cairn-Scotty)	140	7.5	14	10
Bonnie (Cairn-Scotty)	140	8.5	16	5

In these trials a simple test meal of wheat flakes and meat scrap (55 per cent) in equal parts by weight was used. Much can be learned by such simple methods about the rate of digestion and absorption of foodstuffs. Chemical analysis of the residues will give a more complete picture of the rate of absorption of the components of the food.

As time passes, much of the blind sentiment that now expresses itself in endowments for pet cemeteries and anti-vivisection movements will doubtless provide for research directed to keeping pets in good health until they die of a ripe old age. Such research will doubtless make use of many techniques now employed in the physiological laboratory. The results will mean advances in the field of nutrition and the sciences that underlie it. Man as well as his pets will profit by such labors.

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CHAPTER X

PRACTICAL FEEDING AND MANAGEMENT OF DOGS

Feeding Puppies

TO THE average person who has not grown up with animals the rearing of a puppy seems, at first thought, a great burden. After the project is undertaken, however, the adaptability of the average healthy puppy is so great that the composition of his diet is liable to be neglected. The puppy is usually hungry and willing to eat everything offered, in addition to lace curtains, fur lined gloves, and bedroom slippers.

The best diet for a puppy is a well-designed dry feed supplemented with milk. This can be fed at weaning time. Once or twice per week the puppy should have a little cod-liver oil and some cheap organ meat such as boiled pig liver. Special puppy feeds or milks are not needed. Evaporated milk is usually cheapest.

The chief trouble in the development of young puppies is usually caused by round worms. No matter how well they are fed, they will not develop properly if burdened with these parasites. If a puppy is badly infested with round worms, it usually appears "pot bellied" from about the tenth day after birth. The coat will appear thin and rough. The survival of such puppies is helped by feeding them each day a few drops of cod liver oil from a medicine dropper.

The deworming of such puppies can take place in the third week of life, even before they are eating solid food, but this is not advisable if the puppies start eating normally at the end of about three weeks. In the course of seven years we have never lost a puppy in the process of deworming with ethylene tetrachloride. The general practice has been to remove puppies from their mother and keep them in a warm room overnight without food. The next morning they are given a

capsule containing the minimum recommended dose. For the terrier breeds this is 0.2 cc. Care must be taken to see that the capsule is not thrown up. The puppies should be separated by placing them in a partitioned box with newspaper on the floor. If the puppies are kept in a group, the one that loses its medicine cannot be determined.

A couple of hours after giving the capsule, the puppies are fed some Epsom salts dissolved in warm skim milk. By mid-afternoon

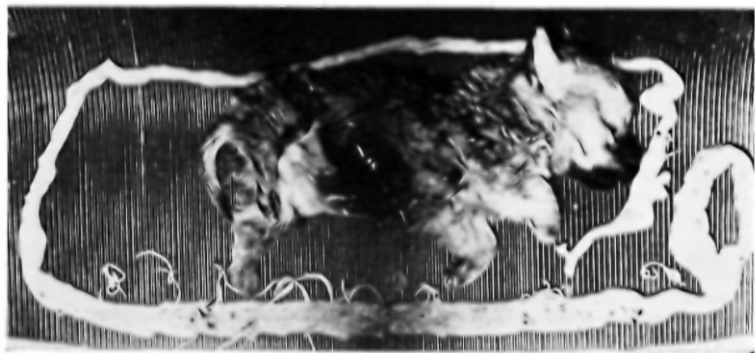


FIG. 11. *The intestinal tract of a puppy showing the location of round worms.*

they can usually be returned to the mother, although dead round worms may not be passed until several hours later. Within a couple of weeks this treatment can be repeated with safety. Within a few days there is usually a marked change in the puppies.

Puppies need to be fed three to five times a day when they are very young. The larger number of feedings is usually preferred, but we have reared very good puppies with only two feedings a day. Puppies should always be so hungry that they clean their dish rapidly. The period of greatest food consumption corresponds to that of the most rapid growth, that is, from the fourth week to about the sixth month of age.

More than a million puppies mature in America each year. Nevertheless, little is known about the comparative growth rates of the different breeds. The average puppy attains about half of its growth during the first three months of life. Within six months it reaches

about two thirds of its adult weight. Three typical growth curves for Cairn Terriers are shown in the graph. The two curves represent females of extreme sizes for this breed. Only the top curve would fit the requirements for this breed.

Such curves are useful for comparing performance on given diets.

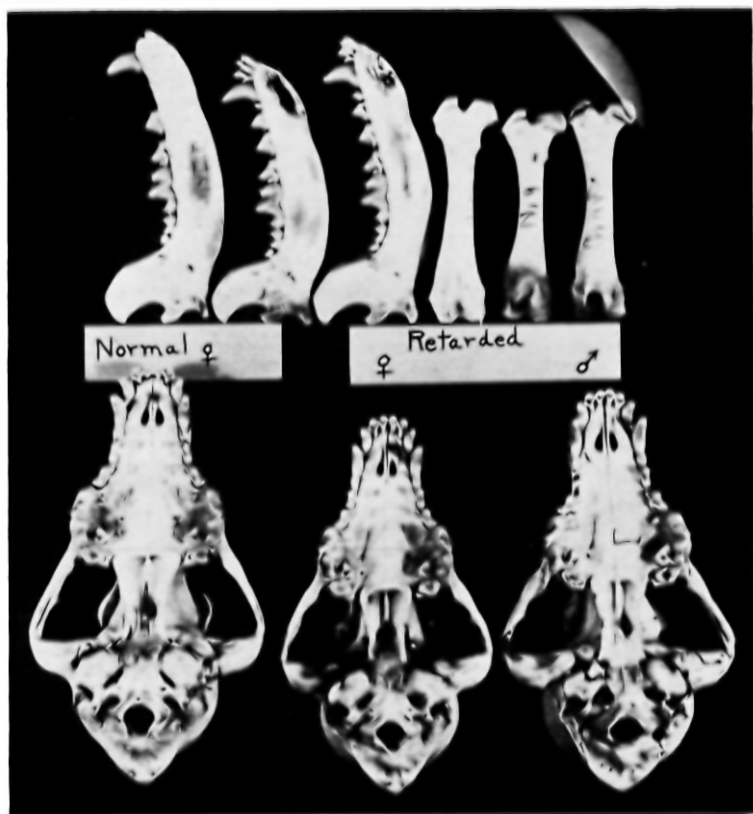


FIG. 12. *The retardation of the growth of a dog by a diet low in calories produces an adult with a smaller skeleton.*

For example, three females reared upon a vegetarian diet by the author grew at the same rate as the larger female of this same breed.

Puppies can be severely retarded in growth by feeding a diet rich in minerals, protein, and vitamins in such small amounts that increase in body weight occurs very slowly. Such puppies remain very

thin. Their skeletons slowly increase in size. When they are allowed all the food needed, however, growth is resumed, but they never attain the same body size as normal dogs of the same breed. They tend to be about 10 per cent smaller. Diets like the above may ultimately prove useful in reducing the ultimate size of specific types that tend to become too large. Dogs whose growth is retarded by a reduced diet retain the carefree attitude of puppies, because they are always



FIG. 13. *Female litter mates. "Nig" on the right was retarded in growth by a low calory diet. She remained in good health and high spirits.*

hoping that a square meal is an event of the near future. They are fully as resistant to disease as normal puppies and may be superior in this respect.

Feeding during Lactation

The female dog should have a good diet during the gestation period, which lasts about two months. Most of the materials of the developing puppies are built into their bodies during the last three weeks before birth. The bitch should be fed all she wishes during this period. After the puppies are born, the feeding should be moderate for the first three days, since no great amount of milk is consumed by the pups during this early stage of lactation.

During gestation the female may actually store nitrogen in her own tissues as well as provide it for the development of the puppies. The storage of nitrogen seems most marked during the late weeks of gestation (Marshall, 1922).¹

The composition of dog's milk has seldom been determined with attention to both the diet and the completeness of milking. Hohlfeld analyzed the milk of a Dachshund, and Daggs² has provided recent values for the composition of the milk of the Boston Bull Terrier. Hohlfeld's and Daggs' analyses are presented in the following table:

Constituent	<i>Dog Milk</i> (Hohlfeld) %	<i>Dog Milk</i> (Daggs) %	<i>Evaporated</i> <i>Milk</i> (Cow) %
Fat	9.7-13.4	10.7-13.2	6.7
Total solids		21.5-29.2	
Ash	0.9-1.1	1.0-1.6	1.5
Proteins	5.4-10.0	6.3-9.7	6.7
Casein	0.5-0.9	4.0-7.0	
Albumin		1.5-2.1	
Lactose	2.8-3.5	2.8-3.8	10.1

In four cases Daggs was able to milk out from 865 to 2159 cc. per week during the 5th week of lactation. At most, this yield of milk amounted to about 300 cc., or less than a third of a quart, per day.

In comparing liver, kidney, and eggs as sources of protein during lactation, Daggs concluded that liver had something that stimulated the secretion of milk and maintained its composition. This accords with some earlier observations that meat stimulated the dog's secretion of milk.

The volume of milk secreted by different breeds of dogs is unknown. Gerhartz³ made careful studies on four litters of fox terriers to evaluate milk secretion. He found that the growth rates were very uniform from birth until 99 days of age, when the puppies had attained a weight of 3 kg. To increase the body weight of the puppy by one gram, he found 1.4 to 6.0 calories were needed. His mean values were 3.2 and 4.4 calories in two cases.

Gerhartz suggests a technique for measuring milk secretion in the bitch that seems very promising. The pups are separated from the mother, for a period of six hours. They are weighed carefully at the beginning and end of the period. They lose weight because they get no food and are excreting urine, feces and respired air. When this

body loss is multiplied by eight it gives an estimate of the total excreta for 48 hours. Forty-two hours after the pups are returned to the mother they are weighed again. They will now have gained from drinking milk and growing. If the weight of the excreta for forty-eight hours is added to the increase in the weight of the body for the same period, one gets the weight of milk consumed because the pups have had no other source of food or water than the milk of the bitch. Such experiments must be done before the pups start to eat and drink part of the mother's food and water.

Few determinations have been made of the calcium in dog's milk. Dibbelt ⁴ found 0.19 g. of CaO per 100 cc., while von Bunge ⁵ had found a much higher value.

Von Bunge compared the ash found in a kilogram of dog milk with that in the body of a newly born pup per kilogram of weight. The following table gives his determinations in grams per kg.

	<i>Pup</i>	<i>Milk</i>
K ₂ O	2.55	1.70
Na ₂ O	2.38	1.00
CaO	6.60	3.09
MgO	0.41	0.17
Fe ₂ O ₃	0.16	0.001
P ₂ O ₅	8.82	3.89
Cl	1.87	1.92

The vitamins in dog's milk have been given little attention. Williams and others ⁶ studied the B vitamins in a single sample of milk from an English Bull Terrier. The values, in comparison with those found in cow's milk, were the following:

	<i>B₁</i>	<i>Ribo- flavin</i>	<i>Niacin</i>	<i>Panto- thenic Acid</i>	<i>Pyri- doxin</i>	<i>Biotin</i>	<i>Inosi- tol</i>	<i>Folic Acid</i>
Dog	0.05	3.0	6.8	4.9	0.08	0.12	440	0.46
Cow	0.44	0.95	0.66	2.9	0.06	0.05	180	0.05

All values, except for folic acid, in micrograms per ml. (γ/ml.)

Since kennel owners may wish to improve the feed of lactating animals, the following abbreviated table from Williams ⁶ may be useful:

<i>Vitamin</i>	<i>Good Source</i>	<i>Poor Source</i>
Thiamin (B ₁)	Pork, green vegetables, tomatoes, grapefruit, wheat germ	Processed cereals, milk, beef muscle
Riboflavin	Organ meats, milk, eggs, leafy vegetables	Cereals, non-leafy vegetables
Niacin	Mushrooms, meat, whole wheat	Processed cereals, milk, eggs
Pantothenic Acid	Organ meats, many fresh vegetables	Processed cereals, cheese, raisins
Pyridoxin	Fresh vegetables	Processed cereals, milk, eggs
Biotin	Organ meats, fresh vegetables, dairy products, sea foods	Cereals, raisins
Inositol	Vegetables, heart, brain, wheat germ	Processed cereals, beef, muscle, fish
Folic Acid	Green vegetables, wheat germ	Milk and lean meat

Sanitation in Dog Kennels

Cleanliness, good nutrition, sunshine, and exercise are the best methods of preventing diseases in dogs.

To keep pens clean, the author has followed the practice of turning all dogs loose twice daily at the time of feeding. The dogs are taken over trails through the woods, and most of them excrete during this period. As a result, the puppies tend to form regular habits of excretion and are easier to housebreak later. After this run twice daily, the dogs are fed.

The old question of the number of times to feed dogs each day remains unsettled. Many kennels operate without trouble under a system of feeding only once.

In summer, the author's dogs are housed outdoors in an old orchard that affords shade. Pens are built in sections that hook together. These can be moved to new areas at periods of a week or two. For puppies a special pen of light construction is used, so that it can be moved more frequently.

For watering dogs, earthenware crocks are used in summer, and metal pans in winter. Feed pans in unheated kennels are washed only once a week during the winter; in summer they must be washed more often. The feed pans are held in simple wooden holders having holes to fit the pans.

The dog houses used by the author are simply constructed, with a hinged top and tarpaper roof. The roofing is covered with galvanized wire so that the dogs can lie on the roofs. The same houses are moved into an unheated barn for winter quarters. They are sprayed with kerosene, washed with hot soap and water, and dried in the sunshine twice yearly.

The secret of controlling all parasites is to exterminate them as soon as discovered. This is especially true of lice, ticks, and fleas. The author has followed the practice of clipping all long-haired breeding stock late in the month of May. This practice has undoubtedly kept down lice and fleas.

To keep them clean and dry, the indoor winter kennels are covered with straw once weekly, and the floor under the straw is given a coat of dry lime at each cleaning.

It is important that dogs be provided with some shade during the summer. Puppies in closed houses may be lost during a hot spell if the dog house is the only source of shade.

At the time new litters arrive the dog house is usually given a special cleaning, and a clean cloth sack tacked to the floor. Even with the best of intentions, this sack is frequently scratched out of place by the female expecting the arrival of the litter. In a few cases, puppies have been born in the open and thoroughly chilled. Some have been saved by returning them to the mother, even though they seemed dead. As a rule, whelping takes place without trouble. Except to make sure there is no trouble, the kennel master will usually do best to keep well out of sight. For the most part, the bitch requires little attention for the first four days after whelping, except for the provision of adequate water and a modest amount of food. After the first four days she is usually willing to leave her puppies for brief periods.

The time for weaning is usually revealed by the mother after the third or fourth week, when she grows weary of the constant demands of the pups for milk. As a result, she nips the puppies from time to time in order to get some rest. During the fourth week she can be separated from the pups during the daytime. As soon as the puppies

learn to eat and drink well, the separation can be permanent. If the milk supply of the mother fails during the third week, it is usually possible to teach the young to drink. However, this rarely happens.

The Energy Requirements of the Dog

Many maintenance studies indicate that the dog needs 70 to 80 calories per kilogram of body weight per day. Most of these studies have been made with dogs weighing about 7 kilograms, or 15 pounds. They have also been made with dogs in cages, where they are relatively quiet. A working dog naturally needs much more energy than this. The need must also differ considerably for the dog that must remain outside in cold weather in comparison with the dog in a heated house. These are all individual variations that are difficult to evaluate, since it is hard to measure the energy consumed by a dog in a day of hunting.

One factor that can be calculated in dog feeds is that of utilization. With a few exceptions, most of the dry dog feeds on the market are relatively low in fat. The available energy from the feeds can be estimated if the digestibility and absorption are known. In the course of about thirty balance experiments in which dogs were fed carefully weighed allotments of feed and the feces carefully preserved, it was found that the average dry feed sold in New York today has a utilization value of between 70 and 80 per cent. In other words, the dog excretes in its feces 20 to 30 per cent of the dry matter of the feed. In occasional instances this may even increase to as much as 40 per cent.

The residue that appears in the feces originates for the most part in the feed, since a meat diet may give a residue so small that a dog will defecate only once or twice per week. Most of the cellulose of a feed is excreted. Part of the protein passes through the dog unutilized. Ash constituents must, in a mature dog, be excreted. Usually, the diet is low in fat, and so are the feces. Upon a diet containing 10 per cent or more of fat, the fecal fat increases.

In most of the better known dry feeds the protein utilization varies between 70 and 80 per cent. The fats are usually low and more than 90 per cent utilized. The starches, which usually originate from cereals such as breakfast foods, are more than 90 per cent digested and

absorbed. This becomes an important item, since products such as corn flakes contain 55 to 65 per cent of starch. The usual dry dog feed also contains 5 to 10 per cent of moisture. This must be accounted for in any calculations concerning energy value.

Water Is Important

The water is an item of great importance in estimating the nutritive value of most canned feeds. If a canned product contains 75 per cent of moisture, this figure can be divided by four to get it to a dry basis. For example, a pound of canned feed with such a moisture content may contain one-fourth of a pound of dry feed. This is very important when estimating the relative amounts of dry feeds and canned feeds to satisfy the energy requirements of a dog. If a canned feed is mostly meat, no correction need be made for utilization, since it may be assumed to be quite completely digested and absorbed. On the other hand, if it contains large amounts of cereal, some correction similar to that for dry feeds, will need to be applied.

Calculating the Value of a Ration

For purposes of calculation, the following energy values are commonly used: protein, 4.3, carbohydrate, 4.2, and fat, 9.5 calories per gram. For the usual dry feed a simple method to determine the calories in a pound of feed is the following: 1 pound equals 453 grams. Since 75 per cent of the dry feed can be utilized by the dog, we have 75 per cent of 453, which equals 340 grams of nutrients. Since the usual dog feed has little fat, this value can be multiplied by 4.2, which equals 1438 available calories from a pound of the dry feed. If a dog weighs 15 pounds, which is approximately 7 kilograms, and if it needs 80 calories per kilogram, it will require every day 560 calories. Therefore, a pound of this feed will be sufficient for about three days of feeding.

Another method of calculation from the chemical analysis of the feed is the following: Assume that the ingredients are utilized as follows—protein, 75 per cent; fat and carbohydrate, 95 per cent. Assume the analysis of the feed is the following, which represents one that is on the market: water, 7; fat, 9; fiber, 3; protein, 24; carbohy-

drates, 42; ash, 15. The calories from the protein are $0.75 \times 24 \times 4.3 = 77$. From fat they are $0.95 \times 9 \times 9.5 = 81$. From carbohydrate they are $0.95 \times 42 \times 4.2 = 168$. These three values of 77, 81, and 168 added together give a value of 326 calories per 100 grams of feed, or (multiplying by 4.53) 1477 calories per pound.

The same calculations can be used for canned meat, except that it is probably more nearly right to assume complete utilization of the protein. At best, all of these are estimates, for the reasons previously given.

The maintenance of dogs under conditions of different amounts of work has been given little study from the viewpoint of the hunter and the feeding of his dogs. To measure the increase in energy requirements, physiologists have usually had dogs run in tread mills for limited periods of time. These measurements do not help much to define the needs of the racing or hunting dog.

There has been some prejudice in favor of feeding diets containing more meat while a dog is exercising severely. This is probably a reflection of the need for more vitamin B₁ rather than for more meat or even more protein. In Japan, Takeda⁷ reared puppies upon a mixture of half-polished rice, 200 g.; sweet potato, 150 g.; and fermented bean paste, 20 g. This provided a diet low in protein. For a protein-rich diet, he used half polished rice, 250 g.; horse meat, 250 g.; and fermented bean paste, 20 g. When these dogs were grown, they were used for exercise studies after 22–23 hours of fasting. Periods of exercise varied from a quarter hour to two hours, and in some cases until the dogs were exhausted. This author favored the mixed diet low in protein. He concluded that the diet rich in meat was the poorer.

Some years ago a table by Dechambre appeared,⁸ in which an attempt was made to relate the work to food needs. The evidence behind this table is questionable, but it has served some kennel owners as a rough guide. Dechambre gives the following data:

BODY WEIGHT IN KG.	FOOD NEEDED IN GRAMS OF DRY MATTER		
	<i>Rest</i>	<i>Moderate work</i>	<i>Heavy work</i>
5	130	170	217
10	214	286	360
15	270	340	420

Cowgill⁹ studied the variation in the energy requirements of dogs of different weights. In one case, for a dog weighing 5.82 kilograms, his values ranged from 68 to 83 calories per kilogram per day, with an average value of 78. In three other dogs of different sizes he found the following:

<i>Weight of dog in kilograms</i>	<i>Range of values in calories per kilogram</i>
3.4	99.3 to 91.9
5.8 to 6.4	77.4 to 78.1
15	65.4 to 65.6

In a study of twelve dogs of different weights Cowgill found the following values:

<i>Body weight in kilograms</i>	<i>Calories per day</i>	<i>Calories per kilogram per day</i>	<i>Calories per hour per square meter of body surface</i>
3.4	338	99.2	55.6
4.3	454	105.0	64.0
4.4	437	99.0	60.5
5.0	439	87.0	55.6
5.4	581	107.5	70.2
5.8	455	78.1	52.5
7.9	620	78.1	57.9
8.6	883	103.0	78.5
12.0	851	71.9	61.3
13.5	1,058	78.4	69.5
14.9	974	65.4	59.5
15.4	948	61.6	56.4

These values show the general trend of decreased calorie requirement per unit of body weight as a dog becomes larger. It also shows some of the variability that can be expected among individuals. The diets used in these determinations contained tallow. As a whole, it seems to have been well utilized, but there was probably some variation in the ability of individuals to digest and absorb this high melting fat.

Home Remedies

Under good conditions dogs are seldom sick. For minor accidents such as an infected eye, every dog owner needs to apply boric acid as he would to himself. Some good general text such as that by Gar-

butt ¹² is very useful. When a good dog is really injured or sick it deserves the attention of the skilled veterinarian.

Distemper is the worst enemy of many dog owners. The author has always attempted to keep his kennel well out of the path of exposure. At the same time he has had his dogs immunized when six months old. As a result no case of distemper has developed.

One of the best barometers of the condition of a dog is the character of the feces. Either constipation or diarrhea for any considerable number of days indicates trouble. The condition should be treated and the composition of the diet checked.

Skin diseases are one of the greatest sources of trouble to most dog owners. Many attempts have been made to relate them to diet, but no one has done so. The nutrition worker would have a means of approach to these problems if he could produce these skin diseases at will. The author has had such experiences as the following: Dogs were divided into four experimental groups with widely different diets. One dog in each group developed severe skin troubles, with the loss of much hair. The experiments continued for six months and no other dogs were affected in each of the groups. If diet were the primary cause, the other members of the groups should have developed the trouble, but they did not.

In general, at least in the Cairn Terrier breed, dogs that overeat and become very fat tend to develop skin diseases. The loss of hair is also liable to become severe toward the end of gestation and during the period of lactation. Usually, the trouble disappears after the pups are weaned. In cases in which the loss of hair develops, or the hair is pulled out making the skin moist and raw, the trouble will usually disappear in a few days if the dog is placed upon a diet consisting only of a limited amount of milk. This has been observed in a considerable number of cases with Cairn Terriers but the author has not tried other breeds.

The dog owner is often illogical in trying to relate skin diseases to diet. Once the author observed a litter of well-grown French Bulldogs which had all suffered severe loss of hair. The owner was asked if she fed the meal manufactured by A, which was known to be a complete mixture. She replied that she did not, because she had heard

that this mixture produced skin disease in dogs, and that the product of B, which she was using, did not.

Shipping Dogs

The author has shipped dogs from New York to both Florida and California, as well as to closer points, without a single loss. Various

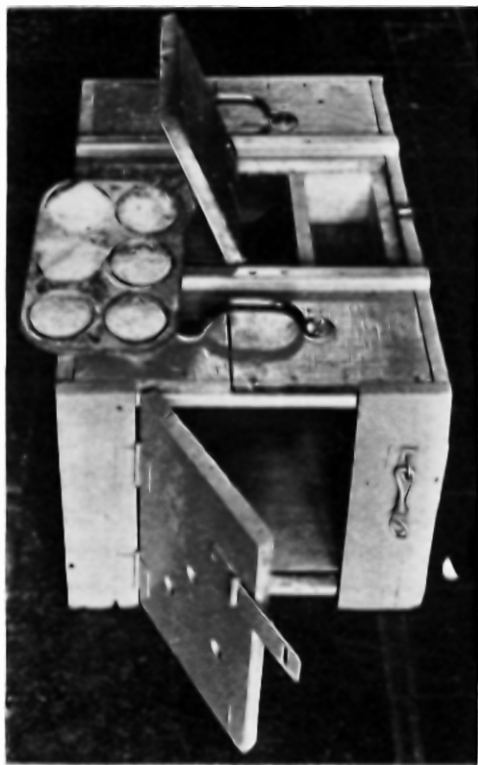


FIG. 14. *Convenient shipping box with the feed opening at the top. Adjoining is the feed storage box. Note the muffin tin containing frozen feed and ice to start the trip.*

shipping crates have been used. The homemade one shown in the illustration is very satisfactory. As a container for an initial supply of feed and water, a simple muffin tin has proved useful. Three of the cups can be filled with moist feed and three with water, and the contents then frozen hard. They tend to melt as the journey progresses,

and even if no additional feed and water were provided, the dog would, under these conditions, stand a journey of five days without trouble. Sled-dog owners in the Far North have told the author that they leave their dogs chained without food or water for periods as long as ten days. Under normal conditions, however, dogs are fed and watered carefully while in transit.

Dog Breeding

The physiology of reproduction in the dog has been reviewed by Marshall ¹⁰ and also by Evans and Cole.¹¹ Dogs usually come in "heat" twice a year. The cycle may be as short as four months and as long as eleven. The length of the period of heat varies from two to three weeks, with an average of eighteen days. The female can usually be bred only during the latter half of this period. A period of nine weeks elapses from the time of breeding until the pups are born, but the time may vary by several days.

The beginner in the breeding of dogs should have someone who has had experience select his stock very carefully. Good stock is worth its price if large numbers of puppies are to be produced and sold. In no field is the evidence of inheritance more marked. The characters of the puppies reflect not only the bodies, but also the temperament, of the sire and dam. Good breeding and careful selection of stock are important combinations, along with good nutrition, to produce a first-class product.

The greatest satisfaction of the dog breeder is the constantly growing list of friends whom he supplies with well-bred and healthy pets.

Dog Books

Every dog owner will enjoy a small library. Some interesting works, in addition to those listed elsewhere, are: *The Complete Dog Book of the American Kennel Club* and *Training the Dog*, by Judy. The library of the American Kennel Club is one of the pleasant places in New York City for studying about dogs. Most good second hand shops carry a shelf of dog books. Some of the older works, such as Stonehenge's *The Dog* (1879) are worth careful reading.

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Dear, dumb, intelligent, little friend,
Your life too is made up of pleasure, and pain—
Of happiness and sorrow the same as ours.
For you (alert, adventurous and always ready
 for what may happen next)
The past can hold but few regrets—
The future fewer fears.
For you live in the ever present now.
Your body may grow old—
Your little mind grow feeble
And both disintegrate,
But you will never be deprived of the pleasure
 of being a Dog.

DR. C. F. SAYLES
Miami, Florida

AUTHOR INDEX

- Allers, W. D., 40, 52
 Alvarez, W. C., 36, 38
 Anderson, H. D., 79, 83
 Arnold, A., 37, 62, 80, 81
 Aron, H., 46, 53
 Axelrod, A. E., 76, 82

 Bateman, W. G., 33, 37
 Beazell, J. M., 9, 16
 Bennett, H. B., 53
 Beraz, H., 46, 53
 Bering, V., 81
 Bernard, C., 8, 16
 Bernard, R., 99, 105
 Berryman, G., 104, 105
 Bills, C. E., 66
 Birch, T. W., 74, 82
 Bischoff, E., 10, 63, 81
 Black, H. C., 80
 Blackstock, M. R., 82
 Block, S., 83
 Boas, M. A., 34, 38
 Bradfield, D., 80
 Brand, E., 89, 98
 Branion, C. B., 81
 Brinkhaus, K. M., 79, 83
 Bunge, G. von, 123, 133
 Bussabarger, R. A., 49, 53
 Busson, A., 80

 Cahill, G. F., 98
 Cajori, F. A., 15, 16
 Cannon, W. M., 18, 24
 Carlin, G. T., 80
 Chambers, W. H., 15, 16
 Cheldelin, V. H., 133
 Chick, H., 65
 Chittenden, R. H., 35, 38, 73, 75
 Cole, H. H., 132, 133
 Collazo, J. A., 60, 81
 Cowgill, G. R., 33, 35, 37, 58, 76, 80, 82,
 83, 115, 117, 129, 133

 Crandall, L. A., 40, 52
 Crim, P. D., 80

 Daft, F. S., 82
 Daggs, R. G., 122, 133
 Dechambre, 128, 133
 Deuel, H., 15, 16
 Deutech, H., 81
 Dibbelt, W., 50, 53
 Dillman, L. M., 81
 Dinkel, J. H., 98
 Dinks, M., 14, 16
 Donders, F. C., 12

 Evelhjem, C. A., 6, 59, 61, 62, 74, 80, 81
 Escher, T., 27, 28, 37
 Etzinger, J., 49, 53
 Evans, H. M., 132, 133

 Farmer, C. J., 70, 81
 Findlay, L. D., 47, 53
 Fine, M. S., 32, 37
 Forster, J., 5, 6, 40, 52
 Fouts, P. J., 82, 83
 Frank, O., 19, 23, 24
 Fraser, H. F., 82
 Freeman, A. S., 53
 Freeman, S., 70, 81
 French, R. B., 35, 38
 Fritz, J. C., 67, 81
 Fröhring, W. O., 57, 80

 Garbutt, R. J., 130, 133
 Gerard, P., 52
 Gerhartz, H., 122, 133
 Gies, Wm. J., 53
 Gmelin, L., 19, 24
 Goldberger, J., 74, 75, 82
 Gonce, J. E., 83
 Gottberg, K. V., 81
 Graaf, Regnier de, 32
 Green, D. F., 98

- Greenberg, D. M., 45, 52
 Gyorgy, P., 82
- Hafner, F. H., 37
 Halpin, J. L., 81
 Halstead, 41
 Harris, L. J., 82
 Hart, E. B., 80
 Harvey, H. I., 75, 82
 Hawk, P. B., 22, 24
 Hayward, J. W., 32, 37
 Heath, M. K., 82
 Heller, V. G., 52
 Helmer, O. M., 82, 83
 Herrin, R. C., 55, 80
 Hermann, F., 28
 Herrin, R. C., 55, 80
 Hoesslin, H. von, 114, 117
 Hoffman, F., 23, 24
 Hofmeister, F., 12, 16
 Hoobler, S. W., 45, 52
 Hooper, J. H., 81
 Hopkins, F. G., 65, 67
 Hunt, J. H., 82
- Innes, J. R. M., 77, 83
 Ivy, A. C., 53, 104, 105
- James, W. T., 22, 24, 93
 Jones, J. H., 48, 53
 Judy, W., 132
 Jukes, T. H., 82
- Karr, W. G., 52, 58, 80, 115
 Kassel, B., 98
 Kaufmann, M., 29, 37
 Kay, H. D., 81
 Klein, D., 70, 81
 Klein, R. I., 81
 Koehn, C. J., 32, 35, 37, 91, 98
 Kogl, F., 34, 38
 Kranke, E. H., 81
 Krauss, E., 13, 16
 Kruse, H. D., 52
- Lebedef, A., 21, 24
 Leder, L., 31, 37
 Lelu, P., 33, 37
 Lenhart, C. H., 41, 52
 Lepkovsky, S., 82, 83
- Levinson, J. S., 59, 80
 Lewis, R. C., 31, 33, 37
 Light, R. F., 60, 80
 Ling, S. M., 18, 24
 Lintzel, W., 43, 52
 Lipschutz, A., 47, 53
 Lipton, M. A., 82
 Loewi, O., 37
 Lothrop, A. P., 49, 53
 Lusk, G., 15
- McCance, R. A., 52
 McCay, C. M., 23, 24
 McCollum, E. V., 52, 65, 67
 McKibben, J. M., 76, 83
 MacQueen, J. W., 82
 Madden, R. J., 6
 Magendie, F., 5, 10, 16, 26, 27, 37, 54, 80
 Maly, R., 36, 38
 Mann, F. C., 13, 16
 Marshall, F. H., 121, 132, 133
 Massengale, O. N., 66
 Maynard, L. A., 105
 Mellanby, E., 47, 51, 53, 55, 65, 71, 80, 82
 Mellanby, M., 71, 72, 82
 Melville, 2
 Melnick, D., 33, 37
 Mendel, L. B., 31, 32, 33, 37, 65, 74, 82
 Meyer, G., 11, 16
 Mitchell, H. K., 133
 Miwa, S., 46, 53
 Morgan, A. F., 48, 49, 53, 62, 77, 83
 Morris, M. L., 89, 96, 98
 Munilla, A., 81
 Munk, I., 13, 16, 24, 30, 36, 37
- Nelson, E. M., 80
 Nicholes, H. J., 80
 Nussmeier, M., 66
- Onstott, R. H., 82
- Panum, P. L., 12
 Papillon, M. F., 44, 52
 Papin, D., 27, 37
 Park, P. G., 65
 Parsons, Helen, 34, 37
 Paton, Noel, 53
 Patton, J. W., 14, 16
 Pavlov, J. P., 2, 6

- Persons, E. L., 75, 82
Pfluger, E., 8, 15, 16, 21
Pomarang, M. M., 105
Prout, Wm., 10
- Radeff, T., 52
Radziejewski, S., 20, 24
Reed, C. I., 70, 71, 81
Rice, E. E., 29, 37, 56, 80
Rieder, H., 12, 16
Robinson, H. E., 80
Robscheit-Robbins, F. S., 6
Rockwood, E. W., 31, 37
Roloff, F., 46, 53, 63, 81
Rose, S. B., 80
Rose, W. B., 80
Rose, W. C., 29, 37
Roseboom, B. B., 14, 16
Rosenberg, H. R., 67, 81
Rosenheim, L., 13, 16
Rosenheim, T. H., 58, 80
Ruigh, W. L., 66, 81
Russel, W. C., 70, 81
- Schaefer, A. E., 77, 83
Schaible, P. J., 40, 52
Schlotthauer, C. F., 104, 105
Schmorl, G., 48, 53
Schoenheimer, R. H., 81
Sebauer, R., 46, 53
Sebrell, W. H., 76, 82
Sharpe, J. S., 53
Shipley, 65
Shohl, A. T., 48, 53
Short, D. M., 80
Simonnet, H., 80
Smith, D. T., 75, 82
Smith, M. C., 80
Smith, S. E., 25, 36, 101, 104, 105
- Spies, T. D., 82
Steck, I. E., 62, 81
Steel, M., 49, 53
Steenboch, H., 80
Stockard, C. R., 89, 98
Stoeltzner, W., 46, 53
Stonehenge, 132
Street, H. R., 76, 82, 83
Strong, F. M., 6
Struck, H. D., 81
- Takeda, E., 128, 133
Taylor, N. B., 81
Thacker, E. A., 81
Thomas, K., 20, 24
Tiedemann, F., 19, 24
Toverud, K. V., 51, 53
Tufts, E. V., 45, 52
- Underhill, F. P., 73, 74, 75, 82
- Verdeil, F., 42, 52
Voit, C. von, 10, 21, 23, 114, 117
Voit, E., 46, 53
- Warner, E. D., 79, 83
Welch, J. W., 81
Weld, C. B., 81
Wells, J. A., 104, 105
Werch, S. C., 104, 105
Wheeler, G. A., 73, 82
Whipple, D., 23, 24, 80
Widdowson, E. M., 52
Williams, G. A., 115, 117
Williams, R. J., 123, 133
Wolf, C. G., 31, 37
Woolley, D. W., 6
- Zimmerman, H. M., 83

SUBJECT INDEX

- Alfalfa meal, 103
- Amino acids, 27
- Anaesthetics in rickets, 72
- Antioxydants, 23
- Appetite, thiamine effect, 58
- Asparagin not utilized, 36

- Balance, chemical technique, 109
- Basal metabolism, vitamin D in, 71
- Bernard discovers glycogen, 8
- Bile in fat digestion, 20
- Biopsy methods, 116
- Biotin, 34
- Bischoff and Voit, early studies, 10
- Biscuits, 92
- Black tongue, 5, 73, 75
- Blood, volume, 43
 - , sampling, 115
- Blood meal, 101
- Body fats, 20
- Books about dogs, 132
- Bone, ash, 50
 - digestion, 26, 49
 - meal, 104
- Bran, not utilized, 12
- Bread as food, 7, 10-12
- Breed differences, 89, 93
- Breeding, 132

- Calcium in the body, 46
 - in tissues, 71
 - utilization, 113
 - rickets, 46, 63
- Calculation of rations, 127
- Canned feeds, 92, 95-97
- Carbohydrates, historical use, 10
 - , utilization, 7
- Carotene absorption, 56
- Carrots as food, 57
- Cats, need for nicotinic acid, 75
- Cod liver oil, 103
 - , storage, 66
 - , lion feeding, 65
- Colostrum, rich in vit. A, 55
- Consumer protection, 98
- Corn flakes, 99
- Corn meal for sled dogs, 9
- Cottonseed meal, 32
- Crates, shipping, 131
- Cystinuria, 89

- Data sheets, metabolism, 112
- De Graaf's fistulae, 3
- Diets producing rickets, 72
- Diets, synthetic, 114
- Digestion, in vivo, 116
- Dog feeds, control of, 96
 - , evaluation, 96

- Eggs, 92
- Egg white, 33
- Energy needs, 126
- Enzymes, added to feeds, 104
- Equipment for dog studies, 107
- Excreta, preservation of, 109
- Exercise, food needed for, 128

- Fasting dogs, 22
- Fat, diets low in, 18
 - digestion, 17
 - in intestine, 19
 - in lymph, 19
 - , melting point, 23
 - , protein as source, 21
 - in stomach, 18, 24
- Fatty acid utilization, 21
- Feces, acid from bread feeding, 11
 - , composition of, 130
 - , modified by starch, 11
- Feeding times, daily, 119
- Feeds, home mixed, 91
 - , improved, 94
 - , formulas, 84, 86
- Fish meals, 103

- , raw, 35
- Forster describes thiamin deficiency, 5
- Gelatin, 5, 27
- Gestation, mineral balance, 51
- Gliadin, 33
- Glucose for working dogs, 8
- Glycogen, 8
- Growth, 108
 - curves, 110
 - retardation, 22
- Horse meat, 92
 - , composition, 104
- Houses, 108
- Human nutrition, 2
- Ingredients, 99
 - , mixing small amounts, 66
- Insulin discovery, 3
- Intestinal gases, 36
- Iodine, 41, 104
- Iron, 42
 - in gestation, 43
- Kibbled feeds, 92
- Kidney function and vitamin A, 55
- Lactation, feeding for, 121
 - , mineral balance, 51
- Lactase, 15
- Lactose, diarrhea from, 11
 - , utilization, 13, 15
- Lard, 17
- Lipstick dye for fat studies, 20
- Liver, blood formation from, 4
 - , low in A at birth, 55
 - meal, 100
- Low calory diets, 22
- Magendie, early studies, 5, 10, 54
- Magnesium, 44
 - , blood, 45
 - , milk, 45
- Maintenance requirements, 93
- Malt diastase in feeds, 9
- Manganese in feeds, 40
- Mange, 72
- Meat as feed, 26
 - , maintenance with, 30
- , meals, 100
- Milk, ash, 123
 - composition, 122
 - products, 101
 - secretion, 122
 - , vitamins in, 123
- Mineral balances, 51
 - requirements, 39
 - storage in body, 113
- Muscle paralysis, 79
- Nicotinic acid, 73
 - , discovery, 5
 - , requirement, 75
- Number of dogs in America, 2
- Palatability testing, 113
- Pancreatic secretion, 3
- Pantothenic acid, 77
- Parathyroids and vitamin D, 70
- Pectin, 103
- Pellets, 94
- Pen construction, 106
- Pflüger, carbohydrate feeding, 8
- Phosphorus, low diets, 47
 - , retention, 48
- Plant foods, 31
- Plant proteins, 31
- Potatoes as food, 7, 90
- Potassium, 40
 - , low diets, 115
- Preservation of vitamins, 56
- Protein, concentrates, 100
 - level, 35
 - , plant vs. animal, 30
 - , quality, 5, 27
 - , digestion rate, 31
 - utilization, 25, 126
- Prout praises milk as food, 10
- Puppy feeding, 118
- Purine metabolism, 89
- Putrefaction, 36
- Pyridoxin, 76
- Rachitogenic substances, 71
- Raw starch, 88
- Reproduction, Ca needs, 50
- Retarded growth, 120
- Riboflavin, 76
- Rickets, 61

- Rickets, history of, 46, 63, 65
 —, rapid growth, 72
 Round worms, 118
 Running fits, 60

 Salt, diets low in, 5
 — needs, 40, 41
 Sanitation in kennels, 124
 Scurvy, unknown in dogs, 54
 Skeleton in retarded growth, 120
 Skin disease, 130
 Soaps, digestion, 21
 Soy beans, 110
 Soy bean meal, 101
 —, protein, 32
 Starch digestion, 7
 Starch, raw vs. cooked, 9, 14
 — utilization, 12, 13, 99
 Sterol metabolism, 68
 Stomach, emptying time, 117
 Sugar feeding, 12
 Synthetic diets, 10, 115

 Teeth, effect of Ca low diets, 46
 —, vitamin D and, 72
 —, eruption and Ca, 50
 —, shedding time, 72
 Testing dog feeds, 106
 Tetany from low Mg diets, 44
 Thiamin, 58, 60
 Thiry fistula, 69
 Toasting cereals, 100
 Tomato pomace, 103

 Vegetarian diets, 84
 Vitamin, destruction in meats, 26
 — imbalance, 77
 — preservation, 94
 Vitamin A, black tongue, 75
 —, determination in liver, 116
 —, dog biscuits, 56
 —, dog foods, 55
 —, deafness, 55
 —, discovery, 54
 — needs, 57
 —, teeth and, 55
 —, sore eyes in pups, 54
 Vitamin B, 57
 Vitamin C, not essential, 77
 Vitamin D, 61
 — needs, 62
 —, destruction, 67
 —, toxicity, 62, 70
 Vitamin E, 78
 Vitamin E and carotene absorption, 56
 Vitamin K, 78
 Vivisection, 117

 Wheat flakes, 99
 Wheat germ, 102
 Whelping, preparation for, 125
 Whipple, studies on blood formation, 4

 Yeast, 101

 Zein, 32

TABLE OF THE COMPOSITION OF COMMON DOG FEED INGREDIENTS

	Protein	Fat	Fiber	Ash	Water	Calcium	Phospho- rus	Potas- sium	Sodium	Magne- sium	Iron	Sulfur	Chlorine	Manga- nese
Flaked wheat feed	15.2	3.9	3.8	3.6	4.2	0.03	0.43	0.44	0.04	0.11	0.005	0.18	0.06	
Toasted corn flakes	9.5	3.0	2.3	1.8	2.3									
Flaked corn feed	8.5	1.4	0.8	3.0	5.0									
Cheese rind	65.9	8.1	0.4	9.2	7.7	0.93	0.68	0.09	0.61	0.04	0.001	0.26	0.89	
Wheat germ	29.3	10.0	2.9	4.0	9.3	0.07	1.05	0.30	0.72	0.34		0.32	0.07	0.016
Tomato pulp	24.1	14.5	32.9	4.0	7.1									
Dried yeast	52.3	2.5	7.9	7.0	4.7	0.8	1.4	1.8	0.09	0.10		0.05		
Bone meal	6.8	1.7		81.0	3.8	32.6	15.2	0.18	0.52	0.85		0.40	0.09	0.001
White fish meal	64.5	6.0		22.0	5.6									0.004
Liver meal	66.7	13.4		5.6	7.0	0.04	0.73				0.02			0.0004
Dried skimmed milk	33.8	1.0		7.6	6.5	1.3	1.0	2.54	0.49	0.15		0.35	0.95	0.00006
Beef scrap	64.7	8.9		17.5	6.9									0.002
Alfalfa meal	20.4		19.7	10.6	6.8	1.4	0.2	2.0	0.1	0.3	0.06	0.25	0.24	0.007
Soybean oil meal	44.0	5.0	5.2	5.1	10.9	0.3	0.66	2.2	0.5	0.25	0.02	0.45	0.04	0.003
Shredded wheat	10.7	1.4	1.7	2.1	8.1									
Wheat bread (white)	9.0	1.2		1.0	37.	0.03	0.09	0.11	0.39	0.02	0.001	0.10	0.61	
Corn meal	7.8	1.3	0.8	0.6	12.									
Ground whole corn	10.0	4.3	1.7	1.5	10.7	0.01	0.28	0.33	0.03	0.11	0.004	0.14	0.05	0.0006
Rolled oats	16.7	7.3	1.3	2.1	7.7	0.06	0.45	0.37	0.06	0.11	0.004	0.20	0.07	0.004
Peanut oil meal	45.0	8.6	9.2			0.17	0.55	1.16	0.07	0.22	0.03	0.21	0.03	
Pearled barley	8.0	1.7		1.3	11.3	0.05	0.38	0.52	0.05	0.12	0.004	0.02	0.11	0.001
Polished rice	7.2	0.3	0.4	0.5	12.3	0.009	0.09	0.07	0.02	0.03	0.001	0.12	0.05	0.001
Fresh carrots	1.1	0.4	1.1	1.0	88.	0.06	0.06	0.4	0.12	0.02		0.02	0.09	
Wheat bran	15.8	5.0	10.0	6.0	9.	0.12	1.3	1.22	0.15	0.51	0.008	0.25	0.09	0.010
Potatoes (raw)	2.2	0.1		1.0	78.	0.01	0.05	0.4	0.03	0.05	0.003	0.02	0.04	0.00006
Eggs (fresh)	13.4	10.5		1.0	74.	0.07	0.18	0.14	0.14	0.01	0.003	0.19	0.10	
Fresh beef (hamburger)	19.5	7.3		1.0	64.	0.01	0.22	0.34	0.08	0.02	0.003	0.23	0.08	
Canned salmon	19.5	7.5		2.0	57.	0.03	0.23	0.34	0.07	0.03	0.001	0.22	0.11	

This list does not include various "special" or "unusual" ingredients (sometimes advertised as essential to the dog's health) for the reason that the vitamins, minerals or nutrients supplied by these special ingredients can be adequately supplied by a balanced formula of the more common and cheaper ingredients listed above.