

Canine Life Stages/ Lifestyles



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The nutritional requirements of an animal vary throughout its life. The requirements of a growing puppy, for instance, are different from those of a senior dog. Requirements change not only with the life stage but also by lifestyle. An adult working dog, for instance, typically requires a different dietary regimen than a normal pet dog. This article discusses how the nutrient requirements of dogs vary according to the life stage and lifestyle.

PUPPIES

In relation to their bodyweight, the energy and nutrient requirements of growing animals are far greater than those of adult animals. The young growing animal needs a higher plane of nutrition to fuel its rapid growth and to provide the boundless energy that is so characteristic of puppies.

The first 2 weeks of puppies lives are spent eating and sleeping, and their energy needs are catered for by their mother. Clearly during this period they have no need for any external source of food. Puppies grow at a rapid rate and double their birth weight in a matter of days. Because of this, puppies require quite large quantities of their mother's milk or a liquid food that can substitute for it. Milk replacers have to be a concentrated source of nutrients based on the composition of normal bitches' milk.

In the early stages of weaning (3 to 4 weeks after parturition), the bitch's milk is still the most important source of nutrients and the puppy's digestive system is learning to handle new sources of nutrients. At this age, puppies should be encouraged to take soft, wet food or even small kibbles of dry food moistened with warm gravy or water. Although it is often assumed that milk and milky feeds should figure prominently in a weaning regime, they are not essential. Highly palatable, energy and nutrient dense foods are those most suitable for weaning, and it is useful to encourage puppies to start eating their mother's food. Puppies become fully weaned between 6 and 8 weeks of age, after which they are ready to leave their mother's side. At this stage, it is better to feed them four small meals a day rather than to allow them continuous access to food.

Bitches' Milk

Table 1 below shows the average composition of milk from bitches, cows, goats, and cats. It is clear that cow's and goat's milk are inadequate as a substitute for rearing puppies since the protein, fat, and calcium levels are too low. Cat's milk would also be inadequate because of the different lactose and calcium levels. Many commercial bitch's milk substitutes are now available. They are usually based on cow's milk that has been modified to more closely resemble bitch's milk.

Table 1: Average analysis of milk of various species

	Bitch	Cow	Goat	Cat
Moisture %	77.2	87.6	87	81.5
Dry matter %	22.8	12.4	13	18.5
Protein %	8.1	3.3	3.3	8.1
Fat %	9.8	3.8	4.5	5.1
Ash %	4.9	5.3	6.2	3.5
Lactose %	3.5	4.7	4	6.9
Calcium %	0.28	0.12	0.13	0.04
Phosphorus %	0.22	0.1	0.11	0.07
Energy* kJ/100g	565	276	293	443

*Calculated using protein 16.72 kJ/g, fat 37.62 kJ/g, and lactose 16.72 kJ/g.

Feeding Objectives

Growth is a complex, highly integrated process involving interactions between nutrients, genotype, environment, and a host of different hormones and their receptors. In formulating a diet suitable for growth in puppies, the following objectives should be considered:

- The diet must contain the correct amount and balance of nutrients to support normal body functions
- The diet should permit normal development in the puppy and prepare it for a long, active, and healthy life
- Growth should be achieved at a rate that will allow the puppy to fulfill its genetic potential while its long bones are still capable of lengthwise growth (i.e., before closure of the growth plates) but not so rapid as to produce abnormalities of growth
- The diet must be balanced in respect of all the nutrients required to achieve these objectives
- The diet should be palatable to encourage adequate intake and to give enjoyment.

The rapid growth phase of puppies is a nutritionally demanding time, and errors in the diet at this stage can have long lasting and often irreversible consequences. More importantly, generalized undernutrition in the young dog can lead to poor growth and condition, but this can be reversed if the diet is corrected while the puppy is still growing. Deficiencies or imbalances of specific nutrients can have more serious effects.

General overnutrition may lead to the development of excessive fat tissue, which can predispose dogs to obesity in adult life. Furthermore, overnutrition may increase the risk of the development of skeletal disorders such as osteochondrosis and hip dysplasia.

Energy Requirements

The dog is unique in that it has the widest range of normal adult bodyweight (in relative terms) within any single species. The rate of growth in the early stages is very rapid and, in general, most breeds of dog will attain 50% of their mature adult weight at a similar age, that is, 5 to 6 months. However, because of the wide variation in adult bodyweight, different breeds continue to mature at different rates and larger breeds take longer to reach their adult bodyweight than smaller breeds of dog.

Giant and large breeds deserve special consideration as they are susceptible to a variety of developmental disorders during growth. Skeletal disorders such as osteochondrosis and hip dysplasia most commonly affect large and giant breed dogs fed to achieve maximal growth rate rather than controlled growth.

Puppy Phase

At weaning (between 6 and 8 weeks of age), the energy requirement per unit bodyweight of a puppy is about double that of an adult of the same breed. To satisfy this high demand required to support the initial rapid growth, a high energy dense (between 390 and 400 kcal/100g) and highly digestible (over 80% dry matter digestibility) diet should be provided for all breeds during this phase.

As puppies grow, this requirement decreases until they reach the adult requirement. Table 2 illustrates the energy needed by puppies of different sizes as their weight increases. Assuming canned puppy foods are around 120 kcal/100 g, a 12-week-old puppy weighing 20 kg would have to eat 2.5 kg/day to cover its energy requirement. It is easy to understand why this should be provided via a concentrated puppy food in at least four meals a day to allow the digestive system to digest and absorb all the nutrients necessary for optimal growth. The frequency of feedings should then be decreased throughout growth (twice daily after they have reached 50% of adult bodyweight) until adult bodyweight is reached. It is not recommended to feed puppies ad libitum since they will tend to overeat. Studies by WALTHAM have shown that optimal growth and body

composition can be achieved in Labrador Retriever puppies fed at a controlled rate of 85% of maximal (ad libitum) intake.

Table 2: Energy requirements (kcal/day) of puppies throughout growth

<i>Bodyweight</i>	<i>Age (months)</i>				
<i>(kg)</i>	2	3	5/6	12	24
1	248	199			
2	418	334	250	209	209
5	1040	831	499	415	415
10	1749	1749	840	700	700
15		2371	1423	948	948
20		2980	1764	1176	1176
30			2790	1993	1594
50			4677	2924	2338
60				3352	2682

Junior Phase

Small and medium sized dogs can make a direct transition from a puppy diet to an adult maintenance diet, usually at about 6 months of age. However, because large and giant breeds have a higher rate of growth over a longer duration and hence take longer to reach their adult bodyweight, their transition from puppy to adult is often interceded by a junior phase.

Peak growth rate and energy intake is achieved by most large/giant breeds by 6 months of age. Growth will continue, albeit at a slower rate until 12 to 24 months of age (depending on the breed) when adult bodyweight is achieved and the intake approaches the average adult requirement of 110 X kcal/kg bodyweight^{0.75} per day.

Once peak growth has been completed and the energy requirement decreases, a diet with a lower energy content (5% to 10%) than the puppy food and possibly a reduced protein content can be fed, although all nutrients must still meet the requirements for growth.

Controlled growth is crucial in order to ensure ideal development and body composition. Animals fed to achieve maximal growth (ad libitum) may deposit excess body fat predisposing to obesity in adult life. A further risk of overnutrition is the development of skeletal disorders such as osteochondrosis and hip dysplasia.

Nutritional Requirements

Not only do puppies have higher energy requirements than adults, but some nutrient requirements are also different.

Protein

In particular, the protein requirements of growing puppies are much greater than those of adult dogs. In addition to the requirement for protein to replace that which is broken down and lost from the body every day, growing puppies also need protein to synthesize tissue for growth.

The following amino acids are required by the immature dog for optimum growth and nitrogen balance:

- Arginine
- Methionine
- Histidine
- Phenylalanine
- Isoleucine
- Threonine
- Leucine
- Tryptophan
- Lysine
- Valine

It is important that a diet for a growing dog supplies all these amino acids at the appropriate levels, as well as supplying extra nitrogen to allow the dog to synthesize dispensable amino acids and other nitrogen-containing compounds.

The minimum level of protein recommended for growth in dogs varies between 11% and 22% of energy intake (Johnson, 1993), depending on variables such as environmental factors, breed of dog, and dietary source of protein, and decreases with age after weaning. The dietary requirements of a particular protein or a mixture of proteins are determined by the ability of the protein(s) to meet the dog's metabolic requirements for amino acids and nitrogen. The closer the supply of the complement of amino acids to the requirement, the lower the overall percentage of protein required in the dog's diet.

Based on the results of a number of studies, the National Research Council (NRC) concluded that 12% protein from lactalbumin or a similar high-quality source should

support growth (NRC 1985). However, a more recent study by Nap et al (1991) suggests that a protein level of 15% is marginal for giant breeds, such as the Great Dane. Moreover, they found that a high-protein diet (33%) does not have a causative role in the development of osteochondrosis in dogs.

The amino acid profile of the diet must be suitable to support growth in the young dog. In addition, the protein must be in a highly digestible form.

Some breeders believe that the inclusion of large amounts of additional protein in a puppy diet will aid the development of good condition and muscle. Unfortunately, protein consumed in excess of requirement is metabolized to produce energy or stored as fat. Excess protein intake during growth can therefore lead to obesity.

Fats

Fat is a useful dietary source of energy in growth formulations since it is a concentrated source of energy (without adding bulk) and it enhances the palatability of the food.

The number of fat cells is determined in the growth phase of the animal's life. An energy intake above requirements during growth will lead to the development of excess fat cells. Once a fat cell is created it will remain within the body forever. Thus, adolescent bodyweight has a direct influence on the number of fat cells in the body. In adult animals, a calorie intake above requirements is more likely to lead to excess fat deposit and thus obesity if there are a high number of fat cells to be filled.

Carbohydrates

Carbohydrate is not an essential component of the puppy's diet, provided that sufficient protein is available for glucose synthesis. However, carbohydrates form a useful and economical source of energy in the dog's diet. Certain carbohydrates have also been shown to help promote gastrointestinal health and digestive function.

Once weaning has taken place, young animals become less efficient at digesting lactose and some individuals become totally intolerant of this particular nutrient. Even if some ability to digest lactose is retained, the animal may not be able to cope with large amounts. Contrary to popular belief, milk is not an essential part of a puppy's diet after weaning, but it remains a useful source of nutrients for individuals who can tolerate it, if fed in restricted amounts.

Vitamins

The requirements for vitamins in the growing dog do not differ markedly from those of adult dogs. However, the supply of fat-soluble vitamins, which can be stored in the body, is more critical in the growing dog than in the adult and care should be taken to ensure that toxicities do not occur through injudicious supplementation. The vitamin E requirement of growing puppies is approximately double that of an adult.

Unlike other species, puppies do not synthesize sufficient vitamin D through UV irradiation to match their requirements, hence a dietary source of this vitamin is required. Vitamins A and D are essential for the handling and absorption of calcium, and a diet containing incorrect levels of these vitamins can also give rise to skeletal problems.

Thus, particular importance should be paid to vitamin and mineral levels in diets intended for growing animals.

Minerals

The demand for minerals required for bone formation (especially calcium) is higher in the growing dog than in the adult, particularly in the fast growing large and giant breeds. It is essential that these nutrients are provided not only in the correct amounts but also in the correct ratio to each other. In particular, the requirement for calcium is closely linked to the phosphorus content of the diet, and a relative deficiency of calcium may arise in a diet that is apparently sufficient in calcium if the phosphorus content is too high.

The optimal absolute amount of calcium in the diet of growing puppies needs to be strictly controlled and should be in the range 0.8 to 1.5 g/400 kcal on a dry matter basis. Furthermore, the amount of phosphorus in the diet should be adjusted to ensure the ratio of Ca:P is not lower than 1:1 or greater than 1.5:1. However, a certain amount of regulation of calcium absorption and retention does occur, and it would seem that unless the Ca:P deviates vastly from the normal, the calcium content per se is more important than the Ca:P ratio.

Since animals eat to meet their energy requirements, all nutrients must be balanced in respect of the energy content of the diet.

A properly balanced diet formulated for growth does not require supplementation, and injudicious use of additives can have serious deleterious effects. This is true even of large breeds since their extra needs are catered for by their increased food intake.

Supplementation

Do giant breed puppies require extra supplementation ?

If we look at the Table (*right*), we can see that a 5-month-old Chihuahua weighs about 1 kg and requires 250 kcal/day. In contrast, the Wolfhound weighs 30 kg and requires 3,200 kcal/day. Therefore the energy requirements of the Wolfhound are approximately 13 times that of the Chihuahua.

Minimum requirements/day 5 months old		
	Chihuahua	Irish Wolfhound
Weight	1kg	30kg
Energy	250 kcal	3200 kcal
Protein	1.4g	1.6g
Calcium	0.7g	8.8g
Phosphorus	0.6g	8.0g
Vitamin E	3.1mg	40mg

If we look at the nutrient requirements, we can see that the Wolfhound also requires approximately 13 times the amount of calcium, phosphorus, and vitamin .

So, as long as we feed the Wolfhound calories of a nutritionally balanced diet formulated for puppies, then there will be no need for extra supplementation.

Food Types

Diets for puppies may be moist (canned), semi-moist, or dry, but in very young animals it is recommended that dry foods be softened with water, gravy, or milk and that food be finely divided (chopped or minced) to make it easier for the young animal to eat.

It may be possible to feed an adult formulation, but the young animal has very high requirements and will need to eat proportionately more of the diet. A young puppy has a limited stomach capacity and may not be physically capable of ingesting enough to meet its requirements. A suitable diet for weaning and growing puppies, therefore, should be concentrated, highly digestible, and very palatable. Many products are commercially available that have been specifically formulated for puppies. A typical canned dog food designed for adults will have an energy density of approximately 80 kcal/100 g (335 kJ/100 g), whereas one formulated for puppy growth will provide 120 kcal/100 g (500 kJ/100 g).

Growth formulations should not be supplemented with other foods, but some owners may like to offer alternative foods from time to time. If so, only a few different foods should be introduced gradually at any time to allow the digestive system to adapt to the new food.

GESTATION AND LACTATION

Ensuring the best possible start in life for young animals begins with the correct nutrition of the pregnant and lactating bitch or queen. In this section we consider how the nutritional requirements of reproducing animals differ from those of adults.

Feeding Objectives

The reproductive life stage is a nutritionally demanding time for the bitch. Lactation, in particular, places great stresses on the female, and her energy and nutrient requirements may rise to up to four times maintenance levels.

A suitable diet for the animal during this period must:

- Supply all the energy and nutrients needed to meet the maintenance requirements of the bitch plus
- Supply all the energy and nutrients required to support fetal growth and development during pregnancy and milk production during lactation

Because the requirements may be very high and therefore large amounts of food must be ingested, achieving a sufficient intake may be a problem. To remedy this, it is advantageous for the diet to be:

- Concentrated in terms of its energy and nutrient density
- Palatable to encourage feeding
- Highly digestible to reduce bulk

Requirements

Energy

The average duration of pregnancy in the bitch is 63 days, but it is not until the last third of the gestation period that most fetal weight gain occurs. Accordingly, the bitch's energy

requirement will not increase until this time, although there is considerable development of mammary and uterine tissues beforehand.

Overfeeding early in pregnancy should be avoided since this may lead to the deposition of unwanted fat and may predispose to problems at whelping.

Even during the last trimester, the need for extra energy and nutrients over and above maintenance requirements is relatively small. All that is required is to gradually increase the amount of food over the last trimester of gestation. A satisfactory regime would be to provide weekly increments of 15% of the bitch's maintenance ration from the fifth week onward. At the time of whelping, the bitch will then be eating 60% more than when she was mated.

Lactation presents the biggest test of nutritional adequacy of any feeding regime. The bitch must eat, digest, absorb, and use very large amounts of nutrients to produce sufficient milk of adequate composition to support growth and development of several puppies. The extra energy needed is dependent on the normal energy intake of the bitch and the size and age of the litter.

Consider a Labrador Retriever bitch weighing 28 kg with a litter of six 4-week-old puppies weighing 2.5 kg each. At this stage each puppy will require an energy intake of about 500 kcal/day (2090 kJ/day), which is obtained from the bitch's milk. The bitch, therefore, has to supply 3000 kcal (12550 kJ) as milk each day. Bitch's milk contains about 1300 kcal/L (5440 kJ/L), and so the amount of milk needed is at least 2.3 L.

There are obviously some losses of energy in the production of milk by the bitch; if it is assumed that the process has an efficiency of 75%, then in order to produce 3000 kcal (12550 kJ) as milk, the bitch must obtain $3000/0.75$ (12550/0.75) or 4000 kcal (16740 kJ) from her food. In addition, to maintain her own bodyweight and condition, she will need her usual 1339 kcal/day (5624 kJ). The bitch's total energy requirement is therefore 5339 kcal (22424 kJ) or nearly four times her maintenance requirement. Obviously, it is strongly recommended to feed such an amount of food in several small meals of a highly palatable and digestible diet, or alternatively, offer the food constantly over 24 hours.

If the bitch is unable to produce enough milk or to eat the amount of food it needs, then early supplementary feeding of puppies may be necessary if they are to do as well as they should. This is initially best done with a milk replacer that has a nutritional profile close to the bitch's milk. From about 4 weeks of age onward, the puppies can also be encouraged to eat small amounts of their mother's food.

Nutrients

Energy needs are increased during pregnancy and lactation, but requirements for other nutrients are similarly increased. Protein quantity and quality will affect fetal growth and milk production. It is therefore necessary to ensure that the extra food supplied is of good quality and contains sufficient amounts of good quality protein.

Carbohydrate

In 1981, it was suggested that gestating/lactating bitches needed carbohydrate in order to whelp and rear healthy puppies. However, a later study conducted on Labrador Retriever and Beagle bitches (Blaza 1989) showed no differences in the reproductive performance of bitches fed either a diet in which there was no available carbohydrate or one where carbohydrate represented 11% of the estimated metabolizable energy. This is probably due to a higher protein content of the diet fed in the Blaza study, which supplied sufficient gluconeogenic amino acids to allow the maintenance of the plasma glucose level. It was then concluded that, while carbohydrates are physiologically essential, it is not an indispensable component of the diet of gestating/lactating bitches.

Protein

The protein requirements for reproduction and lactation in the bitch have not been well defined. In one study, 12 out of 15 dogs maintained nitrogen balance and weight during gestation and lactation when fed diets containing approximately 25% protein. Another study showed that bitches fed a carbohydrate-free diet required 30% protein compared with 16% in diets containing carbohydrate.

Food Types

During the period of pregnancy and lactation, the bitch must eat sufficient food to satisfy her energy and nutrient requirements for maintenance plus an allowance for the additional demands of fetal growth or milk production.

Pregnancy

During early pregnancy, the additional requirements are relatively small and it may be sufficient to simply increase the amount of the animal's normal food, provided that it is complete and nutritionally balanced. However, in late pregnancy and particularly if the litter is large, the gravid uterus may take up so much space in the abdomen that the

physical capacity for food intake is limited. In this case, it may be useful to offer a more concentrated diet to ensure an adequate energy intake. Feeding of smaller, more frequent meals may also be beneficial.

Lactation

During lactation, the nutritional demands on the female are very high. At peak lactation, the energy requirement may be between three and four times that of maintenance. In order to achieve an adequate food intake during this period, it is preferable to feed an energy- and nutrient-dense diet (such as puppy food) that is both highly digestible and highly palatable. The extra food supplied should be of good quality (not simply high fat or high carbohydrate) because protein quantity and quality in the diet will affect milk production.

Many diets are suitable for lactating bitches. If canned food and a good quality mixer is the usual diet, it may be necessary to increase the proportion of biscuit used to achieve satisfactory energy intakes. The use of more concentrated foods, such as puppy food, semi-moist or complete dry foods, is another means of achieving higher energy intakes. If the dog is willing to eat different kinds of food, this makes it easier, although it is quite satisfactory to keep to one or two foods if this is the normal regimen.

It is important that the bitch can eat several times a day. Ideally the food should be placed close to her bed, so that she does not have to leave her puppies in order to eat. This will also encourage the puppies to try their mother's food.

The breeding bitch does not require special vitamin/mineral supplements if a balanced diet is used. Indeed this could actually cause an imbalance in the food. Supplements of calcium and vitamin D are sometimes given to bitches in late pregnancy or lactation, but these do not prevent eclampsia and may produce calcinosis in the bitch and developmental abnormalities in the puppy.

ADULT DOGS

Although the dog is a member of the order Carnivora, in a nutritional sense it is more accurately defined as omnivorous. Its long association with man has resulted in a degree of flexibility and adaptation in its nutritional requirements. Unlike the cat, the dog is potentially able to survive on a diet composed entirely of vegetable material, although a diet based on animal tissue is more suitable and likely to be preferred.

Many aspects within the diet help to strengthen the dog's natural defense mechanisms. Physical barriers to disease, such as the skin and coat and the lining of the gastrointestinal

tract are supported through specific nutrients aimed at promoting the health of cells in these regions. Nutrients to support good skin and coat condition include zinc, linoleic acid, the B vitamins, and biotin. Specific fermentable fibers help to promote gastrointestinal health and ensure good digestion and faeces quality.

In addition to this, the dog's level of antioxidants can be increased through specific diets. Antioxidants are essential for the dog's natural defenses and act by entrapping free radicals, which may be associated with cell destruction and the ageing process.

Feeding Objectives

Most pet animals are healthy adults that live mostly indoors in a temperate climate. Animals that are not pregnant or lactating, not involved in regular work or excessive exercise, and not subjected to extremes of temperature are said to be in maintenance, nutritionally.

For an animal in maintenance, the diet must:

- Provide the correct amount, balance, and availability of nutrients to sustain physical and mental health and activity
- Promote peak condition in the animal and hence reduce its susceptibility to disease
- Be sufficiently concentrated to allow the animal to meet its requirements by eating an amount well within the limits set by appetite
- Be sufficiently palatable to ensure an adequate intake, since an uneaten meal has no nutritive value.

The feeding occasion should be enjoyable, since this will help to reinforce the bond between a pet and its owner.

Energy Requirements

Adult dogs in peak condition vary in size from around 1.1 kg up to 115 kg (Burger and Johnson 1991). To make allowance for this wide range of bodyweights, and since energy needs are not directly proportional to bodyweight but the weight of actively metabolizing tissue, it is necessary to use an estimate for metabolic body size when calculating energy requirements in the dog. The most reliable estimates of metabolizable energy (ME) requirements of moderately active dogs can be obtained by using the formula:

$$\text{ME (kcal/day)} = 110W^{0.75}$$

where W is the bodyweight of the dog, measured in kilograms and $W^{0.75}$ is the metabolic body size of the dog. For more active dogs, this can be increased to $125W^{0.75}$.

The allometric relationship, however, assumes that neither shape nor body composition (ratio of lean body mass to fat) varies with size, and this will not be the case for a range of breeds as widely disparate as those of the dog. Feeding studies have shown that Newfoundlands needed less energy than the predicted amounts whereas Great Danes needed more despite these two breeds being of comparable bodyweight.

A dog will ideally eat until its energy requirement has been fulfilled. It is important within the amount of food needed to fulfill its energy requirements, there are also enough nutrients to fulfill its nutritional needs

Nutrient Requirements

Diets for adult dogs in maintenance should be complete and balanced in respect of all the nutrients outlined below :

- Water
- Protein
- Fat
- Carbohydrate
- Vitamins
- Minerals

All of these nutrients must be present in the diet in the correct amounts.

The minimum dietary requirement has been clearly defined for most of the nutrients, and clinical signs of deficiency have been identified if this level is not reached in the diet. Similarly, the maximum tolerable levels of certain nutrients are known and if the dietary concentration exceeds this limit, toxicity will result.

The range of the acceptable intake that lies between the minimum and maximum recommended requirement will change depending on the individual nutrient and the overall dietary composition.

An important aspect to consider when deciding upon nutrient levels are nutrient interactions. Excessive amounts of phytate, for example, will interfere with the intestinal absorption of zinc and high levels of calcium will reduce the absorption of both copper and zinc. The availability of biotin is reduced in the presence of the protein avidin, found in raw egg white.

Food Types

Healthy adult dogs can be fed on one complete food (canned, dry, or semi-moist) or with a number of varieties. Sudden changes in diet should be avoided as this may lead to diarrhea. The simplest way to offer a varied diet without the risk of gastrointestinal upset is by making use of the different varieties available within a brand of dog food.

A subgroup of the dog population, however, may display poor feces quality on a range of products, with no apparent gastrointestinal disease. This is often referred to as nonspecific dietary sensitivity (NSDS). These dogs may benefit from being fed a high-quality, easily digested diet specifically developed for sensitive dogs.

Regimen

Adult dogs in maintenance will usually have a good enough appetite to eat all they require in one meal per day, and it is quite satisfactory to adopt a once-a-day feeding regimen. The advantages of a single meal are that it can usually be of sufficient size to satiate appetite; it is more controllable in that errors of dispensing occur only once a day, so under- or overfeeding is less likely; and it can easily be fitted into the household routine at whatever is the most convenient time. It is usually best to avoid late evening meals since dogs may need to excrete feces or urine within a few hours of feeding, and this can be inconvenient in the middle of the night.

There is no disadvantage in feeding more frequently than once a day, provided that the total daily intake is limited to the dog's daily needs. Feeding two or three times a day after family meals is a common practice. The risk is that more food may be given and thus overeating and obesity may result. The correct number of meals for any adult dog is that which the owner and dog find most convenient. It is desirable to establish a routine and stick to it. Meal times are the high spot of most days, and dogs quickly become accustomed to being fed at the same time and place each day. Dogs that are unwell or have poor appetites or very old dogs may benefit from being fed smaller meals two or more times daily.

SENIOR ANIMALS

Ageing is unfortunately irreversible. The modifications of cellular and biochemical structures that are responsible for the decrease of the mass and activity of muscular, nervous, and other tissues cannot be stopped. However, providing adequate food which takes into account the particular needs of the older animal can help in the care and management of this life stage. As in human medicine, improvements in the prevention of serious life-threatening diseases and the feeding of a nutritionally balanced food means

that our companion animals are living longer, so caring for elderly pets will obviously become an area of increased interest.

It is difficult to define the point at which a dog can be classified as “senior” since there is a wide variation in the life expectancy of different breeds. Generally, medium- and small-sized dogs tend to live the longest, with some breeds living to 17 or 18 years of age. Giant breeds however, tend to have a much shorter life expectancy, often only living for 7 or 8 years. On this basis, it is more realistic to define a senior dog as one which is in the final third of its anticipated lifespan. A small- to medium-sized dog is therefore considered to be senior from 8 years of age, whereas a large breed such as a Great Dane is senior from only 5 years of age.

Evidence from human studies shows that the energy expenditure of the elderly is reduced for two main reasons. Firstly, their level of activity falls, although there is a wide variation between individuals. Secondly, there is a decrease in lean body mass and a subsequent decline in their basal metabolic rate.

Evidence from animal studies suggests that the energy requirements for young adult dogs are inappropriate for most senior dogs and that energy requirements decrease by around 20% in old age.

One WALTHAM study (Taylor et al 1995) compared energy requirements of young adult dogs (under 6 years) with senior dogs (over 8 years). The data showed a significant decrease in the energy (ME) required for bodyweight maintenance of older dogs compared to the younger ones.

Another WALTHAM study established that for the majority of older dogs, the following equation for energy requirements is appropriate :

$$\text{Energy Requirement (kcal/day)} = 90 \times \text{Bodyweight}^{0.75}$$

Some individual animals may, however, differ from this estimation. It is therefore crucial to monitor the dog's individual development and bodyweight, just as it is during growth and maintenance.

Digestive Function

Proteins

There is little information available from studies assessing the digestive function and the particular nutrient requirements of elderly pets. One study compared digestive functions of sixteen 10- to 12-year-old pure-bred Beagles with those of eight 1-year-old Beagles. The results showed that the apparent digestibilities for protein, fat, ash, and energy were higher for old dogs than for young dogs regardless of the diet being fed. Other

researchers measured digestibilities in three groups of Beagles aged 2 to 3, 8 to 10, and 16 to 17 years. Mean nutrient digestibilities for dry matter, nitrogen, and fat were all slightly lower for the oldest group, but none of the differences between the groups were statistically significant. Despite these results, other researchers showed that the optimal intake of dietary protein was greater for 12- to 13-year-old Beagles than for 9- to 12-month-old Beagles.

Historically, there has been a belief that reducing protein intake in older animals will relieve "stress" on their renal function and may help to prevent or slow progression of renal disease. More recent data, however, has shown that this theory cannot be substantiated. Whereas older dogs have a higher incidence of renal disease than young dogs, not all old animals invariably develop renal failure. Studies in geriatric dogs receiving either a 18% protein or a 34% protein diet have shown no harmful effects of the higher protein diet, and mortality was actually higher in the dogs receiving only 18% protein. The routine use of protein restricted diets in all geriatric dogs is therefore not recommended.

Protein restriction, however, is recommended in patients with diagnosed renal failure in order to ameliorate the signs of uremia. It is also important to consider the quality of protein rather than the quantity. For old animals, the protein should have a high biologic value and a high digestibility.

FAT

The tolerance of fat is not generally reduced in elderly dogs, and their requirements for essential fatty acids appear to be the same as their younger counterparts. However, restricting the fat intake in the diet can be beneficial in order to reduce energy intake by about 20%.

Minerals

Little is known about the mineral requirements of older healthy animals. It may be beneficial to control the intake of certain minerals, such as sodium and phosphorus, as they are associated with commonly diagnosed diseases of the older dog, such as heart disease and renal failure. On the other hand, it is recommended to increase the intake of certain trace mineral, such as copper, zinc and manganese, to about twice the levels for adult maintenance to account for reduced bioavailability with age.

Vitamins

There are only a few studies on the vitamin requirements of older dogs. As with the trace elements, it is recommended to increase intake of the water soluble B complex vitamins to twice adult maintenance requirements to account for losses of bioavailability.

Furthermore, a similar increase in the vitamin E intake is regarded as beneficial, as vitamin E is an important antioxidant, which may help to combat oxidative stress and other age-related processes.

WORKING DOGS

A further time when dogs may require a high level of energy and other essential nutrients is during periods of work and stress. Working dogs perform many different functions and may include:

- Racing dogs
 - Sprint racing dogs (e.g., Greyhounds)
 - Endurance racing dogs (e.g., sled dogs)
- Other working dogs, such as
 - Military and police dogs and other dogs trained to detect explosives and drugs
 - Dogs trained to assist disabled people
 - Farm dogs
 - Dogs taking part in competitions (e.g., agility competitions)

Depending on their function and activity, working dogs can have very different training, working, and resting schedules necessitating different diets and feeding regimens. A number of factors, such as level and duration of activity, the nature of work, and the environment, influence energy and nutrient requirements, and it is therefore not possible to give strict feeding guidelines to encompass all working dogs. Owners must aim at supporting and sustaining their animals' body condition by closely monitoring the dog's weight and development and making individual adjustments to feeding where appropriate. However, available data will help to select the optimum feeding regimen for a particular dog.

Feeding Objectives

The feeding objectives for working dogs are to:

- Provide good quality nutrition at adequate levels supporting dietary requirements for maintenance, exercise, thermoregulation, and stress
- Help maintain a good state of hydration

Energy

The daily energy requirement of a normally active adult pet dogs are estimated as $110 \text{ kcal} \times W^{0.75}$ (W = bodyweight; $W^{0.75}$ = metabolic bodyweight). But as the activity or work load of an individual increases, the demand for energy will be raised, depending on the environment, the amount of exercise, and the nature of the work; thus a working dog could need as much as two to three times the normal adult ration.

Data about energy requirements are only available for racing dogs, who can be regarded as “athletes.” A study by WALTHAM shows energy requirements for racing Greyhounds to be between 155 and $175 \text{ kcal} \times W^{0.75}$, while racing Huskies may use 130 to $200 \text{ kcal} \times W^{0.75}$ during training and up to 300 to $900 \text{ kcal} \times W^{0.75}$ during long-distance races.

However, for the average active working dog, it can be estimated that for every hour of increased activity or for every 5 extra miles covered, energy requirements will increase by about 10%.

Translated into realistic and practical feeding guides, it is recommended to use the following equations:

- Energy requirements (kcal/day) for dogs under normal to light work = $125 \times W^{0.75}$
- Energy requirements (kcal/day) for dogs under heavy work = $175 \times W^{0.75}$

Dietary Energy Source

Racing Dogs

Within the group of racing dogs there is a distinct difference between the short duration, high intensity of the activity of racing Greyhounds compared with the long duration, lower intensity racing of the sled dog. The energy sources of the sprint racing dogs are distinctly different from those of the endurance athletes.

Sprint Racing Dogs

The racing Greyhound's activity is characterized by very intense periods of exercise of very short duration of around 30 to 40 seconds.

During this exercise, the muscle fibers contract very quickly and the energy source must therefore be easily and quickly available. These muscle fibers rely on glucose and anaerobic oxidation for ATP supply. Glucose from glycogen stores in the muscle supplies 70% to 80% of the energy requirements, with fat providing the rest. For this reason, carbohydrate should be a major component in the diet for sprint animals. Good sources of carbohydrate include corn, oat flakes, potatoes, and rice.

Traditionally, racing Greyhounds have been fed a mixture of lean meat and dry kibbles to provide a diet high in protein and carbohydrate and low in fat. However, recent studies in this area have shown that increasing the fat content from 12% to 18% (on a fresh matter basis) enhances performance in Greyhounds and so does reducing protein content from 39 to 26% (on a fresh matter basis); it is therefore not recommended to add high levels of meat to the diet (Hill et al. 1998).

Endurance Racing Dogs

Endurance racing dogs are active at lower intensity for long periods of time and require a steady supply of energy over an extended time period. Fat is therefore the most important source of ATP, with the occasional demand for aerobic breakdown of carbohydrate to support bursts of increased demand, such as going up a slope.

Fat is the main fuel for energy, and the muscle fibers produce energy through aerobic fatty acid oxidation, with fat providing 70% to 90% of the energy and carbohydrate providing the rest. The composition of dietary fat may also be important, especially the proportions of saturated long-chain fatty acids, medium-/short-chain fatty acids, and essential fatty acids. It has been recommended that at least 25% of dietary fats are composed of medium- and short-chain fatty acids (such as from coconut and palm oil), as they are more rapidly absorbed and utilized in oxidative processes and less likely to be deposited as body fat (Grandjean and Paragon, 1992 and 1993).

Racing sled dogs, such as Huskies, may also work in extreme conditions and will therefore not only require more energy for their exercise but also to maintain their body temperature.

Other Working Dogs

This group of dogs includes a number of different breeds performing very different tasks, such as German Shepherd Dogs and Labrador Retrievers in the military and police force doing a number of different jobs. Labrador Retrievers are equally popular as service dogs, such as guide dogs, hearing dogs, or assistance dogs. Then there are farm dogs, such as Collies performing herding roles, and a variety of breeds enjoy agility competitions.

These dogs are usually not heavily exercised. However, they may have higher levels of exercise compared to normal pet dogs, and feeding rations may have to be increased depending on the duration and intensity of their activity (Table 3). Additionally, other factors, such as environmental temperature and stress, can influence dietary requirements.

It is, however, equally important to avoid overfeeding working dogs, as this can lead to obesity and impair performance. Dogs who perform only very light work over short

periods of times may have similar demands to normal adult pet dogs; in some cases they may even require a calorie-controlled diet to avoid excess weight gain.

There are a variety of commercial diets available for these working dogs, from calorie-controlled “light” products to products for normally active adult dogs to diets for more active dogs.

Table 3. Recommended energy requirements for pet and working dogs:

<i>Type</i>	<i>Category</i>	<i>Type of Activity</i>		<i>kcal/kg^{0.75}</i>	<i>Multiplication of WCPN Recommendation for Typical Pet</i>
		Duration	Intensity		
Pet	Typical	<3 hr/day	Mainly low	110	1
	Active	1-3 hr/day	Mainly high	125	1.15
	Highly active	3-6 hr/day	Mainly high	175	1.6
	Senior / neutered / inactive	<3 hr/day	Mainly low	90	0.9
Working	Light (e.g. police, prison, patrol, sniffer, guide dogs)	<3 hr/day	Mainly low	130-150	1.2-1.4
	Moderate (e.g. herding dogs, sprint racing huskies, greyhounds)	1-3 hr/day	Mainly high	150-175	1.4-1.6
	Heavy (e.g., racing huskies, hard-working herding dogs)	3-6 hr/day	Mainly high	175-250	1.6-2.2

WCPN = Waltham Centre for Pet Nutrition.

Protein

Protein requirements of working dogs have not been thoroughly evaluated. Protein is not a primary fuel source, and at present there is no scientific evidence that feeding a high-protein diet will promote superior muscle development. Furthermore, a more recent study has established that high protein levels may slow down sprinting Greyhounds, and reducing protein content from 39% to 26% (on a fresh matter basis) has a beneficial effect on their performance (Hill et al. 1998).

Additional Factors

Apart from determining the energy intake and the major energy source within the working dog's diet, a number of further factors are crucial in ensuring maintenance and good performance.

Digestibility

All working dogs should be fed a diet with high-quality ingredients of high digestibility. This is important for a number of reasons:

- Exercise decreases the gastrointestinal transit time (i.e., the ingesta spend less time in the gastrointestinal tract with less time for enzyme action and digestion)
- When eating a diet with lower digestibility, it is necessary to eat larger volumes in order to satisfy energy requirements (i.e., the food is usually more “bulky”); this can be a problem if the diet is not very palatable or the animal has little time to eat between exercise periods
- Highly digestible diets produce less feces of better quality, which is particularly useful when the working regimen does not allow frequent defecation
- Diets with high levels of fiber and poor digestibility can impair the bioavailability of other nutrients, such as zinc, leading to poor skin and coat quality

Vitamins and Minerals

Working dogs may also have increased requirements for certain vitamins and minerals.

Although synthesized by the dog, extra vitamin C within the diet may be beneficial at a dosage of 1 mg/kcal ME (Donoghue et al., 1987). Vitamin C has a positive effect on the organic and metabolic response to exercise stress, as it is important for the synthesis of carnitine helping to transport fatty acids across the mitochondrial membrane.

Vitamin E and selenium are known antioxidants and can reduce exercise induced oxidative stress (i.e., cell damage due to the release of free radicals and peroxides). Antioxidants help to protect the polyunsaturated fatty acids which are part of the cell membrane walls, including muscle cells.

It is generally recommended to increase intake of the water soluble B complex vitamins. Pyridoxine (vitamin B6) supplementation may be beneficial to support transamination with increased protein intake (Kohnke, 1983). However, it is recommended not to exaggerate vitamin B6 intake in dogs that receive a diet with high levels of carbohydrate, as it can lead to very rapid muscle glycogen utilization (Black et al., 1977).

Furthermore, the minerals iron, copper, zinc, and calcium should be carefully balanced in a diet for working dogs.

Environmental Factors

Working in extreme climates (i.e., in very hot or very cold conditions) can significantly influence animal's energy requirements. Sled dogs usually train under very cold conditions, and apart from requiring energy for maintenance and hard work, they need additional energy to maintain a constant body temperature. The total energy requirement therefore consists of maintenance energy requirement (MER) + thermoregulation energy requirement (TER) + racing energy requirement (RER) (Grandjean and Paragon, 1992 and 1993).

The requirements for thermoregulation can vary widely and are influenced by the temperature, wind chill, and rain as well as the thermal insulation capacity of the dog's coat.

Dogs living in outdoor kennels may also need more energy in the winter when it is cold.

Stress

Stress is a very important environmental factor. Working dogs may be subject to higher levels of stress than normal pet animals. Stress can be of organic nature (training, competition) as well as physiologic (transportation, mental concentration, anticipation). These increased stress levels have an influence on the dog's nutritional requirements.

Stress in dogs leads to an increased demand in certain amino acids, particularly tryptophan, which is the precursor of serotonin, a neurotransmitter involved in many physiologic functions. Dogs under stress have therefore an increased demand for good quality protein with a high level of essential amino acids (Grandjean, 1996).

The intake of sufficient levels (minimum of 30% ME in fresh food) of good quality protein is also beneficial to avoid the development of stress-related anemia in working dogs (Kronfeld et al., 1976; Kronfeld and Downey, 1981; Kronfeld, 1983).

Severe nervous stress can also lead to the development of lactic acidosis with many negative effects on metabolism. It is therefore important to prevent acidosis by restricting stress as much as possible (i.e., by ensuring a calm environment, by regular training to help the body cope with lactacidemia, and by providing a buffer, such as sodium carbonate, administered with the dog's drinking water) (Grandjean, 1996).

Some individuals may exhibit stress-related gastrointestinal disturbances, such as non-specific dietary sensitivity or idiopathic colitis, both characterized by recurrent poor feces quality or diarrhea. These dogs may benefit from being fed a high-quality, highly digestible diet specifically designed for sensitive dogs.

Water Requirements

Dehydration is one of the major threats in racing dogs and can severely affect their electrolytic homeostasis and acid-base balance (Grandjean, 1996). Working dogs have increased demands for water intake for a number of reasons:

- Many working dogs are fed dry diets and so have a limited water intake via the food
- Relatively high levels for water are required for metabolism and energy release
- Water is needed for thermoregulation
- Water is lost via urination and saliva production, both of which are increased under physiologic stress (e.g., while waiting for a race)

In order to avoid dehydration, it is therefore important to provide fresh, preferably cool, drinking water in sufficient quantities and to make sure not to deprive animals of water over long periods of time.

Feeding Regimen

Working dogs should be fed a highly digestible, energy dense diet that supports increased energy requirements. Depending on the type of exercise, specific attention may be given to certain nutrients and their ratios, such as the levels and ratios of fat, carbohydrate, and protein, and a possible increased intake in specific vitamins and minerals.

Food should be offered in two or more meals per day, avoiding large volumes of food at any given time and thus encouraging animals with high energy demands to eat sufficient to meet their requirements.

The largest part of the daily food ration is best given after work. If the dog is fed prior to exercise, 1.5 to 2 hours of rest should be allowed before exercise commences.

Providing treats high in carbohydrate to sprinting dogs can increase blood insulin levels and glycogen oxidation and can therefore have a negative effect on performance. However, high-fat, high-protein treats supplied during endurance exercise can improve long-term performance.

As energy and nutrient requirements depend on the level and type of exercise, the duration of exercise, environmental factors, and individual variations, it is crucial that owners determine the dog's individual food ration by closely monitoring the dog's body condition and weight and adjusting food intake as appropriate. Dietary requirements may also differ significantly between periods of hard work and periods of rest or moderate training.

In order to ensure good hydration, sufficient amounts of fresh drinking water should be available at all times.

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