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VEGAN NUTRITION OF DOGS AND CATS

Diplomarbeit

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1. Preface

Many people enjoy a vegetarian lifestyle today, with its most popular reasons being ethic, moral, economic or religious. There are different types of vegetarianism, each including or excluding specific foods. At its minimum, living a vegetarian lifestyle means abstaining from the consumption of meat and fish (“ovo-lacto vegetarianism”). More restricted diets are known as “Ovo-vegetarianism”, which includes eggs, but not dairy products or “Lacto-vegetarianism”, which includes dairy products, but no eggs. At one of its most restricted forms, all animal flesh and products, including milk, honey, eggs are excluded from the diet, but also by-products of animal slaughter (e.g. leather) avoided. This may even also include vitamin and mineral sources if they are derived from animals. This type of diet is called veganism. The vegan society of America defines it as following: “Veganism is a way of living which seeks to avoid, as far as possible and practical, the use of animals for food, clothing or any other purpose. At the heart of veganism is the core principle that animals are not ours to be used. It’s essentially about respecting other animals, not causing them harm or using them as property.” Other than maybe some years ago, it seems today vegan nutrition has become a more present topic in media, television and newspapers around us. Vegan restaurants and supermarkets are opening and living a vegan lifestyle generally seems to become a growing trend. Among most people, it is their love to animals and the worry about intensive farming, as well as the abuse of animals and their intention to avoid any animal suffering, that drives people to the only logical conclusion of avoiding anything that comes with exploitation of animals. This love for animals however often comes with the wish of sharing one's life with a pet. If a carnivorous animal such as dog or cat gets chosen, it might lead to contradictions with ones own dietary philosophy. Vegan pet-owners often reach the point where they ask themselves if it is acceptable to continue feeding their cats and dogs animal derived foods and by doing so supporting the system they actually intend to boycott. Therefore, some vegan pet owners decide to apply their own ideas of a plant based diet on their cats and dogs.

What might have been rather unthinkable a few years ago, or at least more difficult, has become easier and rather quickly implementable. A constantly growing supply of pet foods, specifically composed for this type of diet, paves the way for an uncomplicated change of feed and will therefore gain more and more importance in a veterinary clinic.

Proper nutrition is among the more important considerations in health maintenance and a key to disease management. A basic knowledge of nutrients, requirements, availability and consequences of deficiencies or excesses is important to feed dogs and cats correctly and give advice about feeding. To feed cats and dogs, who systemically belong to the group of carnivora, on a purely plant-based diet, gives rise to the question if it is a safe and arguable option.

Both, plant- and meat-based foods, contain a fair amount of most vitamins and nutrients. Specific ones, like vitamin B12 however, can not be found in plant products.

In this paper the issue shall be addressed, if vegan nutrition meets the nutrient requirements of carnivorous pets such as cats and dogs, and if the supposition of this kind of diet causes a lack of nourishment with certain nutrients. It could be expected that a purely plant based diet, might lack of nutrients like Vitamin B12, iron, folic acid or protein among others and lead to malnourishment of carnivorous pets like dogs and cats.

It is the intention of this paper to provide general information on vegan nutrition of dogs and cats and furthermore to deal with how an adequate nutrient intake can be met with only plant based feeds. Also it will provide information about what there is to be minded and what a lack of nourishment with certain vitamins, essential amino acids, and other nutrients can result in.

In the following, after a short summary of general basic nutrition informations, the paper will elaborate on specific nutritional issues of a vegan diet and take a closer look at commercially produced vegan pet-foods and give examples of recipes used in home prepared vegan diets.

2. Basic Nutrition Review

A basic knowledge of nutrients, requirements, availability and consequences of deficiencies or excesses is important to feed dogs and cats correctly and give advice about feeding. A nutrient is any food constituent that helps support life and is needed by an organism to live and grow. Nutrients are essential in that they are involved in a number of functions of the body. Macronutrients are needed in larger quantities and include organic nutrients such as carbohydrates, fats, and proteins, and also water. Macronutrients may be used for supplying energy but can also serve as structural components. Micronutritions are nutrients needed in very small amounts and include organic nutrients like vitamins, and inorganic chemical compounds such as minerals (HAND et al., 2010).

2.1. Macronutrients

2.1.1. Energy

All living organisms need energy, not only to keep their body temperature up but also to fuel all bodily functions such as breathing, circulation, digestions, excretion and to sustain metabolism (MEYER and ZENTEK, 2010).

Providing energy is a key function of dietary intake, with fat and carbohydrates being the main supplier. Although energy itself is not a nutrient, fats, carbohydrates and amino acids contain energy in the form of chemical bonds and are the energy-containing nutrients in food. Once eaten, these organic nutritional components are digested, absorbed and transported to body cells where they are used to generate energy. The body captures nutrient energy in energy-containing compounds through a series of enzymatic biochemical reactions (GROSS et al., 2010).

In nutrition, the joule is the internationally recognized unit of measure for energy.

A more commonly used energy measure is the calorie, which expresses energy in terms of heat. A kcal is 1,000 calories and a kilojoule (kJ) is 1,000 joules. Kcal and kJ can be interconverted using the formula 1 kcal = 4.184 kJ (KAMPHUES et al., 2009).

The biochemical reactions that take place in the body either use or release energy. Anabolic reactions require energy and, conversely, catabolic reactions release energy.

Without energy supplied by food, reactions like pumping ions, molecular synthesis and activation of contractile proteins would rapidly cease and death would occur. The most important energy-containing compound is ATP.

ATP is the usable form of energy for body cells (HAND et al., 2010). Knowledge of energy requirements is needed to determine how much food has to be fed to an animal. Determining energy requirements involves measuring energy expenditure of an animal under a defined set of physiologic and environmental conditions (HAND et al., 2010).

Maintenance Energy Requirement is calculated for dogs using the formula 0,47 ME/kg $bw^{0,75}$ and 0,41 ME/$kgbw^{0,75}$ for cats (KAMPHUES et al., 2009).

In dependance of breed, individual conditions and age, deviations from the mean of -25% to +50% are possible. MER will be higher in temperamental young short haired dogs, which are kept outside and possibly less in old, lazy, long haired dogs, kept in-door (MEYER and ZENTEK, 2010).

Daily energy requirement (DER) represents the average daily energy requirement of any animal and depends on life-stage and activity. Calculation is based on the resting energy requirement (RER) for the animal modified by a factor to account for normal activity or production (e.g., growth, gestation, lactation, work). The DER for growing, pregnant, lactating and exercising animals includes energy needed for maintenance plus the additional energy for work and production. Estimates of the DER for dogs range between 397 to 850 kJ of DE $BWkg^{0.75}$ per day (HAND et al., 2010).

The NRC recommends a DER for adult cats of 290 to 380 kJ/$BWkg^{0,75}$/day.

2.1.2. Fats

Lipids are high energy compounds that supply nutritional and functional requirements in mammals. Lipids that are solid at room temperature are commonly called fats whereas those that are liquid at room temperature are referred to as oils. Dietary intake of lipids benefits dogs and cats in many different ways including membranes, energy storage, signaling and other functions. After absorption and breakdown of the absorbed fats, fatty acids are burned and serve as energy supply. Dietary fats are the most concentrated forms of energy sources in pet foods, supplying 2.25 times the metabolizable energy of proteins and carbohydrates. Dietary fat provides a physical positive environment in the gut that enhances absorption of fat-soluble vitamins (A, D, E, K) (HAND et al., 2010; MEYER and ZENTEK, 2010).

There is no requirement of „fat“ as such but rather a requirement of essential fatty acids. Fatty acids are the key constituent of lipids. Certain long-chain fatty acids that are necessary for adequate physiologic functions cannot be synthesized de novo and the metabolism thus depends on adequate dietary intake. These fatty acids are called essential fatty acids and insufficient supply leads to classic signs of deficiency. The Ω-3 and Ω-6 fatty acid families are essential fatty acids. α-linolenic acid belongs to the Ω-3 family and is required for brain and retinal function, contributing to cell membrane fluidity and skin health. Members of the Ω-6 family include linolenic acid, γ-linolenic acid and arachidonic acid. Linolenic acid and α-linolenic acid are essential fatty acids for both cats and dogs. Good examples of plant sources of linolenic acid and α-linolenic acid are safflower oil, sunflower oil or corn oil. Soybeans offer both linolenic acid and α-linolenic acid in a great amount (FASCETTI and DELANEY, 2012; NRC; 2006).

Dogs are able to synthesize arachidonic acid by elongating and desaturating linolenic acid; However a study performed by MacDONALD et al (1984) suggested, cats cannot. Cats therefore strongly depend on sufficient supply of this essential fatty acid in food, and as no arachidonic acid is found in common plants, in a vegan diet, cats depend on a synthetical composed arachidonic supplement added to their food. Arachidonic acid is important for platelet aggregation, prevention of mild mineralization of the kidneys and for reproduction especially in female cats (HAND et al., 2010).

Table 1: Requirements of linolenic acid (NRC, 2006)

Adult dogs	growing puppies	lactating bitches
0.4 g/ kg	0.8 g/ kg	1.6 g/ kg
Adult cats	growing kittens	lactating female cats
0.14 g/ kg	0.2 g/ kg	0.3 g/ kg

Complete foods should contain a min. of 1-1.3% DM linolenic acid for dogs and 0.55 % DM for cats. Recommendations regarding arachidonic acid in food go from 0.006 % DM for adult cats to 0.02 % DM for weaning cats (F.E.D.I.A.F, 2013).Excess dietary lipids may be assimilated and stored as fat in adipocytes. A Deficiency of fatty acids will impair wound healing, cause a dry lusterless coat and scaly skin, and also change the lipid film on the skin. If deficiency persists, alopecia, edema and moist dermatitis may develop. An EFA deficiency can also lead to neonatal abnormalities and abortions (HAND et al., 2010; MEYER and ZENTEK, 2010).

2.1.3. Carbohydrates

Carbohydrates encompass monosaccharides (e.g., glucose) and disaccharides (e.g., sucrose), oligosaccharides (e.g., raffinose) and polysaccharides (e.g. starches).

The body uses simple carbohydrates and starches in foods as a source of glucose. They provide energy (ATP) and are a source of heat for the body. Certain products can be used as building blocks for other nutrients, such as nonessential amino acids, glycoproteins, glycolipids, lactose, vitamin C, etc.

Simple carbohydrates and starches in excess of the body's immediate energy needs are stored as glycogen or converted to fat (HAND et al., 2010).

Carbohydrates supply approximately 17 kJ/g (BIESALKSI et al., 2010). Although there is no minimum dietary requirement for simple carbohydrates or starches per se, certain organs and tissues (e.g. brain and red blood cells) require glucose for energy. The body always maintains a glucose supply to key tissues; thus, if adequate dietary carbohydrates are unavailable, amino acids will be used for glucose synthesis. When energy requirements are high and tissue accretion is occurring (e.g., during growth, gestation and lactation), adequate dietary carbohydrates or glucose precursors are necessary to maintain metabolic processes (HAND et al., 2010).

Dogs and cats do not have an absolute dietary requirement for carbohydrates in the same way that essential amino acids or fatty acids must be provided. They do, however, have a requirement for adequate glucose or glucose precursors to provide essential fuel for the central nervous system. When energy needs are high and anabolic processes are proceeding at an active rate (e.g., during growth, gestation and lactation), it is best to supply food containing readily digestible carbohydrates and starches. Foods fed to growing animals and those with high-energy needs should contain at least 20% carbohydrates. Grains such as corn, rice, wheat, barley and oats provide the bulk of starch in commercial pet foods and are well digested and absorbed due to cooking and extrusion processes during the pet food production. Starches are the primary carbohydrates found in corn, wheat, rice, barley, oats and potatoes. Meat is a poor carbohydrate source. Most starches from grains are easily digested in the small intestine, when fed raw or cooked to dogs and cats. Sugar is sometimes added to enhance palatability of pet foods. Unlike in people and other primates, dietary sugars do not pose a risk for dental caries in dogs and cats (HAND et al., 2010).

Normal cats can maintain adequate blood glucose levels when fed low-carbohydrate, high-protein foods. Cats produce only 5% of the the amount of pancreatic amylase that dogs produce. Unlike dogs, cats lack hepatic glucokinase activity, which limits their ability to metabolize large amounts of simple carbohydrates. If large amounts of carbohydrates are fed to cats signs of maldigestion occur (e.g., diarrhea, bloating and gas). Despite the limitations of digestive capacity and metabolism, the starch levels found in commercial cat foods are well tolerated (HAND et al., 2010).

2.1.4. Proteins

Proteins are the principal structural constituents of body organs and tissues, function as enzymes, hormones and antibodies or supply energy. Muscle protein composes nearly 50% of total body protein. Proteins consist of a chain of amino acids, several of which are classified as essential because they can not be synthesized in the body. 10 for dogs and 11 for cats. The body is able to synthesize new proteins and enzymes provided that all the necessary amino acids are available. Protein synthesis is limited when certain amino acids are not present or available in the quantities needed (MEYER and ZENTEK, 2010; HAND et al., 2010). A high rate of protein synthesis occurs during the production of red and white blood cells, cells of the skin, GI tract and pancreas. In addition, all body proteins are continuously broken down and re-synthesized. A fraction of amino acids are permanently lost as urea, ammonia, creatinine or nitrate in urine and feces, sweat, semen, secretions, skin desquamation and loss of hair. The efficiency by which amino acids from food are converted into tissue describes protein quality (HAND et al., 2010). Protein quality is influenced by amino acid availability and their concentration as well as the protein source. So called high quality proteins provide all essential amino acids. When a protein lacks one ore more of the essential amino acids it is referred to as poor quality protein.

Plant proteins are said to have a lower digestibility due to higher fiber content. In the stomach, a high fiber content leads to slower passage. However in the gut, high fiber diets lead to quicker passage of the food which might reduce degradation rate of nutrients and thus the availability of amino acids. However studies showed that ileal digestibility of crude protein was higher for diets containing soy protein sources than for ones containing poultry meal. Thus conducting soy protein sources are well utilized by

the dog prior to the terminal ileum, and soy protein concentrations offer a viable alternative to poultry meal as a protein source (CLAPPER et al., 2001; GRIESHOP and FAHEY, 2000). HUBER et al. (1994), observed no differences in protein digestion of cereal based diets containing either soybean meal or meat and bone meal. A large portion of the protein in cereal based dry pet foods typically comes from grains, rice, corn, wheat and barley. Soybean meal and corn gluten meal are concentrated sources of plant protein (HAND et al., 2010). In addition to fiber content, protein availability can be influenced by trypsin inhibitors, which are mainly found in plant protein source. Trypsin and chymotrypsin are enzymes that play a key role in the digestion of protein in animals. If inhibited, quality of food protein drastically decreases with lower availability of amino acids. Mild heat treatment during processing serves to inactivate the inhibitors and improves digestibility of plant usually high in those inhibitors such as soy (HEGARTY et al., 1982). Furthermore a high percentage of the inhibitors is physically removed, leaving soy isolates with a trypsin inhibitor activity as high as 40% of that found in raw soybeans (BAKER and RACKIS, 1986; FOX and CONDON, 1982 ; HAND et al., 2010). Protein quality of food can be improved through protein complementation, feeding multiple protein sources or supplementing single amino acids to the food (NRC, 2006). Rather than having a requirement of proteins, animals have an amino acid requirement. The amount of each amino acid that an animal requires varies based on individual constitutions (HAND et al., 2010). Dogs and cats will increase food intake to meet their amino acid requirements for maintenance if the food contains low quality protein. Clinical signs of protein deficiency include reduced growth rate, anorexia, anemia, infertility, alopecia, fatty liver, brittle hair and a poor coat, muscle atrophy and decreased blood levels of albumin (HAND et al., 2010; NRC, 2006).

Protein intake above requirement should be carefully monitored in any animal with renal or liver diseases. Feeding protein above requirements for healthy dogs and cats does not result in a true toxicity, because the excess amino acids from the protein are catabolized and the waste nitrogen is excreted (HAND et al., 2010).

The National Research Council (NRC) has established that canine foods should contain at least 22% protein, for growth, and 18% DM protein for adult maintenance (maximum of 30% DM dogs, 45% DM cats). Cats have higher protein requirements than most other domestic species (HAND et al., 2010).

2.1.5. Water

Water is one of the largest constituents of the animal body, varying up to more than 80% of the total. It is vital to life and is considered the most important nutrient. Water is necessary for the chemical reactions that involve hydrolysis (e.g., enzymatic digestion of carbohydrates, proteins and fats) and is the solvent in which substances are dissolved and transported from the intestines into the tissue. Water helps regulate body temperature and provides shape and resilience to the body.

Significant negative water balance can result in clinical dehydration, which can manifest in loss of skin elasticity. As a major constituent of body fluids, water helps lubricate the joints and eyes and provides protective cushioning for the nervous system. It aids in gas exchange in respiration by keeping the alveoli of the lungs moist and expanded, and is important for the excretion of urinary excreted substances via the kidneys. Younger, leaner animals contain more body water than fatter older animals. As animals mature, they require proportionately less water (HAND et al., 2010; MEYER and ZENTEK, 2010).

2.2. Micronutrients

Micronutrients are nutrients necessary for the body only in very small amounts but are nevertheless essential for good health. Micronutrients include organic nutrients like vitamins such as vitamin C, A, D, E, K and the B-complex vitamins. They also include inorganic chemical compounds such as dietary minerals (micro minerals), macro minerals (calcium, phosphorus, potassium, chloride, magnesium) or trace elements (iron, cobalt, chromium, copper, iodine, fluoride, manganese, selenium, zinc,…) (WEDEKIND et al., 2010).

Micronutrients can be found naturally in a variety of plant- and animal-based foods. In the following, only those micronutrients are further discussed, which are mainly provided by animal based foods and therefore might not be sufficiently provided in dogs and cats fed on a vegan diet.

3. Vegan Nutrition Issues

3.1. Protein - Amino Acids

Amino acids are the building blocks of proteins. Only 20 different amino acids are used and combined in different ways to make up all proteins needed in the body. Many amino acids are non-essential which means they can be synthesized in the body if adequate nitrogen and energy is available. However, there are several amino acids that cannot be synthesized in the body at all or not in sufficient quantities, and thus are essential amino acids (HAND et al.., 2010; NRC, 2006).

If enough non-essential amino acids are not synthesized and not adequately derived from food, essential amino acids will be converted into non-essential amino acids in the body (LEWIS et al., 1990). Dogs depend on dietary intake of ten essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine). Cats have a dietary requirement for an additional, eleventh, amino acid called taurine (NRC, 2006).

Amino acids are absorbed in the small intestinal lumen or fermented by bacterial enzymes in the hind gut. The availability of amino acids can be affected by high food dry matter intake, fiber, and foods that contain low quality protein (HAND et al., 2010).

Once absorbed, amino acids are reassembled into new proteins by the liver and other tissues of the body for tissue protein synthesis, synthesis of enzymes albumin hormones, and deamination for energy (LEWIS et al., 1990).

If a ration is low of a specific essential amino acid, protein synthesis will stop as soon this one essential amino acid is used up. This amino acid which is available in the smallest amount is called limiting amino acid because it inhibits synthesis and limits the quality of the whole protein of the ration (KIRCHGEßNER et al., 2011).

Thus combining different protein sources can make the amino acid profile of a ration much more efficient and result in food with high quality protein (GILLEN, 2003). As an example, corn protein is low in lysine and tryptophan whereas soybean meal is adequate in both amino acids. Together they make up to a well balanced amino acid profile. Furthermore, individual amino acids can be added to the food (HAND et al., 2010).

Combination of protein sources can result in imbalances or deficiencies of other amino acids.

Imbalance occurs when one or more amino acids needed for protein synthesis are not available in the quantity needed, but at least one other amino acid is provided in excess. Antagonism occurs when amino acids have similar chemical structures. Excess of one increases the requirement of one or more chemically similar amino acids (HAND et al., 2010).

Arginine

Arginine is a key intermediate in the urea cycle, stimulating urea synthesis and activating enzymes that lead to detoxification of ammonia for urea synthesis. It also elicits the release of sexual hormones and metabolic mediators (s.a. insulin, glucagon and gastrin). Arginine can be synthesized from citrulline and ornithine, which can be built from glutamate in the small intestine gut wall (FISCHMANN, 2005) Ornithine and Citrulline, other urea cycle intermediates, can prevent hyperammonemia and substitute for arginine (MORRIS et al., 1979). However, studies showed that neither ornithine nor citrulline are present in high enough quantities to substitute for arginine (HAND et al., 2010). Arginine deficiency can lead to hyper-ammonnia, tremors, emesis, apnea, cyanosis, and even death in cats (MORRIS and ROGER, 1978). Cats develop signs of deficiency rapidly (NRC, 2006).

Histidine

Histidine plays a structural role in proteins, acts glucogenic, and is the precursor of neuroactive and regulative compounds (s.a. histamine). It also plays an important role in oxygen exchange in the lungs. Histidine deficiency leads to decrease in hemoglobin and albumin (NRC, 2006).

Isoleucine

Isoleucine is ketogenic and glucogenic and a constituent of proteins (NRC, 2006).

Leucine

Leucine acts ketogenic and as a constituent of proteins. It enhances protein synthesis, increases plasma insulin and suppresses protein degradation in skeletal muscle (NRC, 2006).

Lysine

Lysine is a constituent of proteins and important for cross linkages in collagen. It is often acting as a limiting amino acid when low protein cereal based diets are fed. Good plant sources for Lysine are soybeans, soy protein isolate, wheat germ and beans. Lysine is the precursor of carnitine (NRC, 2006).

Methionin

Methionin is the most limiting amino acid in a diet for cats and the first or second most for dogs. It plays important role in cell replication and phospholipid synthesis, and deficiency will lead to interference with those processes (NRC, 2006).

If sufficient vitamin B is available, Methionin is a precursor to cysteine. Cysteine is non essential per se, however as it can provide one half of total need for sulfur amino acids, Cysteine has a special position among non-essential amino acids. It is an important component of protein, hair, and gluthationine which is an important. antioxidant.In cats, excess consumption of Methioin can lead to severe hemolytic anemia and heinz bodies formation (NRC, 2006).

Phenylalanine

Is needed for maximal black hair color and a constituent of proteins. It is the precursor for Tyrosine, which spares one half of the phenylalanine needed and therefore takes a special role among the non essential amino acids. Tyrosine is needed for protein synthesis and the synthesis of thyroid hormones and catecholamines (NRC, 2006).

Threonine

Threonine is glucogenic and regulates enzyme activity (NRC, 2006).

Tryptophan

Is the precursor of neurotransmitter (Serotonin, Melatonin) and the precursor of niacin in dogs. Cats cannot synthesize a significant quantity of niacin from tryptophan, thus depend on adequate dietary intake (NRC, 2006).

Valine

Valine is a constituent of proteins (NRC, 2006).

Taurine

Taurine is an important essential amino acid for cats. Taurine is not incorporated into proteins synthesized by the body but is rather found as a free amino acid in many tissues. Taurine acts as a neurotransmitter and neuromodulator and is involved with body temperature regulation, maintenance of normal retinal structure and heart function. Once absorbed in the intestine, it is conjugated to bile acids in the liver (assisting in the absorption of dietary fats). Whereas dogs conjugate bile acids to both taurine and glycine, conjugate cats them only to taurine. Cats have an obligatory loss of taurine in feces and intestinal losses through enterohepatic circulation. Obligatory losses coupled with little capacity for cats to synthesize taurine make it an essential amino acid for cats. Taurine deficiency can lead to reproductive failure and central retinal degeneration. Furthermore, it is well known that taurine deficiency can cause dilative cardiomyopathy in American Cocker Spaniels and Golden Retrievers (SANDERSON, 2006; BELANGER et al., 2005; KRAMER et al., 1995). It can be recommended to add taurine supplementation to dog food in order to guarantee sufficient supply.

Also taurine requirement increases slightly with increased dietary protein (NRC, 2006).

3.2. Vitamin D

Vitamin D is a fat-soluble vitamin that functions in the intestine, bone and kidney by enhancing intestinal absorption of calcium and phosphorus, stimulating deposition of bone calcium and increasing renal reabsorption of calcium.The most important substances in the body with Vitamin D function are cholecalciferol (Vitamin D3), which occurs mainly in animals, and ergocalciferol (D2), which occurs predominantly in plants (MEYER and ZENTEK, 2010). Vitamin D2 is said to be less efficiently used than vitamin D3 (HAND et al., 2010). However in dogs, different from cats, plant based vitamin D2 is proved to be of almost the same efficiency as the animal based vitamin D3 (MEYER and ZENTEK, 2010).

The skin of most mammals can produce cholecalciferol via activation of 7-Dehydrocholesterol with ultraviolet-B light. However, according to HAZEWINKEL et al. (1987), HAZEWINKEL and TRYFONIDOU (2002) and MORRIS (1999), this photosynthesis pathway is inefficient in dogs and cats. Cats and dogs therefore ultimately depend on adequate dietary intake of vitamin D. Vitamin D is absorbed from the small intestine by non-saturable, passive diffusion, which depends on bile salts. Like other steroids, vitamin D is transported in association with proteins. Vitamin D is distributed relatively evenly among the various tissues where it resides in lipid depots. Vitamin D can be found in adipose, kidneys, liver, lungs, aorta and heart (HAND et al., 2010). In mammals, both vitamin D2 and D3 are not the active form of vitamin D. They are activated in the body by hydroxylation first in the liver and again in the kidneys to 1,25-(OH)2-D3 (Calcitriol). The demand for this active substance depends on demand for calcium and intake of phosphorus (MEYER and ZENTEK, 2010)

The vitamin D-dependent homeostatic system responds to changes in calcium concentration. When serum calcium falls below a given level, parathormon (PTH) is secreted by the parathyroid glands, which function is to detect and correct hypocalcemia. The kidneys respond to PTH, resulting in phosphate diuresis and stimulation of calcitriol synthesis, which leads to increased enteric absorption of calcium and phosphate. In addition, calcitriol, cooperates with PTH in bone to promote mobilization of calcium and phosphate. The combined result of these responses is to increase plasma concentration of calcium and phosphate (HAND et al., 2010). Calcitonin is secreted by the thyroid gland when circulating concentrations of calcium

are increased. Calcitonin suppresses bone mobilization and may increase the renal excretion of calcium and phosphate (HAND et al., 2010).

Animal products and tissues, especially fish and fish oils, are known to be good sources of vitamin D, whilst plants are usually rather devoid of that vitamin (MEYER and ZENTEK, 2010) One group of investigators found that moist foods generally contained higher levels of vitamin D than extruded foods (HAND et al., 2010).

Signs of vitamin D deficiency are frequently accompanied by a simultaneous imbalance of calcium and phosphorus. Clinical signs generally include rickets, enlarged costochondral junctions, osteomalacia, osteoporosis and decreased serum calcium and inorganic phosphorus concentrations (HAND et al., 2010). Deficiency generally leads to insufficient mineralization of the skeleton (MEYER and ZENTEK, 2010).

In cats, deficiency results in neurologic abnormalities associated with degeneration of the cervical spinal cord (MORRIS, 1996). Other signs include hypocalcemia, elevated PTH concentrations, posterior paralysis, ataxia and eventual quadriparesis (HAND et al., 2010). The vitamin D allowance recommended by NRC (2006) is 13.8 µg cholecalciferol (552 IU)/kg DM for dogs regardless of life stage, and 5.6 µg cholecalciferol/kg DM (250 IU) for cats for growth, and 7 µg cholecalciferol/kg DM (280 IU) for maintenance and reproduction (HAND et al., 2010). Excessive vitamin D3 supplementation; even if it is still below the toxic level, decreases bone remodeling and causes focal enlargement of the growth plate in growing puppies. Excessive vitamin D concentrations may result in hypercalcemia, soft-tissue calcification, and ultimately death (HAND et al., 2010). The NRC (2006) proposed a safe upper limit of 80 µg cholecalciferol (3,200 IU)/kg DM for dogs and 750 µg cholecalciferol (30,000 IU)/kg DM for cats regardless of life stages.

3.3. Vitamin A

Vitamin A, retinol, is a general term describing a group of compounds with the biologic activity of retinol. Most of the preformed vitamin A in food is in the form of retinyl esters, whereas the source of vitamin A from plants is in the form of provitamin A carotenoids (HAND et al., 2010).

In nature, all of the vitamin A ingested by animals originates from carotenoids synthesized by plants. The conversion of carotenoids to vitamin A requires oxidative cleavage of the carotenoid molecule beta-carotene (NRC, 2006). Dogs have the ability to use carotenoid precursors of vitamin A (s.a. beta-carotene) and convert it to retinol (NRC, 2006). Cats can absorb β-carotene but are unable to convert carotenoids to vitamin A and therefore cannot meet their vitamin A requirement from carotenoids (SCHWEIGERT et al., 2002).

1 IU of vitamin A is equal to 0.3 μg of retinol. 1mg beta carotin is equal to approximately 500 IU vitamin A (MEYER and ZENTEK, 2010)

Vitamin A is essential for growth, reproduction, immune function and maintenance of healthy epithelial tissue and is involved in the expression and regulation of many genes (HAND et al., 2010). Vitamin A is also the major component of the retina and therefore of special importance for vision (MEYER and ZENTEK, 2010).

Retinyl esters and carotenoids are hydrophobic, thus their dispersion into the aqueous environment of the small intestinal lumen requires bile salts for micellar solubilization. Dietary carotenoids are therefore only absorbed half as well as preformed dietary vitamin A. Vitamin A is transported through the lymphatic system to the liver, which is the main storage site in both cats and dogs. In cats, kidneys contain a much higher vitamin A concentration than other species (NRC, 2006).

NRC (2006) recommends a vitamin A allowance of 1,515 RE (retinal equivalent) (5,050 IU)/kg DM for dogs for all life stages and 1,000 RE (3,333 IU)/kg DM for cats for growth and maintenance.

Signs of vitamin A deficiency can be night blindness, retinal degeneration and extreme dryness of the conjunctiva. Other signs include anorexia, weight loss, ataxia, skin lesions, increased susceptibility to infection, poor coat, weakness, increased cerebrospinal fluid pressure, nephritis, skeletal defects and impaired reproduction

(NRC, 2006). The most characteristic signs of hypervitaminosis A are skeletal malformation, spontaneous fractures and internal hemorrhage . Other signs include anorexia, slow growth, weight loss, skin thickening, suppressed keratinization, increased blood clotting time, reduced erythrocyte count, enteritis, congenital abnormalities, conjunctivitis, fatty infiltration of the liver and reduced function of liver and kidneys (HAND et al., 2010).

NRC (2006) proposed a safe upper limit of 64,000 RE (213,333 IU)/kg DM for adult dogs. The safe upper limit of vitamin A for cats is 100,000 RE (333,333 IU)/kg DM for maintenance, gestation and lactation.

Naturally rich sources of vitamin A are fish oil, liver, egg and dairy products. The most common vitamin A supplements used in pet foods include vitamin A esters (HAND et al., 2010). Plants, particularly bright yellow and orange ones, such as carrots, sweet potato, kale, pumpkin are a good source for beta carotene, provitamin A (O'HEARE, 2013).

3.4. Vitamin B3

Niacin is a water-soluble vitamin and is essential to several physiologic oxidoreductive reactions and others that are significant in normal cell function.

Dietary niacin (nicotinic acid and nicotinamide) is absorbed readily through the gastric and small intestinal mucosa. In most mammals, foods high in tryptophan can alleviate signs of niacin deficiency. However, cats cannot efficiently use tryptophan to synthesize niacin and therefore have a strict dietary requirement for preformed niacin (HAND et al., 2010). Deficiency of niacin can result in dermatitis, diarrhea, dementia and death.

Cats are more likely to develop signs of deficiency than dogs because of their strict requirement for niacin. Niacin deficiency may occur when foods with low quantities of niacin and tryptophan are ingested (HAND et al., 2010). No niacin toxicity information in cats or dogs is available, as excess niacin is excreted in urine.

The greatest amounts of niacin are found in animal based products, however cereals, legumes (s.a. kidney beans), oilseeds and yeast especially are also rich of Niacin (HAND et al., 2010). According to the NRC (2006), the recommended allowance for niacin is 17 mg/kg DM for dogs and 40 mg/kg DM for cats for all life stages.

3.5. Vitamin B12

Cobalamin is a water soluble Vitamin and the largest and most complex B vitamin.
It is synthesized only by certain microorganisms and all animals ultimately depend on microbial synthesized cobalamin (NRC, 2006).
After oral intake, dietary vitamin B12 is freed from food peptides and proteins in the stomach by hydrolysis through gastric acidification and pancreatic enzymes (HAND et al., 2010). Free vitamin B12 binds to a glycoprotein, called the intrinsic factor (IF). IF is essential for vitamin B12 absorption. In dogs, unlike humans, the pancreas is the major and the stomach a lesser source of IF. According to the NRC (2006), in cats, the pancreas is the sole source of IF. The resulting stable vitamin B12-IF complex is mainly absorbed in the ileum but significant absorption was also noticed in the jejunum of dogs and cats. After absorption by enterocytes, vitamin B12 is transported as methylcobalamin in blood by proteins. In cats cobalamin is mainly present in the form of adenosylcobalamin and hydrocobalamin (NRC, 2006). Transcobalamin II, a protein without a carbohydrate moiety, carries about 75% of vitamin B12 in the blood of dogs and cats. (cf. HAND et al., 2010) A recessive heritable blockage of vitamin B12 absorption is known in Giant Schnauzers (MEYER and ZENTEK, 2010).
Cobalamin is bound to protein as methylcobalamin or adenosylcobalamin. (NRC, 2006)
The active forms of B12, coenzymes, adenosylcobalamin and methylcobalamin, participate in the functioning of more than a dozen enzyme systems and have an important role in biochemical processes.The two most important reactions involving cobalamin are the conversion of methylmalonyl-coenzyme A (CoA) to succinyl-CoA and the remethylation of homocysteine which leads to synthesis of methionine (HAND et al., 2010).
All DNA- synthesizing cells take up vitamin B12 from the blood as vitamin B12 is required by the enzyme methionine synthase, which is needed for pyrimidine biosynthesis (HAND et al., 2010).
The intestinal flora of dogs and cats can synthesize cobalamins in the presence of cobalt, however, as the site of production is caudal to the site of absorption, this ability is not of much use. Vitamin B12 therefore has to be supplied by adequate dietary intake. (NRC, 2006)

Only certain microorganisms synthesize cobalamin. Microbes and yeast can make vitamin B12 for absorption by animals. The major food sources of cobalamin are animal products. Meat, and to some degree milk products, are good sources of vitamin B12. Plant products are generally devoid of this vitamin or contain only very small amounts (NRC, 2006). HAND et al. (2010) suggest that longterm feeding of vegetarian diets may lead to vitamin B12 deficiency, as vitamin B12 is only made by microbes and found in animal tissue. However, most commercial pet foods, including vegan or vegetarian pet foods, are supplemented.

Vitamin B12 deficiency first becomes a problem in tissues with rapid cell division, because fast dividing cells (such as enterocytes, bone marrow cells, neurocytes) especially depend on cobalamin (KOOK, 2013).

Deficiency may result in poor growth and neuropathies, but can also lead to GI signs and systemic complications such as immune deficiency and anemia (HAND et al., 2010). Other than inadequate dietary intake, exocrine pancreatic insufficiency is also often associated with subnormal serum cobalamin concentrations, because secretion of the intrinsic factor is reduced or absent. Furthermore, gastrointestinal diseases can cause cobalamin deficiency. GI problems may affect the absorptive capacity of the ileal (and jejunal) mucosa and chronic enteropathies will lead to serum hypocobalaminemia and ultimately to cobalamin deficiency (KOOK, 2013). Clinical signs of deficiency can not be expected to occur immediately, as reserves of vitamin B12 in the liver can be mobilized (MEYER/ZENTEK, 2010).

According to a recent study (GRÜTZNER et al., 2010), Shar Peis have a high prevalence of cobalamin deficiency compared to other breeds and healthy appearing Shar Peis may have subclinical cobalamin deficiency.

To detect early or mild cobalamin deficiency, measuring methylmalonic acid (MMA) or total plasma homocysteine can be useful, as cobalamin deficiency leads to reduced activity of these enzyme systems (NRC, 2006). However, this test is expensive and therefore rarely used in veterinary medicine. Vitamin B12 may also be directly assessed by determination of serum vitamin B12 levels. The active forms of cobalamin from dietary intake are very unstable. Commercially produced cobalamin is derived from fermentation, and during isolation a cyano group is attached. Cyanocobalim is considered very stable in foodstuff (NRC, 2006) and may be used as pharmaceutical supplement, sane as hydroxocobalamin or nitritocobalamin (HAND et al., 2010).

The NRC (2006) recommended allowance for vitamin B12 is 35 µg cobalamin/kg DM for dogs and 22.5 µg/kg DM for cats, regardless of life stages. A dietary maximum concentration for vitamin B12 has not been proposed.

Cobalamin should be considered for supplementation whenever serum cobalamin is subnormal or in the low normal range.

The Gastrointestinal Laboratory of the University for Texas, currently recommends repeating subcutaneous injections of 250 µg per injection in cats and, depending on the size of the patient, 250-1500 µg per injection in dogs.

3.6. Folic Acid

Folate stands for a group of compounds with the biologic activity of folic acid.

Folic acid is absorbed in the small intestine and is important for the transfer of methyl groups in intermediary metabolism (MEYER and ZENTEK, 2010).

Pathways include nucleotide biosynthesis, phospholipid synthesis, amino acid metabolism, neurotransmitter production and creatinine formation. In addition, vitamin B12 is closely paired with folate in the production of methionine from homocysteine (HAND et al., 2010). Microorganisms in the intestine synthesize a large amount of folate, therefore adult dogs with normal intestinal function only have a small demand for dietary intake (MEYER and ZENTEK, 2010). Folate is found in plant-based and animal-based foods. Liver, egg yolks, green vegetables, salads and yeast are good sources of folate. The vitamin is destroyed by heating, prolonged freezing and during storage in water. Commercial pet foods are supplemented with folate to overcome the effects of processing and storage (HAND et al., 2010). Folate deficiency is characterized by poor weight gain, hypo chromic megaloblastic anemia, anorexia, leukopenia and decreased immune function (MEYER and ZENTEK, 2010).

In cats, folate deficiency is associated with hyperhomocysteinemia. There have been no reported cases of folate toxicity and therefore no dietary maximum concentration for folic acid has been proposed (HAND et al., 2010).

The NRC (2006) recommended allowance for folic acid is 270 µg/kg DM for dogs and 750 µg/kg DM for cats regardless of life stage.

3.7. Iron

Iron is a micro mineral which plays an important role in several enzymes and other proteins responsible for oxygen activation, for electron transport, and for oxygen transport (in hemoglobin and myoglobin) (HAND et al., 2010).

67% of iron in the body is present in hemoglobin, 27% in storage sites, 4% in muscle tissue as myoglobin and the remainder in various enzyme systems that are important in energy metabolism. The primary role of iron is the synthesis of hemoglobin and myoglobin, where it functions as a binder and transporter of oxygen (NRC, 2006).

Iron in foods exists in two forms, heme iron present in hemoglobin and myoglobin (as in meat) and non-heme iron present in grains and plant sources (HAND et al., 2010).

The amount of iron absorbed from food is determined by the iron status of the body, the availability of dietary iron and the amounts of heme and nonheme iron in food (HAND et al., 2010). Heme iron absorption is not greatly affected by iron status or other dietary factors. In contrast absorption of nonheme iron is markedly influenced by iron status and by several dietary factors such as phytate, tannins and excesses of phosphorus, manganese, zinc, copper and ascorbic acid. Food rich in ascorbic acid has been proven to have a positive influence on iron absorption. Calcium is a dietary factor that inhibits both, heme and nonheme iron absorption (HAND et al., 2010). Various fiber sources (s.a. psyllium, pectin) also have shown to reduce the apparent percentage absorption of Fe intake (in human diets) (NRC, 2006).

Iron is transported by plasma and is taken up by the bone marrow for hemoglobin synthesis. Although a small amount of hemoglobin circulates in plasma, by far the greatest amount of plasma iron is complexed to the specific iron-binding transferrin. The degree of saturation of transferrin affects deposition of iron in liver stores and the supply of iron to red blood cell precursors (HAND et al., 2010).

Iron is stored predominantly as ferritin and hemosiderin in liver, bone marrow and spleen. Iron is continuously lost in sweat, hair and nails, but because of the limited capacity of the body to excrete iron, iron homeostasis is maintained primarily by adjusting iron absorption (HAND et al., 2010).

NRC (2006) recommends a minimum of 88 mg/kg DM iron for growth and 30 mg/kg DM iron for adult dogs. Iron recommendation for cats is 80 mg/kg DM for growth and adult life stages.

Iron concentrations are high in most meat ingredients, especially organ meats such as liver, spleen and lungs. Seaweed, soybeans, lentils, spinach and fiber sources such as beet pulp, soy mill run and peanut hulls can be listed as good vegetarian sources of iron (HAND et al., 2010).

Signs of deficiency are microcytic hypochromic anemia and a low percentage saturation of plasma transferrin, poor growth, pale mucous membranes, lethargy, weakness, diarrhea, hematochezia, and melena (FASCETTI et al., 2012).

Intake of larger amounts than necessary can overwhelm the small total binding capacity of proteins and result in the presence of toxic amounts of free Fe in the system. However, since there are no studies of Fe toxicity in dogs being fed standard diets, no recommendation as to a safe upper limit can be made by the NRC (2006). However, iron excesses should be avoided because of potential antagonism with other minerals (e.g., zinc and copper) (HAND et al., 2010).

3.8. Urinary pH

pH, power of hydrogen, is the measure for acidity or basicity of a solution. The range of pH values goes from pH 0 to pH 14, with 0 being the value for concentrated hydrochloric acid, 7 being neutral pH and 14 the value for concentrated sodium hydroxide. Therefore pH 1 – pH 6,9 describes an acidic solution, pH 7 a neutral solution and pH 7,1 – 14 a basic solution. The normal healthy range for the pH of a cat's urine is pH 5,5 - 7, the normal healthy range for the pH of a dog's urine is pH 5 – 7 (KRAFT and DÜRR, 2013); However it is normal for some healthy normal dogs to have values a little more acidic or basic. pH is important at it acts directly to crystallization in the urinary system and bladder stones.

A change in urinary pH does not indicate the presence or absence of stones but influences conditions that are more or less likely to trigger stone production.

Excessive dietary vitamin C is raised as a concern in patients with a history of calcium oxalate urolithiasis since it can increase urinary oxalate excretion (BAXMANN et al, 2003).

4. Vegan Pet foods

The increasing demand for vegan pet feeds has prompted the marketing of commercially produced canned diet or kibble that meet up to the requirements and the idea of a strictly plant based diet and the vegan philosophy. Many options and brands are available worldwide.

4.1. Commercial diets

A number of commercial vegetarian and vegan pet foods are available in Germany and Austria, of which the following were most commonly fed to dogs and cats participating in this study on a regular daily basis.

4.1.1. Wet Food

- BENEVO DUO. Benevo Foods, Unit 5 Downley Point, Downley Road, Hants, P09 2NA, USA. www.benevo.com

A complete and nutritionally balanced adult vegetarian dog and cat food. Formulated by professional pet nutritionists, Benevo Duo is a tasty and digestible vegetarian food prepared without animal ingredients, artificial flavours or colours. Free of all common allergens such as meat, fish, soya, wheat and dairy. Complete diet with balanced nutrition. Contains vegeterian Taurine, good for dogs & essential for cats (label, 05/2014)

Composition: water, potatoes, carrots, oat groats, sunflower oil, peas, brown rice, tomatoes, blueberries, cranberries, brewers yeast (label, 05/2014)

- AMÌ wet food, 5 Elements Italia srl, via Boccalerie 12, 35139 Padova, Italia, info@amipetfood.com, www.amipetfood.com

Complete vegetable based food for adult dogs. The product contains only plant based protein sources. It is also suitable for animals particularly predisposed to food sensitivities. The needs of individual animals are nonetheless subject to peculiarities and variations (label, 08/2014)

Composition: beans, carrots 12%, lentils, potatoes 10%, peas, sunflower seed oil, pea protein, minerals, hydrolyzed vegetable protein (label, 08/2014)

- VEGUSTO, Vegi-Service AG, CH-9315 Neukirch, www.vegi-service.ch
  Complimentary food for cats. Recommendation to combine or alternate the wet food with dry food for example VEGUSTO CAT and AMÌ CAT dry food.

  Vegusto's cat food is specifically designed for vegan gourmet cats using the finest and freshest ingredients. All of Vegusto's cat food contains Vegecat™, a purely plant-based supplement for all essential cat nutrients which has been used in the U.S. since 1986 and is recommended by veterinarians.
  Composition: water, wheat protein (gluten), vegetable oils (non-hydr.), Vegecat™, spices, yeast, spices, rice starch, rock salt.

4.1.2. Dry Food

- AMÌ DOG MINI. Amì srl, Corso Milano 5, 35139 Padova, Italia, www.amipetfood.com

An healthy daily food for smaller friends. Vegetable based Amì Dog (mini) is a complete food for small size adult dogs, light and easy to digest. No need to add supplements. It helps your dog to be more vital and healthy. Balanced formula, only 100% vegetable raw materials, without any artificial colors and preservatives, hypoallergenic (label, 08/2014)
Ingredients: corn, corn gluten, corn oil, rice protein, peas, linseed, beet pulp, potato protein, brewers yeast, L-Carnitine, linoleic acid (6,90%) (label, 08/2014)

- AMÌ DOG. Amì srl, Via Boccalerie 12, 35139 Padova, Italia. www.amipetfood.com

Complete pet food for adult dogs. Amì Dog is a vegetable based complete and balanced food for adult dogs of all sizes, no need to add supplements. Raw materials 100% vegetable, no dyes, nor preservatives, balanced nutritional formula. (label, 08/2014)
Composition: corn, corn gluten, corn oil, rice protein, whole peas, beet pulp, linseed, bicalcium phosphate, hydrolyzed vegetable protein, potato protein, brewer's yeast, calcium carbonate, sodium chloride, rapeseed oil. (label, 08/2014)

- YARRAH Organic Vegetarian Dog Food. Yarrah Organic Pet food B.V., P.O. Box 448, 3840 AK Harderwijk, The Netherlands. info@yarrah.com, www.yarrah.com

Complete pet food for adult dogs. Yarrah Organic Vegetarian Dog Food is a 100% organic, healthy and complete meal, which is prepared with the finest ingredients. This recipe is completely vegetarian / vegan and contains no meat or animal by-products. Yarrah Organic Vegetarian Dog Food can prevent skin and coat problems, stomach and intestinal problems and hyperactivity, which can be caused by meat consumption (www.yarrah.com, 2014)

Composition: wheat*, soya beans*, corn*, sunflower seed husks*, semolina*, minerals, brewers yeast. *= from controlled organic farming sources, Skal 1301 (label 08/2014)

- AMÌ CAT, 5 Elements Italia srl, via Boccalerie 12, 35139 Padova, Italia, www.5elementsitalia.com

  Complete pet food for adult cats. Amì Cat is a complete balanced plant based food for adult cats of all breeds. Ami Cat is based on exclusive vegetable proteins and gives the cat more vitality and health. Its natural formula is hypoallergenic in almost all cases, and helps to solve typical problems of poor nutrition: heavy or slow digestion, appetite and fatigue. The ingredients are 100% vegetable raw materials, without artificial dyes and preservatives, a traditional balanced formula (www.amipetfood.com, 2014).

  Composition: corn gluten, corn, corn oil, rice protein, whole peas, pea fibre, brewer's yeast, bicalcium phosphate, linseed, hydrolyzed vegetable protein, potato protein, sodium chloride, calcium carbonate, rapeseed oil (label, 05/2014).

4.1.3. Nutrional additives

Table 2: Nutritional additives of selected vegan diets

	AMÌ DOG reg. size (label, 05/2014)	AMÌ DOG small size (label, 08/2014)	YARRAH organic (company, 05/2014)	BENEVO Duo (label, 05/2014)	AMÌ wet (label, 05/2014)	AMÌ CAT (label, 05/2014)
	per kg					
Vitamin A (IU/kg)	26000	18000	25000 (Retinol)	✓	4050	27500
Vitamin D (IU/kg)	1350 (D3)	1350 (D3)	1500 (D2)	200 (D2)	120 (D3)	1600
Vitamin E (mg/kg)	355	265	125	✓ (n.s.)	9	270
Copper (mg/kg)	50	20	13	✓ (n.s.)	-	10
Iron (mg/kg)	348	-	70	✓ (n.s.)	-	186
Iodine (mg/kg)	25	-	1,5	✓ (n.s.)	-	4
Selenium (mg/kg)	20	-	0,3	✓ (n.s.)	-	10
Zinc (mg/kg)	160	-	150	✓ (n.s.)	-	100
Manganese (mg/kg)	56	-	47	✓ (n.s.)	-	12
L-carnitine (mg/kg)	300	300	235	-	-	300
Taurin (mg/kg)	-	-	470	6,6	-	1500
Vitamin B12 (mcg/kg)	-	-	0,07	✓ (n.s.)	-	-
Vitamin B1-B7 (IU/kg)	-	-	-	✓ (n.s.)	-	-
Vitamin C (IU/kg)	-	-	-	✓ (n.s.)	-	-

✓ added * n.s. ….. not specified

4.2. Home-prepared diets

Feeding commercially prepared pet foods offers several advantages over feeding homemade foods, including convenience, cost, consistency and potentially better nutritional balance. Nevertheless, a growing number of pet owners prefer to prepare homemade foods. Owners mainly state that they feel comfortable knowing and being in control about what they feed, the composition and the origin of ingredients.

REMILLARD (2010) suggests that without adequate supplementation, using synthetic ingredients, cats fed vegan diets are at high risk for various deficiencies.

To provide adequately balanced self made rations, a conscientious examination with the subject of vegan pet nutrition is necessary. Focus of attention should mainly be paid to adequate composition and supplementation of nutrients that can only be found in animal products or only in little amounts in plants (vitamin B12, arachidonic acid, iron, …)

Example recipes for home-prepared diets for cats can be found in the book „Vegetarian Cats & Dogs“ (PEDEN, 1999). Guaranteed dry matter analysis of the „Vegecat Kibble™“ recipe published in the book shows sufficient or the requirement exceeding supply with nutrients (AAFCO, 1999; PEDEN 1999).

Another recipe published by PEDEN (1999) is a wet food composition for adult cats.

Another example for a self-prepared vegan diet is provided by JAMES O'HEARE in his book „Vegan Dogs“ (2013). The diet was formulated to be balanced and complete by a nutrition consultant, for a healthy 30kg dog in average condition, getting average low to moderate exercise. For dogs much outside of this range, the diet needs to be formulated to meet their specific needs (O’HEARE, 2013).

4.3. Supplements

VEGECAT™ : Dried kelp (source of arachidonate), calcium carbonate, monocalcium phosphate, DI-methionine, Taurine, Choline chloride, DI- alphatocopheryl acetate, Zinc oxide, Ferrous sulfate, Vitamin A-acetate, Copper sulfate, Ergocalciferol, Sodium selenite, Vitamin B_{12}supplement Guaranteed anaylsis (100g): Calcium 10068 mg, Phosphorus 1253 mg, Methionine 3717 mg, Taurine 3585 mg, Choline 1895 mg, Arachidonate 400 mg, Vitamin E 227 IU, Zinc 55 mg,
Iron 73 mg, Vitamin A 8963 IU, Copper 3,5 mg, Vitamin D_2 896.3 IU, Selenium 0.135 mg, Vitamin B_{12} 0.036 mg

VEGEYEAST™ composition: Dried yeast, Dried autolyzed yeast, Dried yeast extract; according to the producer, Vegeyeast™ is 100 times more acid than other yeasts such as brewers or nutritional yeast and is 35% lower in magnesium. (http://www.vegepet.com). According to the producer, the higher acidity and low content of magnesium both are supposed to keep the urinary pH within a healthy acidic range and help prevent the building of Struvite within the urinary tract.

VEGEDOG™ : Monocalcium phosphate, Calcium carbonate, dried kelp, Taurine, Zinc oxide, Ferrous sulfate, DI-alphatocopheryl acetate, Choline chloride, Sodium selenite, Vitamin B_{12}supplement, Vitamin A-acetate

Guaranteed anaylsis (100g): Calcium 24185 mg, Phosphorus 9692 mg, Taurine 2360 mg, Zinc 400 mg, Choline 365 mg, Vitamin E 350 IU, Zinc 55 mg, Iron 156 mg, Vitamin A 19880 IU, Selenium 0.27 mg, Vitamin B_{12} 0.1 mg

5. Material and Method

Over a period of 2 years pet owners from Austria, Germany and Switzerland were gathered via notice boards in veterinary practices, numerous articles in various forums and groups of the online platform Facebook®, and word of mouth, to participate in this study or to complete a questionnaire about their experience of feeding their cats and dogs on a vegan, plant-based, diet, it's implementation and consequences that come with it. The compilation of the questionnaire contained questions which were to be answered with predetermined selectable answers and semi-open or open questions that could be answered in own words and descriptions.

A template of the questionnaire used in this study can be found at the very end of this paper (Appendix).

Provided pet owners gave their consent, the questionnaire was followed by a standardized clinical examination and blood collection in pets concerned.

An approval for animal testing was obtained for the blood assessment. (GZ: BMWF-68.205/0153-II/3b/2012)

To get an idea of the distribution of the serum levels mentioned above in conventionally fed dogs and cats and to have a possibility of comparison, IDEXX laboratory was approached to send anonymously and randomly picked data of 20 conventionally fed dogs and cats that underwent a routine health check without any known health problems at the time of the sampling. Detailed list of blood test results can be found in the Appendix.

The clinical examination of the participating animals was carried out and noted in the presence of the graduate student or by the graduate student herself in 24 of the 35 animals. In 11 cases, the examination was conducted according to a pre-defined assessment system by an external vet without the presence of the graduate student.

22 of the 35 samples were sent to the veterinary laboratory “IDEXX” in Ludwigsburg, Germany. 7 samples were analyzed in a different laboratory (LABOKLIN, EasyLab).

The token blood was kept in EDTA and Serum tubes, the serum samples were centrifuged and sent within the shortest time possible.

To calculate nutrient- and energy requirements of cats and dogs at a certain age and weight, as well as the nutrient content of a self-prepared diet; The computer aided diet calculation software „Diet Check Munich©“ was used.

Analysis of vegan feed was performed partially at the University of Veterinary Medicine in Vienna and „Futtermittel-Labor Rosenau“. The methods of measuring used at the University of Veterinary Medicine Vienna are validated and conform with the regulations of the method book of the association of german agricultural analytic and research institutes. (NAUMANN, C., BASSLER, R. (1997): Die Chemische Untersuchung von Futtermitteln. Band III. VDLUFA)

The distribution of the data was tested using the Kolmogorov-Smirnov-Test. All data were normally distributed. The independent t-test was used to test for significance. The Program SPSS 17 was used.

6. Results

6.1. Participants

A total of 233 pet owners completed the questionnaire, including 174 dog- and 59 cat owners, some of which having both species living in their household.

The majority of pet owners were in the age class of 26-30 years (27%), followed by the group of 19-25 years old (23%). 3% of pet owners filling out the questionnaire were between 15-18 years, 9% were older than 50 years. 85% of the participants were female and 15% male. 91% stated to be vegan themselves, 6% live on a ovo-lacto-vegetarian nutrition and the remaining 2% specified to eat both, animal- and plant-based-foods.

6.2. Questionnaire

6.2.1. Motifs

90% of participants said conviction (moral and ethical reasons and reasons of animal welfare) was the most important reason that motivated them to feed their pets on a vegan diet. 18% had to change their pets diet to a purely plant-based one, due to acceptance problems with ordinary feed and 2% stated that their main intention is pure curiosity.

6.2.2. Quality of Information

When asked where owners take their information on this specific type of diet, 91% stated the internet (forums and groups of social networks) as their main source of information, followed by discussions with colleagues (45%) and articles in magazines (25%). 25% reported their veterinarian as their primary informant about vegan animal nutrition. The questionnaire showed that from their own estimation, 80% of pet owners feel well informed about the nutritional needs of their pet. Only 3% reported to not be informed at all. When asked about their knowledge about the nutritional content of various foods, 83% of pet owners stated to feel sufficiently informed and 2% to not be informed at all. Out of all participating pet owners, 73% stated to be well informed about possibly occurring deficiencies and 11% do not feel informed.

6.2.3. Feeds

The inclusion criterion to be part of this study was a minimum length of 6 months of exclusively eating a vegan diet for both cats and dogs, with the extra requirements for cats to live indoor only. Out of the dogs participating in this study, the average length of consuming a vegan diet was 2,83 years with a maximum length of 7 years and the shortest period being 6 months. The average length of exclusively eating vegan food in the group of cats taking part in this study was 3,9 years with a maximum length of 6,5 years and the shortest period of 6 months.

39% of participating pet owners feed their cats and dogs industrially produced feed only 9% prepared their pet's food at home themselves and 106 pet owners (52% of 100) stated to mainly feed industrially produced feed but mix it with self prepared food on a regular basis.

Out of the 19 pet owners who feed self prepared food, 14 are dog- and 5 cat owners.

The product “Amicat” was listed as the most popular industrially produced cat kibble (87%) followed by various others (23%, s.a. “Evolution Diet”, “Vegusto”).

In dog foods, the brands “Benevo” (34%) and “Ami Dog” (33%) were named almost equally, followed by “Yarrah” (22%) and other products (9%)

6.2.4. Supplements

Out of 218 pet owners who filled in the questionnaire, 60 (27 %) stated to add supplements to their pets food, with 65 % (140) not adding any supplements.

Supplements mostly mentioned were “Vegedog” (38 %) and “Vegeyeast” (16 %) followed by various different other supplements (64 %) s.a. “Vegecat”, yeast flakes, brewer's yeast, single vitamins,... .

6.2.5. Noticed changes

38 pet owners reported independently from each other, that their pets showed a much shinier and healthier coat. Some animals that had been prone to a particularly scaly or oily coat before the conversion to a vegan diet, no longer showed signs of any dermatological problems. Some pet owners particularly noticed the increased stool volume and not further defined improvement of the stool consistency. 16 owners described the individual scent of their pets as more pleasant and 14 owners were especially happy over the loss of foete ex ore.

6.3. Clinical examination

6.3.1. Dogs

1. General appearance

All 20 dogs were bright, alert and responsive, some of gentle playful behaviour, some fearful. No abnormalities in posture and gait were noticed. Hydration was adequate in all cases.

2. Body condition

Body Condition was assessed with the aid of the Body Condition Score System developed at the Purina Pet Care Center (scheme from 1 – 9 with 4-5 being ideal weight). One dog had a body condition score of 7, but was already put on a restricting diet by its vet and had successfully lost weight over a certain amount of time. One dog showed a body condition score of 6 with the owner being told to carefully watch and control their dogs weight. One dog had a body condition score of 3, however, this might have been a normal score for this breed (greyhound).

3. Skin and coat

Out of 20 examined dogs, the skin and coat of 18 dogs was clinically inconspicuous, shiny and neat. One dog showed localized areas of pyodermia at the caudal part of the neck and the interdigital area of the front limbs, which was already being treated. One dog had a noticeable squamous coat and mild loss of hair. No dog showed signs of pruritus.

4. Lymph nodes

Lymph nodes of all 20 dogs were of a physiologic size and coarseness.

5. Vital signs

The mucosa membranes of all 20 dogs was pink, capillary refill time within the normal healthy range of 2 seconds. In one dog, the lid conjunctiva of both eyes were brick red and showed a mild *Entropium*. Two dogs had mildly red lid conjunctives and ocular discharge on both eyes.

6. Perfusion, Cardio system

The pulse of all dogs was strong, the artery well filled and well taut.

During auscultation of the heart and palpation of the pulse, a respiratory arrhythmia was noticed in 8 dogs. The pulse of the other 12 dogs was regular. Auscultation of the thorax revealed a systolic heart murmur in 2 dogs. Both were diagnosed with a congenital tricuspidal insufficiency, and have been in therapy for this reason already.

7. Respiratory tract

One dog started coughing when palpating the upper neck area and was diagnosed with laryngitis/tracheitis over the course of the examination.

2 dogs showed a mild stridor nasalis due to their bracheocephalic breed.

Auscultation of the lungs was clinically inconspicuous in all 20 dogs.

8. Digestive tract

1 Dog displayed problems swallowing and was diagnosed with laryngitis/tracheitis over the course of the examination. Palpation of the abdomen was not possible in 4 dogs due to their little compliance. The other 16 dogs showed no conspicuousness. The abdomen was soft and easy to palpate. No pain was noticed during palpation and no palpable abnormalities of abdominal organs were noticed.

3 dogs showed mild and 1 dog moderate dental calculus. The mouth cavity of the remaining 16 dogs showed no clinical abnormalities. In 1 dog, mild foete ex ore could be noticed.

9. Defecation

The majority of pet owners (95%) specified the frequency of defecation to be 2 – 3 times daily, 3% said that their dog would settle feces more often than 3 times daily.

In 19 out of the 20 examined dogs, defecation was usually normal and the feces well formed. One dog tended to recurrent diarrhea in stressful situations, but would go back to normal feces without any therapy needed.

10. Other findings

1 dog (from Spain) was previously tested positive to leishmaniosis, but showed no clinical abnormalities.

6.3.2. Cats

1. General appearance

All 15 cats were bright, alert and responsive. Some were aggressive and fearful, others relaxed and curious. Hydration was adequate in 14 cases. One cat showed a marginal hydration status and minimal loss of the elasticity of the skin.

2. Body condition

Body Condition was assest with the aid of the Body Condition Score System developed at the Purina Pet Care Center (scheme from 1 – 9 with 4-5 being ideal weight) 3 out of 15 cats had a body condition above 5, with a highest score of 7. All other 12 cats were found to be at their ideal weight.

3. Skin and coat

Skin of 12 cats was clinically inconspicuous, noticeable shiny and neat.

3 out of 15 cats showed moderate squamous coat. 6 cats showed moderate hair loss at the time of the clinical examination; However pet owners stated this to be a regularity while visiting the vet, and at the specific time with naturally occurring change of coat as a reason. One female cat showed a hairless, red, pruritic area on her left hind tarsus and was previously diagnosed with recurrent Feline Atopic Dermatitis (FAD) for which she had not received treatment at the time of blood assessment. Other than the one cat diagnoses with FAD, no cats showed signs of pruritus.

4. Lymph nodes

Lymph nodes of all 15 cats were of a physiologic size and coarseness.

5. Vital signs

The mucosa membranes of all 15 cats was pink and capillary refill time within the normal healthy range of 2 seconds.

6. Perfusion, Cardio system

The pulse of all 15 cats was regular and strong, the artery well filled and well taut.

Auscultation of the thorax revealed no abnormal sounds or diagnoses in any of the examined cats.

7. Respiratory tract

Auscultation of the lungs was clinically inconspicuous in all 15 dogs.

8. Digestive tract

Palpation of the abdomen was difficult possible in 2 cats due too their little compliance, but showed no abnormalities as far as viable. Abdominal palpation in 13 cats was unremarkable.

No pain was noticed during palpation and no palpable abnormalities of abdominal organs was noticed in 12 cats. Palpation of the kidneys in one cat suggested alteration of the kidney surface; However following blood assessment showed no signs of renal disfunction.

Inspection of the mouth cavity was not possible in 6 cats due to no compliance. Inspection of the mouth cavity in the remaining 7 cats was unremarkable. The tongue of one cat showed little changes in the surface which did not seem to distract the cat.

Dental inspection showed missing, previously extracted, teeth in 2 cats, and dental plaque in 5 of the examined cats.

9. Defecation

In all 15 cats, defecation was described as unremarkable with the feces being well formed. Defecation was stated to be once daily in most cats, some defecating every other day.

10. Other findings

One cat was tested positive of the Feline Immunodeficiency Virus, but showed no clinically abnormal signs during the examination.

6.4. Blood Assessment

Out of 220 pet owners who had filled out the online questionnaire, 134 initially agreed to a blood taking to be carried out on their pet, with subsequent assessment and publication in this study. Out of these 134 animal owners, successful appointments were ultimately made with 23 pet owners and 35 animals. Following a general clinical examination, blood samples were taken in 20 dogs and 15 cats. In 14 animals this was taken over by the respective veterinarian without the presence of the graduate student and samples were sent together with a previously completed order form. Out of the 35 blood samples, blood samples were taken voluntarily from 9 participants in Germany at their own expense at their veterinarian, and the results placed at the disposal of the study. 22 of the 35 samples were sent to the veterinary laboratory “IDEXX” in Ludwigsburg, Germany. 7 samples were analyzed in a different laboratory (LABOKLIN, EasyLab). Detailed results of blood tests can be found in the appendix.

A complete blood count panel ,basis chemistry panel (liver and kidney parameters) as well as pankreatic parameters, magnesium, calcium, iron, total protein, folic acid, vitamin b12, carnitin were analyzed.

Due to too little sampled material or animals not cooperating well, not tolerating the sampling well and the declining of some owners of another sampling, not all parameters could be measured in all participating dogs and cats.

6.4.1. Dogs

1. Folic acid

Serum Folic acid was measured in 17 dogs. Results of 5 dogs (29%) were below the normal reference range (9,3 – 23,8 ng/ml) with a minimum value of 4,2 ng/ml. The serum folic acid concentration of 12 (71%) dogs was within the normal reference range with a minimum value of 10,9 ng/ml and a maximum value of 17,7 ng/ml. The mean serum folic acid value was 11,58 ng/ml

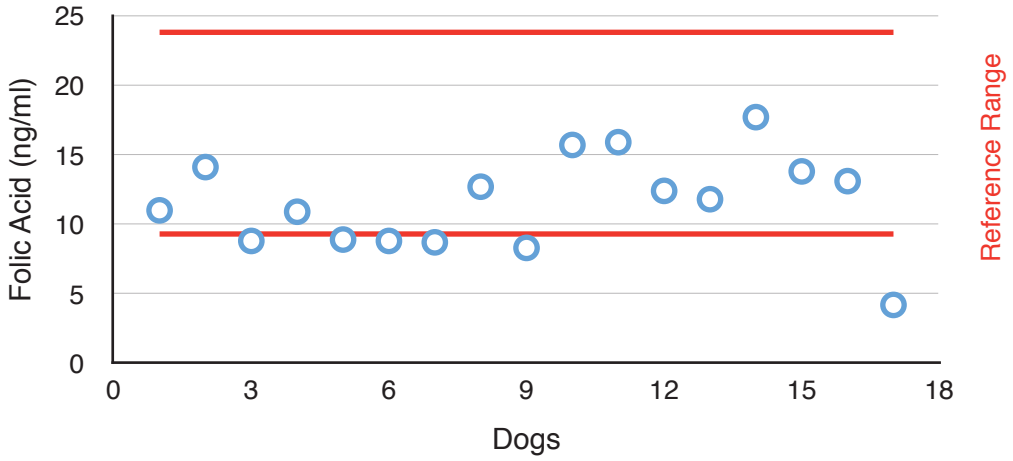

Fig. 1: Distribution of Folic Acid serum levels in 20 vegan dogs

2. Vitamin B12 (Cobalamin)

Serum vitamin B12 was analyzed in all 20 dogs. 15 dogs (75%) showed a level within the normal reference range (234 – 812 pg/ml) with a mean value of 340,09 pg/ml.

Serum cobalamin concentrations of 5 dogs (25%) were below the reference value, with a minimum value of 197 pg/ml.

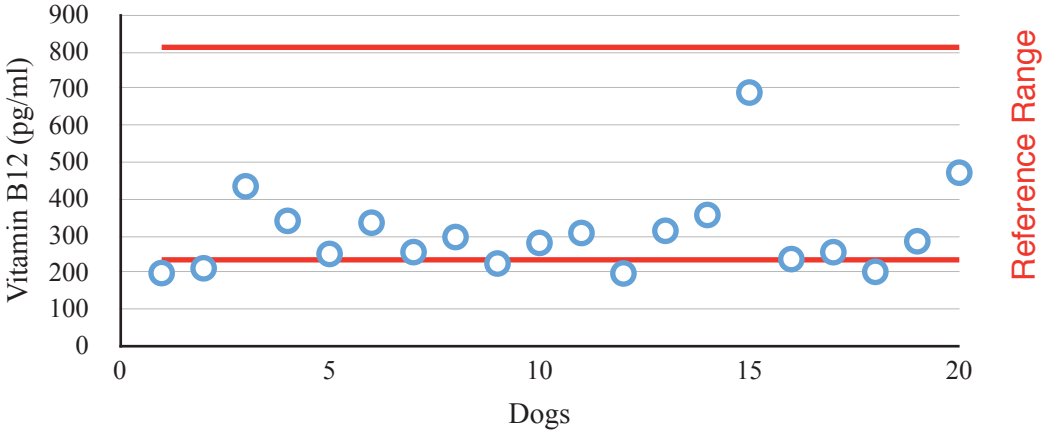

Fig. 2: Distribution of Vitamin B12 serum levels in 20 vegan dogs

3. Iron

Serum iron was analyzed in 19 dogs. The results of 17 (90%) dogs were within the reference range (84 – 230 ug/dl) with a mean of 159,42 ug/dl. Serum iron value of one dog (5%) (41,1 ug/dl) was below the lower reference value. One dog (5%) had a serum iron concentration (237,9 ug/dl) above the upper reference.

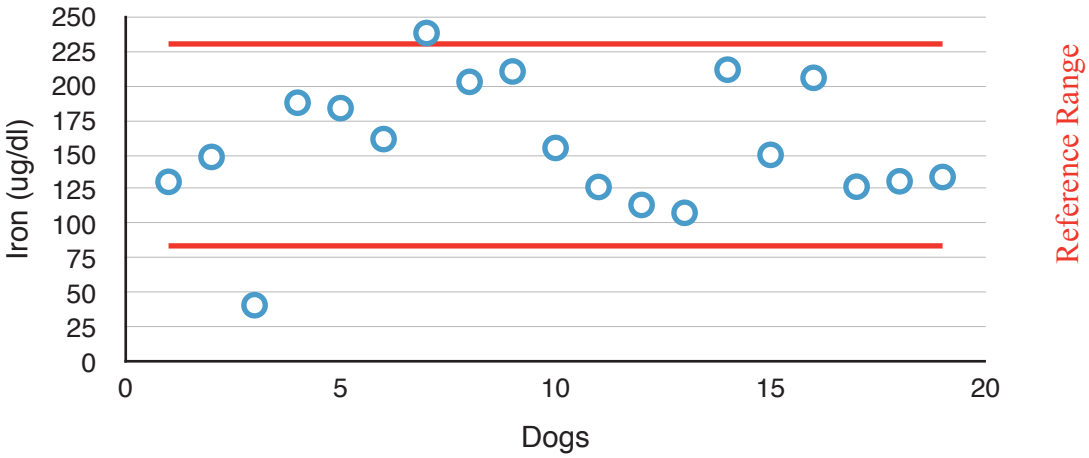

Fig. 3: Distribution of iron serum levels in 19 vegan dogs

4. L-Carnitine

Serum L-Carnitine was analyzed in 7 dogs. 4 out of 7 dogs (57%) showed serum levels within the normal reference range (16 - 42 µmol/l) with a mean of 37,91 µmol/l, a minimum value of 16,3 µmol/l and a maximum value of 35,3 µmol/l. The 3 remaining dogs (43%) all showed elevated L-Carnitine levels with a highest value of 59,2 µmol/l.

5. Serum Total Protein

Serum total protein of all 20 dogs (100%) was within the reference range (5.4 – 7.6 g/dl) with a maximum value of 7.0 g/dl, a minimum value of 5.3 g/dl, and a mean 6,3 g/dl

Serum albumin of all 20 dogs was within the reference range (2.8 – 4.3 g/dl) with a maximum value of 4,1 g/dl, a minimum value of 2,9 g/dl, and a mean 3,3 g/dl

Below is a table (table 3) comparing mean values, standard deviation and percentage of dogs within the reference range of dogs fed vegan diets and dogs fed conventional diets.

Table 3: Blood values of vegan dogs, compared to values of dogs fed conventionally

	Vitamin B12 234 - 812 pg/ml	Iron 84 - 230 µg/dl	Total Protein 5.4 - 7.6 g/dl	Folic Acid 9.3 - 23.8 ng/ml	L-Carnitin 16 - 42 µmol/l
mean (veg. diet)	340.09	159.42	6.3	11.58	37.91
mean (conv. diet)	317.35	134.71	6.1	11.98	40.58
SD (veg. diet)	117	48	0,47	3	15
SD (conv. diet)	159	4	0,59	4	17
within the RR (veg. diet)	15 out of 20 (75%)	17 out of 19 (89%)	20 out of 20 (100%)	12 out of 17 (70%)	4 out of 7 (57%)
within the RR (conv. diet)	13 out of 20 (65%)	15 out of 20 (75%)	18 out of 20 (90%)	15 out of 20 (75%)	8 out of 20 (40%)

SD…….. standard deviation

veg……. vegan

conv…… conventional

*RR…….. reference range

6.4.2. Cats

1. Folic acid

Serum folic acid was analyzed in all 15 cats. The values of 7 cats (46%) was within the normal reference range (11,1 – 21,6 ng/ml), out of which one cat only just reached the lower limit (11,1 ng/ml) Serum Folic acid concentration of 8 cats (53%) was below the reference value with a minimum of 5,3 ng/ml.

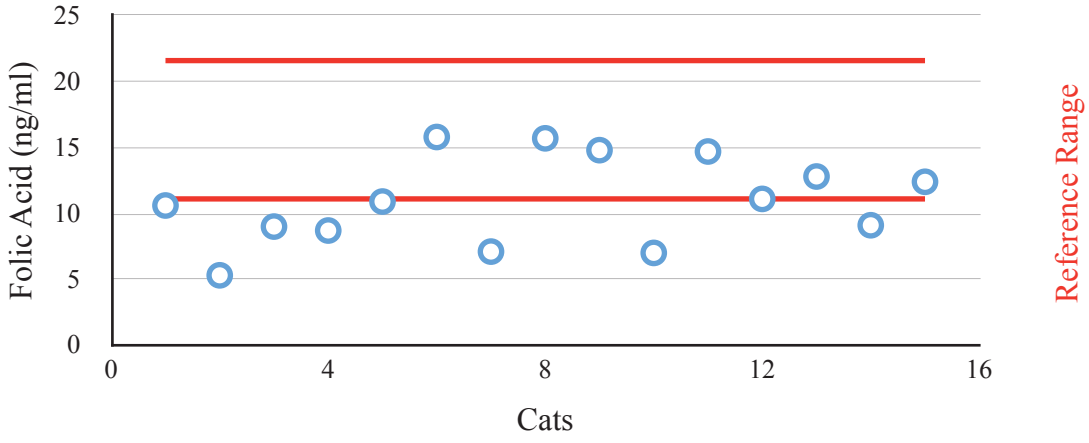

Fig. 4: Distribution of folate serum levels in 15 vegan cats

2. Vitamin B12

Cobalamin was analyzed in all 15 cats. Serum vitamin B12 of 14 cats (93%) was within the normal reference range (269 – 1333 pg/ml), the value of 1 cat (7%) was above the reference value. (1420 pg/ml)

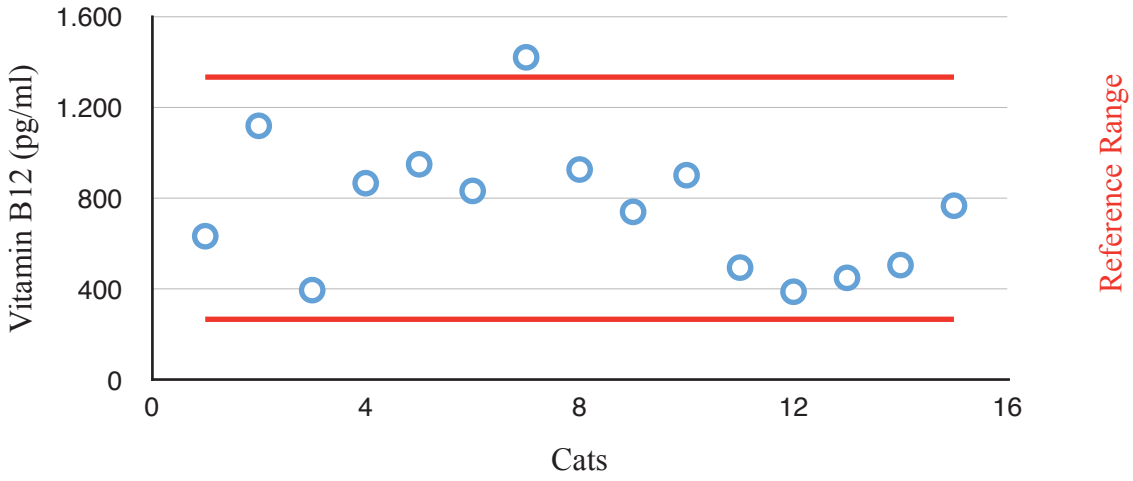

Fig. 5: Distribution of Vitamin B12 serum levels in 15 vegan cats

3. Iron

Serum iron was analyzed in all 15 cats. The results of 14 cats (93%) were within the reference range (70 – 210 ug/dl). Iron of one cat (224 ug/dl) (7%) was above the upper reference value.

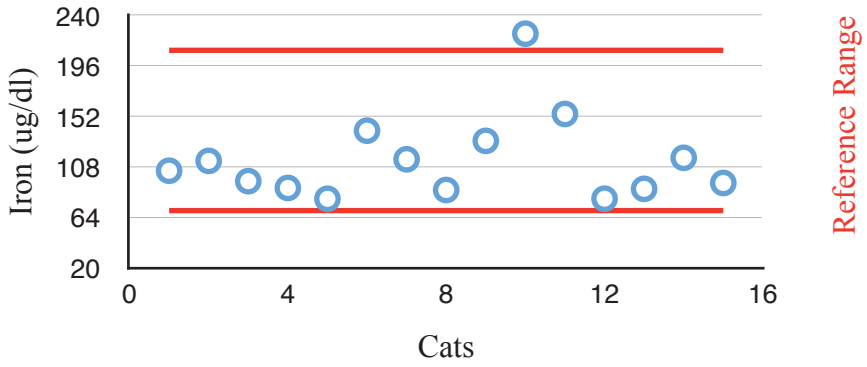

Fig. 6: Distribution of Iron serum levels in 15 vegan cats

4. Serum Total Protein

Serum total protein of all cats (100%) was within the normal reference range (5,9 – 8,7 g/dl) with a maximum value of 9.0 g/dl, a minimum value of 6,6 g/dl, and a mean of 7,3 g/dl Serum albumin of all cats (100%) was within the reference range (2.8 – 4.3 g/dl) with a maximum value of 4, a minimal value of 2,8 and a mean of 3,3 g/dl.

Below is a table (table 5) comparing mean values, standard deviation and percentage of cats within the reference range of cats fed vegan diets and cats fed conventional diets.

Table 4: Blood values of vegan cats, compared to values of cats fed conventionally.

	Vitamin B12 269 - 1333 pg/ml	Iron 70 - 210 µg/dl	Total Protein 5.9 - 8.7 g/dl	Folic Acid 11.1 - 21.6 ng/ml
mean (veg. diet)	760.1	114.4	7.3	11.0
mean (conv. diet)	632.1	96.8	7.3	19.2
SD (veg. diet)	301	39	0,6	3
SD (conv. diet)	668	81	0,9	9
within the RR (veg. diet)	14 out of 15 (93%)	14 out of 15 (93%)	15 out of 15 (100%)	7 out of 15 (46%)
within the RR (conv. diet)	10 out of 20 (50%)	7 out of 20 (35%)	19 out of 20 (95%)	15 out of 20 (75%)

SD… standard deviation; veg…vegan; conv…conventional, *RR…reference range

6.5. Urinary pH

In all examined dogs and cats, normal urination was described by their owners. With the help of the pet owners, test strips (Combur(R) 9 Test) were used for urine examination in spontaneously passed urine of 19 dogs and one cat in their private environment.

Test strips were mostly photographed (10 out of 19) right after use and activation, and results of all 20 test strips were noted on a prewritten paper.

Protein resulted 1 + positive in 3 dogs, but was negative in all other 16 dogs (84%) and the cat (100%). Blood, glucose and ketones came back negative in all 19 dogs and the cat (100%).

As previously stated, our main interest was urine pH, as vegan and vegetarian diets can tend to promote an alkaline urine which may be directly associated with higher risk for crystallization and building of Struvit.

Of 19 examined dogs, one dog (5%) showed a pH above the healthy normal pH range of a dog's urine (pH 5-7). The concerned owner was advised to repeat the examination as the dog showed no clinical signs or problems in the urinary tract and wrong storing might lead to alkalinity too; However results of the repetition are still outstanding. The other 18 dogs (95%) and the cat (100%) were within the normal pH range with 6 times a pH of 5, 7 times a pH of 6 and 5 dogs having a pH of 7.

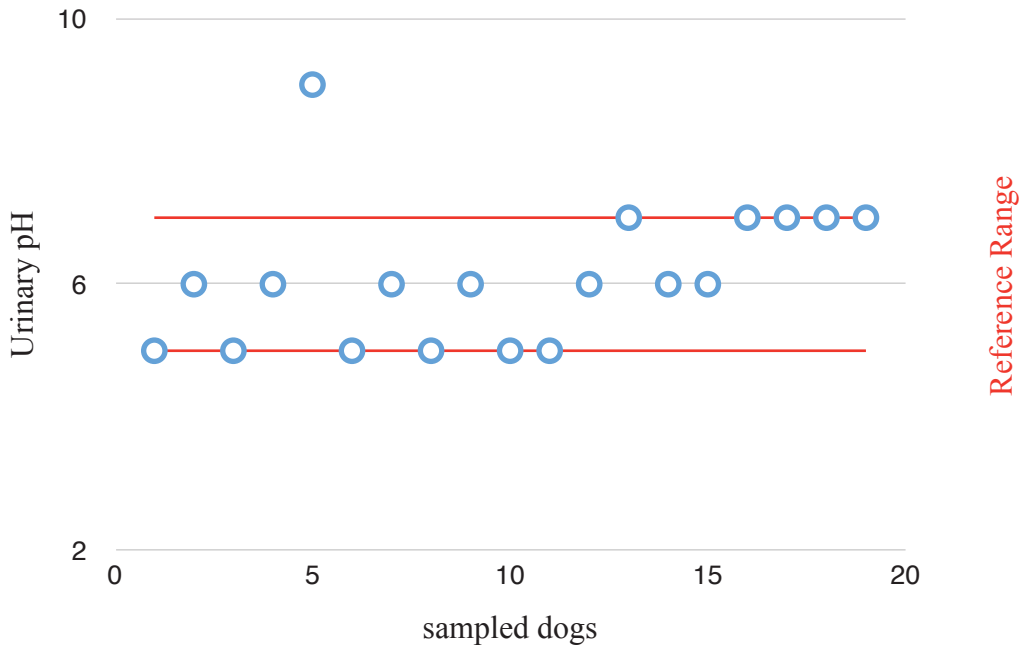

Fig. 7: Distribution of urinary pH in 19 vegan dogs

6.6. Analysis of commercial vegan diets

In the following are results of the analytical investigation of the most commonly used vegan dry and wet dog and cat feed (as per the answers given to the questionnaire).

The amount of following components were analyzed: Moisture, Crude Ash, Crude Protein, Crude Fat, Crude Fiber and dietary elements such as Calcium, Phosphorus, Potassium, Sodium, Copper, Iron, Zinc, Manganese, Magnesium.

Further below the nutrient profile of a self-prepared, wet, vegan diet for a dog was calculated, using the program „Diet Check Munich(c)“. In addition to the nutrients mentioned above, Vitamin A, E and Vitamin B12 was calculated. Furthermore the amino acid profile and amount of linolenic acid provided, was calculated using the nutrient statement provided by the NRC (2006).

6.6.1. Commercial diets for dogs

6.6.1.1. Guaranteed Analysis

Table 5: Guaranteed Analysis of 3 vegan dry diets for dogs

Recommended nutrient levels (MEYER and ZENTEK, 2010)		YARRAH organic (label, 05/2014)	AMÌ DOG reg. size (label, 05/2014)	AMÌ DOG small size (label, 08/2014)
Moisture	< 12%	9% (8%)	8% (5.9%)	8% (4.6%)
Crude Ash	< 10%	7.5% (7.5%)	6.0% (5.3%)	6.2% (5.4%)
Crude Protein	> 18%	22% (22%)	24.5% (25.6%)	27% (28.8%)
Crude Fat	> 5.5 %	7,5% (7.6%)	12% (12.7%)	14% (14.4%)
Crude Fiber	> 1 %	5,7% (5.9%)	2.8% (2.8%)	2.9% (2.3%)

Table 6: Guaranteed Analysis of 2 vegan wet diets for dogs

Recommended nutrient levels (MEYER and ZENTEK, 2010)		BENEVO DUO (label, 05/2014)	AMÌ wet (label, 07/2014)
Crude Protein	> 5.5 %	7.0 % (8.76%)	8.5 % (10%)
Crude Fibre	> 0.2 %	3.00%	2.7 % (1.6%)
Crude Fat	> 1 %	2.00% (3.25%)	6.2 % (8.4%)
Moisture	< 80 %	76.00% (76.80%)	68 % (60.41%)

6.6.1.2. Nutrient Levels

As none of the investigated diets exceeded neither the nutritional nor the legal maximum limit of nutrients as issued by FEDIAF (2013); only too little amounts were marked.

Table 7: Nutrient levels of selected vegan diets for dogs in comparison to maximum recommended allowances per kg DM (FEDIAF, 2013)

	F.E.D.I.A.F. (2013)	AMÌ DOG regular size	AMÌ DOG small size	YARRAH organic	BENEVO Duo	AMÌ wet
		per kg Dry Matter				
Protein (g/kg)	-	256	287	222	378	250
Fat (g/kg)	-	127	144	77	140	212
Calcium (g/kg)	25 (N)	12.2	13.1	13.0	15.7	11.8
Phosphorus (g/kg)	16 (N)	8.9	10.6	10.4	10.4	6.4
Ca:Ph ratio	2/1	1.3	1.2	1.2	1.5	1.8
Kalium (g/kg)	-	4.3	4.3	10.9	16.4	9.5
Sodium (g/kg)	18 (N)	2.5	1.8	4.0	2.7	11
Copper (mg/kg)	28 (L)	28	22.3	21.9	15.4	8.5
Iron (mg/kg)	1420 (L)	269.9	260.6	413.1	217.1	169.5
Zinc (mg/kg)	284 (L)	183.9	176.6	172.2	165.6	43.4
Manganese (mg/kg)	170 (L)	54.8	66.0	98.4	30.7	29.7
Magnesium (g/kg)	-	1.6	1.6	3.1	2.2	1.2

*as per results from analysis performed at Veterinary University Vienna

L ….. legal

N….. nutritional

Table 8: Fulfillment of minimum recommended allowances per kg DM (F.E.D.I.A.F, 2013) of selected vegan diets for dogs

	F.E.D.I.A.F. (2013)	AMÌ DOG reg. size	AMÌ DOG small	YARRAH organic	BENEVO wet	AMÌ wet
		Fulfillment in %				
Protein (g/kg)	180	142	159	123	210	139
Fat (g/kg)	55	231	262	140	255	385
Calcium (g/kg)	5	244	262	260	314	236
Phosphorus (g/kg)	4	223	265	260	260	160
Ca:P ratio	1:1					
Potassium (g/kg)	5	86	86	218	328	190
Sodium (g/kg)	1	250	180	400	270	1100
Copper (mg/kg)	7.2	389	310	304	214	118
Iron (mg/kg)	36	750	724	1148	603	471
Zinc (mg/kg)	72	255	245	239	230	60
Manganese (mg/kg)	5.8	945	1138	1697	529	512
Magnesium (g/kg)	0.7	229	229	443	314	171

*as per results from analysis performed at Veterinary University Vienna

6.6.1.3. Fulfillment of demand

Table 9: Fulfillment of requirements of two vegan dry diets for a 20kg dog

	Requirement dog	AMÌ DOG reg. size (Fulfillment in %)	YARRAH organic (Fulfillment in %)
Energy (MJ)	3.8 MJ	157	141
Kcal	898	159	142
Crude Protein (g)	52	158	135
Calcium (mg)	1230	294	310
Phosphorus (mg)	923	288	329
Magnesium (mg)	185	259	484
Potassium (mg)	1230	104	260
Sodium (mg)	246	311	481
Iron (mg)	9.2	873	1314
Manganese (mg)	1.5	1088	1920
Copper (mg)	1.8	462	350
Zinc (mg)	18.5	296	273

* Calculation based on recommended daily ration provided on packaging (20 kg dog)

Table 10: Fulfillment of requirements of two vegan wet diets for a 9kg dog

	Requirement (NRC, 2006)	BENEVO Duo Fulfillment in %	AMÌ wet Fulfillment in %
Energy (MJ)	2.1	87	144
Kcal	494	88	146
Protein (g)	28	114	129
Ca (mg)	677	198	590
P (mg)	508	175	425
Mg (mg)	102	184	388
K (mg)	622	225	521
Na (mg)	135	172	2773
Fe (mg)	5.1	364	1129
Mn (mg)	0.8	328	1260
Cu (mg)	1	131	280
Zn (mg)	10.2	139	144

*Calculation based on recommended daily ration provided on packaging

6.6.2. Commercial diets for cats

6.6.2.1. Guaranteed Analysis

Table 11: Guaranteed analysis of two vegan wet diets for cats

	AMÌ CAT (label, 05/2014)	BENEVO DUO (label, 05/2014)
Moisture	8.00 % (4.19%)	76.00% (76.80%)
Crude Protein	33.00 % (31.97%)	7.0 % (8.76%)
Crude Fat	14.00 % (12.67%)	2.00% (3.25%)
Crude Fibers	3.50 % (3.9 %)	3.00%
Crude Ash	5.90 % (5.46%)	1.9 %
Omega-3 Fatty acid	0.80 %	-
Omega-6 Fatty acid	6.50 %	-

* as per results of guaranteed analysis performed at Veterinary University Vienna

6.6.2.2. Nutrient Levels

Table 12: Nutrient levels of selected vegan diets for cats in comparison to maximum recommended allowances per kg DM (FEDIAF, 2013)

	(FEDIAF 2013)	AMÌ CAT	BENEVO Duo
	per kg DM		
Calcium (g/kg)	-	9.9	15.7
Phosphorus (g/kg)	-	9.2	10.4
Kalium (g/kg)	-	4.2	16.4
Sodium (g/kg)	< 1.5% DM	4.82	2.7
Copper (mg/kg)	28 (L)	12.6	15.4
Iron (mg/kg)	1420 (L)	206.3	217.1
Zinc (mg/kg)	284 (L)	107.9	165.6
Manganese (mg/kg)	170 (L)	34.6	30.7

Table 13: Fulfillment of minimum recommended allowances per kg DM (F.E.D.I.A.F, 2013) of selected vegan diets for cats

	FEDIAF (2013)	AMÌ CAT	BENEVO Duo
	per kg DM	Fulfillment in %	
Protein (g/kg)	250	133	151
Fat (g/kg)	90	147	156
Calcium (g/kg)	5.9	168	266
Phosphorus (g/kg)	5	184	208
Potassium (g/kg)	6	70	273
Sodium (g/kg)	0.8	603	338
Copper (mg/kg)	5	252	308
Iron (mg/kg)	80	258	271
Zinc (mg/kg)	75	144	221
Manganese (mg/kg)	5	692	614
Magnesium (g/kg)	0.4	425	550
Taurine (g/kg)	1	150	660

* as per results of guaranteed analysis performed at Veterinary University Vienna

6.6.2.3. Fulfillment of demand

Table 14: Fulfillment of requirements of a vegan dry diet for a 3kg cat

	Requirement (NRC. 2006)	AMÌ CAT (as per results of analysis performed at Vet. Univ. Vienna)
		Fulfillment in %
Energy (MJ)	0,9	114
Kcal	209	118
Crude Protein (g)	15	106
Ca (mg)	150	317
P (mg)	134	329
Mg (mg)	21	386
K (mg)	272	74
Na (mg)	36	639
Fe (mg)	4.2	235
Mn (mg)	0.3	553
Cu (mg)	0.3	200
Zn (mg)	3.9	133

*Calculation based on feeding instruction as provided on packaging for a 3 kg cat

Table 15: Fulfillment of requirements of two vegan wet diets for a 4,5kg cat

	Requirement (NRC, 2006)	BENEVO DUO (as per results of analysis performed at Vet. Univ. Vienna)	VEGUSTO CAT FIX (www.vegusto.ch/2014)
		Fulfillment in %	
Energy (MJ)	1.2	76 ↓	70 ↓
Kcal	274	79 ↓	73 ↓
Crude Protein (g)	19	85 ↓	117
Ca (mg)	197	340	112
P (mg)	175	254	231
Mg (mg)	27	348	359
K (mg)	356	197	134
Na (mg)	47	247	321
Fe (mg)	5.5	169	225
Mn (mg)	0.3	433	-
Cu (mg)	0.3	217	1067
Zn (mg)	5.1	139	1063

*Calculation based on feeding instruction as provided on packaging for a 4,5 kg cat

6.6.3. Self-prepared diets

Here is an example recipe, as its used on a regular basis by one of the contestants to feed a 25kg Labrador dog. The recipe was slightly altered - rather than brewer's yeast (as used in our calculation below), the supplement VEGEYEAST™ was used in the original recipe.

Vegan Buckwheat & Lentils Recipe (Participant, 2013)
Ingredients make for a daily ration

130 g buckwheat
190 g lentils
38 g brewer's yeast
10 g Vegedog
700 mg calcium (as Calciumcitrat)
200 IU vitamin D3
1 pinch of salt
100 g spinach (frozen)
20 g sunflower oil
1,3 liters water

To this basic recipe, fruits and vegetables are added by availability.
The program „DietCheck Munich“ was used to review the nutritiousness of the recipe and the adequacy of the nutrient supply. DietCheck Munich calculates the individual requirements based on the publication of NRC (2006) and nutritional values of various feed based on Souci/Fachmann/Kraut.

Table 16: Nutrient supply of the self-prepared „Buckwheat & Lentils“ Recipe

	Requirement dog (25 kg)	Buckwheat & lentils (per daily ration)
	Daily Requirement	Fulfillment in %
Energy	4,5 MJ	127
	1062 Kcal	125
Crude Protein (g)	61	126
Ca (mg)	1455	202
P (mg)	1091	235

Mg (mg)	218	218
K (mg)	1455	230
Na (mg)	291	73
Fe (mg)	10,9	549
Mn (mg)	1,7	247
Cu (mg)	2,2	264
Zn (mg)	21,8	224
Vitamin A (IE)	1838	317
Vitamin D (IE)	198	101
Vitamin	13	77

Table 17: Fullfillment of minimum recommended amino acid and linoleic acid levels of the „Buckwheat + Lentils“ Recipe „Buckwheat and Lentils“ Recipe

	Minimum Recommended Nutrient Levels (F.E.D.I.A.F., 2013)	„Buckwheat + Lentils“ Recipe
	g / MJ	Fulfillment in %
Protein	10.76	716
Fat	3.29	790
Histidin	0.14	165
Isoleucin	0.27	159
Leucin	0.49	128
Lysin	0.25	243
Methionin	0.19	73
Methionine + Cystine	0.37	70
Phenylalanin	0.32	127
Tryptophan	0.1	122
Threonin	0.31	131
Valin	0.35	102
Linolenic acid	0.79	150

7. Discussion

Cats and dogs are both the most favorite and most common pets by far each year (FEDIAF, 2012). Because the natural feeding habit of these carnivorous animals does not conform with the own dietary philosophy of a strictly plant based diet, a growing development among vegan pet owners can be noticed that might be a subject for future veterinarians and one that is not to be ignored. The growing popularity of vegan nutrition, that does not seem to spare carnivorous pets like cats and dogs, can be seen in many various internet boards, groups on social networks or other platforms. Vegan and vegetarian pet owners show a growing interest in extending their own dietary philosophy onto their pets. Observing the answers given to the questionnaire, the majority of pet owners, whether just showing interest in or actively practicing vegan pet nutrition, were found to be mainly women (85%) below the age of 30 (53%).

91% were following a vegan lifestyle themselves and stated moral and ethical reasons and reasons of animal welfare as their main motifs. This reaffirms the findings of a study published by ENGELHARDT in 1999.

A german speaking group on the internet platform Facebook(R) called „Vegan Hund!? Ja klar!“ (= „Vegan dog!? Of course!“) currently lists 2917 members (by 07/2014) and growing, also the group „Vegane Katzen“ (= „Vegan cats“) is followed by 903 members, which shows the definitely existing and constantly growing interest in the implementation of vegetarian / vegan diets for cats and dogs.

Vegan pet-owners often reach the point where they ask themselves if it is acceptable to continue feeding their cats and dogs animal derived foods and by doing so supporting the system they actually intend to boycott. Therefore, some vegan pet owners decide to apply their own ideas of a plant based diet onto their cats and dogs.

The aim of this paper was to provide general information about vegan nutrition, commercially available feeds, recipes for home prepared diets and possible nutritional difficulties that go along with this type of diet.

In the course of researching informations and other papers on for this study, it became apparent that so far not many studies on this subject have been conducted or published.

WAKEFIELD et al. (2006) published a study on 34 cats that had been exclusively fed a commercial or homemade vegetarian diet. Blood and plasma taurine and serum cobalamin was measured in the course of this study.

ENGELHARD (1999) published a study on vegetarian nutrition in cats and dogs looking at 66 adult dogs (of which 29% were stated to be vegan) 8 vegan puppies and 8 cats (25% vegan).

Both the domestic cat (Felis catus, Felis silvestris catus) and the domestic dog (Canis lupus familiaris, Canis familiari) systemically belong to the group of carnivora who further define as meat-eaters. It is readily apparent that their teeth are designed by nature for eating a diet largely comprised of animal tissue. Their short intestinal tracts compared especially to animals like rabbits or horses also indicate that they are not designed to accommodate diets containing large amounts of plant materials. To feed predators a purely plant-based diet, gives rise to the question if it is a safe and arguable option. Also the legal aspect of a vegan nutrition for cats and dogs should be taken into consideration and may make veterinary support of this idea difficult. The legal situation shall be discussed at the end of the discussion.

Although cats and dogs are classified as Carnivora, today the domestic dog is considered more as an omnivorous animal (an animal that eats both, meat and plants) (NRC, 2006). Different metabolic adaptions and metabolic differences (e.g. metabolism of arachidonic acid, vitamin A, taurine) between cats and dogs support this slightly altered classification. Also HAND et al. (2010) agree with the classification of cats as strict carnivores and dogs as omnivores.

At the congress of the European Society of Veterinary and Comparative Nutrition, Dr. Wouter HENDRIKS urged to rethink the classification of dogs as omnivores. The intestinal morphology and physiology of canine and feline are quite similar and so is their low ability to ferment undigested material in the large intestine. Also HENDRIKS presented results of studies showing that wolves in their natural habitat ingests only minor amounts of plants material and avoid consumption of the stomach contents of their prey. HENDRIKS furthermore argued that the higher flexibility in metabolic pathways in dogs compared to cats are the result of the “feast or famine” lifestyle of the ancestors of our modern-day dogs. The feast and famine lifestyle of wolves has resulted in a metabolism which has distinct features also seen in omnivorous animals although clear features are obvious of their carnivorous ancestors. AXELSSON et al (2013) suggest that because of their association with humans and eating people's waste, dogs became scavengers of a mixed diet and this applied a strong selective pressure on the dog’s appetitive behaviors and digestive system. Furthermore their published study

indicates that the gene for amylase (a protein that starts the breakdown of starch) was 28-fold more active in dogs than wolves, indicating that dogs should be fivefold better than wolves in digesting starch (AXELSSON, 2013)

Most vitamins and nutrients are contained in a fair amount of both, plant- and meat-based foods. Specific ones however, can only be found in animal products (e.g. taurine, vitamin A, vitamin B12) or, in trace amounts in some algae. Red and brown seaweeds contain arachidonic acid. (BHASKAR et al., 2004; VAN GINNEKEN et al., 2011).

Also several of the essential amino acids are limited in most vegetable sources, suggesting the necessity to use synthetic forms of some nutrients and informed use of supplements to make a complete and balanced vegan diet (MICHEL, 2006)

Thinking of a strictly plant based diet, there are a few nutrients that instantly rise to the question if and how an adequate supply can be guaranteed when sparing all animal sources. Protein intake is probably the main concern in a vegetarian or vegan diet.

Proteins are the principal structural constituents of body organs and tissues (MEYER and ZENTEK; 2010). There is no requirement for protein as such, but a requirement for its building blocks, the non-essential and essential amino acids (NRC, 2006).

Although meat and other animal products are probably the main source of protein, proteins and amino acids are also found in large numbers in plants. A large portion of the protein in cereal based dry pet foods typically comes from grains, rice, corn, wheat and barley. Soybean meal and corn gluten meal are concentrated sources of plant protein (HAND et al., 2010).

Adequate protein intake can therefore be provided by a healthy balanced vegan diet. Adding to the classification of strict carnivores, cats have a higher protein requirement than dogs in general (HAND et al., 2010).

Serum total protein of all 20 examined dogs and 15 cats in this study was within the normal reference. A study published in 1999 by ENGELHARD showed similar results in the blood assessment of 34 vegetarian/vegan dogs and 2 cats.

Cells use amino acids derived from food proteins, single amino acids added to the food and amino acids synthesized by the body and cannot distinguish between amino acids from grains or plants (e.g. rice, soybean) and those from meats (e.g. chicken). The only importance is that all amino acids are present in sufficient quantities that are needed to synthesize a particular protein (HAND et al., 2010). Plant proteins are said to have a lower digestibility due to higher fiber content. High fiber content might lead to quicker

gut passage which lowers degradation rate of nutrients and thus availability of amino acids (NRC, 2006). Digestibility of proteins is important in animals such as cats and dogs that have a relatively short intestinal tract (O'HEARE, 2009).

In addition to fiber content, trypsin inhibitors can influence amino acid and protein availability; However once mild heat is applied, these inhibitors are inactivated (BAKER and RACKIS, 1986). HUBER et al., 1994 observed no differences in protein digestion of diets, containing either soybean meal meat and bone meal, also other studies (CLAPPER et al., 2001; GRIESHOP et al. 2000) concluded that soy protein concentrations offer a viable alternative to poultry meal as a protein source. CERUNDOLO et al. (2009) suggests that feeding soy to dogs on a long-term basis may influence results of studies in which endocrine function is evaluated, although larger studies are needed to confirm this supposition.

Looking at the effect of administration of dietary soy to cats, WHITE et al. (2004) published a study proving dietary soy to have a measurable although modest effect on thyroid hormone homeostasis in cats and to lead to an increase in total thyroxine (T_4) and free T_4 (fT_4).

KIM et al. (1995) furthermore also suggest that dietary soybean protein leads to a decrease in plasma taurine concentration in cats.

As previously discussed, proteins consist of a chain of amino acids, several of which are classified as essential because they can not be synthesized in the body. Most of these essential amino acids can be found in plants. However Taurine, the amino acid essential for cats, can only be found in animal products and is thus to be synthetically supplemented in a vegan or vegetarian diet (GILLEN, 2003). Although dogs generally are able to synthesize Taurine, it is recommended to supplement it to dog food in order to guarantee sufficient supply, as synthesis rate seem to differ in breeds. BACKUS et al. (2006) showed that on the bases of metabolic body weight and liver weight the Newfoundlands, had less than half of taurine synthesis rates of beagles, conducting that if Newfoundland Dogs are representative of large breed dogs, future studies should determine whether sulfur amino acid requirement scales disproportionally with metabolic energy requirement. FASCETTI et al. (2003) results suggest that consumption of certain commercial diets may be associated with low blood or plasma taurine concentrations and DCM in dogs. DELANEY et al. (2003) published a study, which

showed lower mean whole blood taurine concentrations in dogs fed diets containing whole grain rice, rice bran or barley. The lowest whole blood concentrations were seen in dogs fed lamb or lamb meal and rice diets.

Taurine blood levels had not been measured in vegan cats participating in this study.

ENGELHARD (1999) measured plasma taurine levels of 2 vegetarian cats in their study. Both cats showed levels significantly below the reference.

A study published by WAKEFIELD et al. (2006), measured blood and plasma taurine levels of 17 cats that had exclusively been fed a commercial or homemade vegetarian diet. Taurine levels of 14 of 17 cats were within the reference.

Another important essential amino acid is Arginine. Arginine is essential for both cats and dogs, but no other species has yet been shown to be as sensitive to arginine deficiency as cats, who develop signs of deficiency within three hours (NRC, 2006). Arginine is a key intermediate in the urea cycle that detoxifies nitrogenous wastes such as ammonia (HAND et al 2010). Most animal protein sources supply sufficient Arginine; However in a strictly plant based diet, Arginine intake should be carefully monitored. Arginine deficiency leads to hyper-ammonia, tremors, emesis, apnea, cyanosis, and even death in cats (MORRIS and ROGER, 1978). Ornithine and Citrulline, other urea cycle intermediates, can prevent hyperammonemia and substitute for arginine (MORRIS et al., 1979) However, they can not be made fast enough in sufficient quantities to substitute for arginine (NRC et al., 2006). Good plant sources for Arginine are sesame seeds, soya and seaweed. (nutritiondata.com)

Also important is the essential amino acid Methionine. It is the most limiting amino acid in a diet for cats and first or second for dogs. Together with cysteine, methionine is one of two sulfur-containing proteinogenic amino acids (NRC, 2006). Methionine serves as a precursor for cysteine. It can be transformed to Homocysteine which again can be used to regenerate methionine, or to form cysteine (HAND et al., 2010).

Both Methionine and Cysteine play an important role in many metabolic pathways such as cell replication and phospholipid synthesis (NRC 2006).

Both amino acids do not systemically belong to the group of acidic amino acids; however with the process of degradation and the resulting end product, Methionine and Cysteine are powerful urinary acidifiers (GILLEN, 2003). Due to the higher pH of plant based protein, vegan and vegetarian diets can tend to promote an alkaline urine and struvite formation, which the acidifying effect of Methionine and Cysteine can prevent.

Methionine content of plant proteins tends to be lower than those of animal proteins. Plant proteins also tend to be relatively rich in glycine, which can act as a functional methionine antagonist (McCARTY et al., 2009). Vegan diets can be relatively poor sources of methionine, therefore adequate intake of plant sources high in methionine is recommended. Sesame seeds, brazilian nuts, brown rice, corn and to some extent also soy products can also be good sources of methionine (nutritiondata.com). Supplementation in a vegan diet should be taken into consideration.

The non essential amino acid L-carnitine should also be mentioned for dogs fed on a vegan diet. It does naturally occur in plants only in small amounts and can be synthesized from Lysine by the dog. However; to guarantee adequate supply, supplementation is suggested (MEYER and ZENTEK, 2010).

Looking at the L-carnitine levels of 7 vegan dogs participating in this study, 3 showed serum levels below the reference level; However no significant differences could be noticed (t-test, SPSS17.0) between mean L-Carnitine levels or general distribution of serum Carnitine levels compared to dogs that were fed a conventional diet. The group of vegan dogs had slightly higher percentile fraction of dogs within the reference range than the group of dogs who were fed on a conventional diet.

Other than several amino acids, some fatty acids can not be synthesized by the body but need to be taken in in sufficient amounts with food, thus are essential. As previously mentioned, the requirement of these essential fatty acids (Ω-6 and Ω-3 fatty acids families) can be met with a strict plant based diet.

However, a fatty acid that deserves strong attention in a vegan diet in cats is arachidonic acid, of which little or none is found in plants. It is important for platelet aggregation, prevention of mild mineralization of the kidneys and for reproduction especially in female cats (HAND et al., 2010). Arachidonic acid can be synthesized by dogs, but not by cats (MacDONALD et al., 1984), cats therefore depend on a synthetical composed arachidonic supplement added to their food in order to assure sufficient supply. Informed adequate supplementation is necessary both in commercially produced and home-prepared diets. An example for a plant based supplementation of arachidonic acid is the specifically composed product „Vegecat™“ which uses arachidonic acid, isolated from a norwegian seaweed, Kelp (PEDEN, 1999).

A worry that often comes with vegan/vegetarian nutrition is the excessive intake of

carbohydrates in order to meet the energy requirement. Neither dogs nor cats have a requirement for carbohydrates, they do, however, have a requirement for adequate glucose or glucose precursors to provide essential fuel for the central nervous system. These requirements can be easily met in a plant based diet by consumption of grains potatoes and other legumes which are frequently used in commercially produced diets and can easily be added in home made rations.

Unlike dogs, cats lack hepatic glucokinase activity, which limits their ability to metabolize large amounts of simple carbohydrates (BERNARD, 2003). Lacking glucokinase activity, cats rely on other enzymes, including hexokinase. Although hexokinase is less efficient than glucokinase when glucose concentrations are high, cats have considerably more hexokinase than dogs (LAFLAMME, 2010).

If large amounts of carbohydrates are fed to cats signs of maldigestion occur (e.g., diarrhea, bloating and gas). Despite the limitations of digestive capacity and metabolism, the starch levels found in commercial cat foods are well tolerated (HAND et al., 2010). Other than glucokinase activity, cats also lack glucuronyl transferase which is an enzyme important for glucuronidation, a process needed for detoxification. Lacking this enzyme reduces cats ability to metabolize certain drugs and also toxins such as plant-based phytoalexins (e.g.. Isoflavonoids in legumes) (COURT a. GREENBLATT, 2000). Sufficient supply of most vitamins, minerals and trace elements can be assured by a strictly plant based diet. However, there are certain ones that occur in little or no amount in plant-based foods.

Cobalamin, Vitamin B12, for example can only be synthesized by certain microorganisms. Microbes and yeast can make vitamin B12 for absorption by animals, However the major food sources of cobalamin are animal products (e.g. meat) Plant products are generally devoid of this vitamin (HAND et al., 2010) and whereas ruminants and other herbivores can synthesize sufficient quantities of cobalamin in their intestines to meet their needs, humans, and other omnivorous or carnivorous animals like dogs and cats can not. The intestinal flora of dogs and cats can synthesize cobalamins in the presence of cobalt, however, as the site of production is caudal to the site of absorption, this ability is not much of use.

Vitamin B12 therefore is a big concern when a strictly plant based diet is put on organisms that aren’t able to synthesize this vitamin. Cobalamin on its own puts a question mark over the adequacy of a vegan or vegetarian diet for cats and dogs. HAND

et al. (2010) suggest that longterm feeding of vegetarian diets may lead to vitamin B12 deficiency, as vitamin B12 is only made by microbes and found in animal tissue. In a vegetarian and especially a vegan diet, Vitamin B12 therefore has to be supplied by adequate supplementation (NRC, 2006)

When informed regular supplementation is provided however, requirement of Vitamin B12 can be met in a vegetarian or vegan diet. Results of blood assessment of 20 dogs and 15 cats in this study emphasize this suggestion.

14 out of 15 cats and 15 out of 20 dogs had Cobalamin levels within the normal reference, and showed no significant differences compared to dogs and cats that were fed a conventional diet. Expected significantly lower Vitamin B_{12} could not be observed. Serum cobalamin levels of both tested cats and dogs showed higher mean values compared to the group of cats and dogs who were fed on a conventional diet and also a higher percentage of dogs and cats within the normal reference.

Also in 2006, WAKEFIELD et al. measured serum cobalamin levels in 17 vegetarian cats proving all 17 to have serum B12 levels within the reference.

Other than inadequate dietary intake, Hypocobalaminemia is also associated with gastrointestinal disease. A study from BERGHOFF et al. (2013), showed serum cobalamin concentrations to be significantly lower in dogs with gastrointestinal disease as well as exocrine pancreatic insufficiency or gastrointestinal inflammation (GRÜTZNER et al., 2012).

A retrospective study published by GRÜTZNER et al. (2012) showed the breeds Akitas, Chinese Shar-Peis, German Shepherd Dogs, Greyhounds, and Labrador Retrievers to have increased proportions of serum cobalamin concentrations below the lower limit of the reference interval.

A study from Texas, by GRÜTZNER et al. (2012) also named Shar Peis to have a high prevalence of cobalamin deficiency compared to other breeds and healthy Shar Peis may have subclinical cobalamin deficiency.

Other important vitamins in strictly plant based diet are Vitamin D, A and B3 (Niacin)

The main function of vitamin D is in maintenance and regulation of calcium levels in the body and vitamin D is, therefore, critically important for the development of a healthy skeleton. Main forms of Vitamin D are cholecalciferol (Vitamin D3), which occurs mainly in animals, and ergocalciferol (D2), which also occurs in plants (MEYER and ZENTEK, 2010) The *Solanaceae* family, which includes vegetables such as potato,

tomato, pepper, is said to contain high amounts of vitamin D3 although current knowledge is limited to the content in leaves. Future investigation will elucidate if also the edible portions also contain vitamin D3 (JÄPELT a. JAKOBSEN, 2013)

Cats and dogs can not synthesize Vitamin D through sun exposure as humans can, thus ultimately depend on adequate dietary intake of vitamin D (HAND et al., 2010).

Plant sources of vitamin D are very limited and wild mushrooms are one of the only significant sources of vitamin D2 (MATTILA et al., 2002; TEICHMANN et al., 2007).

Ergosterol is a cell membrane component of fungi and the provitamin of vitamin D2. Thus, vitamin D2 can be found in plants contaminated with fungi. Plants are not known to produce ergosterol, and any vitamin D2 present is probably derived from endophytic fungi or a fungal infection (JÄPELT a. JAKOBSEN, 2013).

Supplementation of synthetically composed Vitamin D is strongly recommended in a vegan and vegetarian diet in both dogs and cats, because of its lack in plant based products. Vitamin D2 is said to be less efficiently used than vitamin D3 (HAND et al., 2010), however unlike in cats, plant based vitamin D2 in dogs, proven to be of almost the same efficiency as the animal based vitamin D3 (MEYER and ZENTEK, 2010) . Unfortunately blood levels of Vitamin D were not measured in the study.

Vitamin A is necessary for normal vision, growth, reproduction, immune function and maintenance of healthy epithelial tissue. Vitamin A is also involved in the expression and regulation of many genes (McCLINTICK et al., 2005).

The source of vitamin A from plants is in the form of provitamin A carotenoids (HAND et al., 2010). In nature, all of the vitamin A ingested by animals originates from carotenoids synthesized by plants. Dogs have the ability to use carotenoid precursors of vitamin A (s.a. beta- carotine) and convert it to retinol (NRC, 2006). Plants, particularly bright yellow and orange ones, such as carrots, sweet potato, kale, pumpkin are a good source for β-carotene, provitamin A. (O'HEARE, 2013).

Cats can absorb β-carotene but are unable to convert carotenoids to vitamin A and therefore cannot meet their vitamin A requirement from carotenoids (SCHWEIGERT et al., 2011) Another study by GREEN et al. (2012) however indicates that cat are indeed capable of converting β-carotene to active Vitamin A, but this is likely inadequate to meet cats requirement. Cats must be provided with a preformed source of Vitamin A and chemists have learned to synthesize it, avoiding the use of animal products (PEDEN,

1999). In a vegan or vegetarian diet for cats, adequate supplementation should be assured in both home prepared and commercially produced feeds.

Vitamin B3, Niacin, is a Vitamin that can be synthesized from the amino acid tryptophan. However; cats cannot efficiently use tryptophan to synthesize niacin and thus have a strict dietary requirement for preformed niacin (HAND et al., 2010). Grains, legumes and potatoes are good plant sources of Niacin. (nutritiondata.self.com)

One of the biggest concern when thinking of a strictly plant based vegan diet, next to Protein, is assurance of adequate iron intake. Iron in foods exists in two forms. Heme iron is present in hemoglobin and myoglobin (as in meat), whilst non-heme iron can be found in grains and other plant sources (HAND et al., 2010). Absorption of non-heme iron is markedly influenced by phytate, tannins and excesses of phosphorus, manganese, zinc, copper and ascorbic acid. Food rich in ascorbic acid has been proven to have a positive influence on iron absorption, whereas calcium is a dietary factor that inhibits both iron absorption (HAND et al., 2010).

Seaweed, soybeans, lentils, spinach and fiber sources such as beet pulp, soy mill run and peanut hulls can be listed as good vegetarian sources of iron (HAND et al., 2010).

However, in vegetarian or vegan commercial pet foods, Iron should be supplemented to guarantee an adequate daily intake. Commercially available vegan diets are usually supplemented with iron in adequate quantities. Iron compounds such as Iron oxide or iron carbonate have little availability and are not recommended for supplementation (MEYER and ZENTEK, 2010).

Blood assessment in this study showed 14 out of 15 cats and 17 out of 19 dogs to have iron levels within the normal reference, and showed no significant differences compared to dogs and cats that were fed a conventional diet. Expected significantly lower iron could not be observed.

Serum iron levels of both tested cats and dogs showed higher mean values compared to the group of cats and dogs who were fed on a conventional diet and also a higher percentage of dogs and cats within the normal reference.

When looking at information sites or talking to people about vegan nutrition, Folic Acid is a nutrient often associated with lacking in a vegan diet. The reason for which is not clear as plants naturally provide a high amount of folic acid. Dark green leafy vegetables, beans, lentils and peas (legumes) are great sources of folate. Folate is important for normal cell function and growth, it prevents anaemia and helps prevent

birth defects during pregnancy. Vitamin B12 (Cobalamin) is required for the body to absorb, store and activate folate to its coenzyme forms. Furthermore, together with Vitamin B12, folic acid is needed for the conversion of Homocysteine to Methionine or Cysteine. Folic acid, particularly in large doses, can mask vitamin B_{12} deficiency by completely correcting hematological abnormalities (HERBERT, 1999). Considering the naturally high occurrence in plants, adequate dietary intake should not be of concern in a vegan diet.

However, results of blood assessment from participating cats showed significantly lower folic acid values ($p < 0,001$) in the vegan group compared to conventionally fed cats and a smaller percentage of cats within the group within the normal reference. Folic acid is a vitamin with very high sensitivity to heat, oxidation, and light (NRC 2006). Foods fortified with folic acid are moderately stable to heat but unstable to light. Significantly lower folic acid values in the group of vegan cats in this study, who were exclusively fed commercially produced diets (mainly Amì Cat and Vegusto) suggest insufficient supplementation of Folic Acid to the feeds or possible loss in the process of production. No information or statement on folic acid levels in the final product, the kibble that is ingested, was given by Ami Pet food. „Vegusto“'s own guaranteed analysis of the finished product showed a sufficient, or the recommendation excessing, amount of folic acid. In comparison, the group of vegan dogs showed no significant differences to folic acid levels of dogs fed a conventional diet.

Other than insufficient dietary intake, low folic acid blood levels can also be achieved by inflammation or diseases of the intestines, as a result of insufficient absorption and metabolization. None of the participating cats however had problems with the GI-tract that were known at the time of blood collection.

Affecting many metabolic reactions and the general well-being of the body, the diet also influences urinary pH. Examination of urinary pH is important as it directly influences conditions that are more or less likely to trigger stone production. The excretion of the nitrogenous waste products of protein catabolism results in the acidic urine of carnivores. Cat and dog urine is usually slightly acidic, with the normal range being 6.0 - 7.5 (GILLEN, 2003).

Plants are poor in acidifying amino acids and therefore, due to the higher pH of plant based protein, vegan and vegetarian diets can tend to promote an alkaline urine. Urine pH 7 and higher indicates Alkalinity which presents an increased potential risk of

formation of Struvite (magnesium ammonium phosphate) crystals or stones (HAND et al., 2010).

To prevent crystallization in dogs and cats fed on a vegan or vegetarian diet, regular monitoring of urine pH is recommended and acidifying agents and supplements can be added to the food (GILLEN, 2003). Asparagus, peas, brown rice, oats, lentils, corn, brussel sprouts and yeast, may be included in vegetarian cat food, and are all urinary acidifiers (PEDEN, 1999).

Also Vitamin C (ascorbic acid) is a urinary acidifier. The BSAVA (British Small Animal Veterinary Association) *Small Animal Formulary* (RAMSEY, 2014) recommends a dosage of 50-80 mg/kg every 24 hours for cats and dogs. As previously mentioned, the amino acids Methionine and Cysteine can additionally be used to acidify an alkaline urine, thus preventing struvite formation. The BSAVA *Small Animal Formulary* (RAMSEY, 2014) recommends a dosage of 200 mg/cat every 8 hours. PEDEN (1999) states that methionine supplementation should not exceed 1800 mg/day for a 10 pound cat. Higher acidity and low content of magnesium both are supposed to keep the urinary pH within a healthy acidic range and help prevent the building of Struvite within the urinary tract. However; acidifying nutrients, agents or products (s.a. VEGEYEAST) should be used carefully as an excess can lead to metabolic acidosis. (LUTZ et al., 2014) Also, a more acidic urinary pH promotes higher urinary excretion of calcium and lower excretion of magnesium. This has to be regularly checked and controlled as magnesium is a natural inhibitor in the formation of urinary stones associated with calcium.(LUTZ et al., 2014)

In the present study, out of 19 examined dogs, one dog showed a pH above the healthy normal pH range of a dog's urine (pH 5-7) whilst the remaining 18 dogs and the one cat were within the normal pH reference.

During clinical examination of participating cats and dogs, no abnormalities were detected that were obviously relatable to a vegan diet. However; it is important to take into consideration that no puppies or kitten were examined in the course of the present study. Findings published by ENGELHARDT (1999) however showed that at 8 weeks, the vegan puppies were approximately half of the normal weight for dogs that age. The adult dogs, equal to our findings in the present study, showed no clinical abnormalities and appeared bright and healthy. One cat showed retina atrophy.

The growing demand and interest in vegan pet nutrition has lead to the marketing of

commercial vegetarian or vegan dog and cat foods.

The present paper looked at by participants most commonly used an available commercially produced vegan pet feed as well as some examples of home prepared diets.

The first products we looked at were dry kibble for both cats and dogs and a wet feed for dogs from the company „Ami Pet Food“.

„Amì Dog regular size“ is labeled as a complete pet food for adult dogs, listing composition, analytical constituents and nutritional additives as well as an instruction for use and daily amount. Other than stating a higher moisture of 8% (compared to 5,9% moisture resulting our own analysis), guaranteed analysis of the company showed no significant deviation to the analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“.

Vitamin A, D3 and E are added to the feed, the source of which is not further described. Taking into account that Ami Pet Food advertises its raw materials as being 100% vegetable, it is likely that mentioned vitamins are derived from a plant based source.

Next to trace elements and minerals, l-carnitine (300 mg/kg) is specifically mentioned as nutritional additives. No declaration of Vitamin B12, Folic Acid or Taurine can be found on the packaging. „Amì Dog regular size“ proved to be sufficient in mostly all nutrients. The nutrient „Potassium“ did not meet the minimum recommended levels per kg DM as published by F.E.D.I.A.F (2013). However, when looking at the nutrition of a 20 kg dog, using the recommended daily ration provided on the packaging, demand of all nutrients is satisfied or exceeded.

„Amì Dog small size“ is labeled as a complete balanced pet food for small sized adult dogs, with no need of additional supplementation. Composition, analytical constituents and nutritional additives as well as an instruction for use and daily amount is provided on the packaging. Other than stating a higher moisture of 8% (compared to 4,6% moisture resulting our own analysis), guaranteed analysis of the company showed no significant deviation to the analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“.

Vitamin A, D3 and E are added to the feed, the source of which is not further described. Taking into account that Ami Pet Food advertises with raw materials being 100% vegetable, it is likely that mentioned vitamins are derived from a plant based source.

Copper, L-Carnitine (no further declaration of amount) and Linoleic acid (6,9%) are specifically mentioned as a nutritional additives. No declaration of Vitamin B12, Folic Acid or Taurine can be found on the packaging. Also, declaration on the packaging of „Amì Dog small size“ differs from the declaration provided on the company's website (www.amipetfood.com) The website seems to state the same declaration as provided for „Amí Dog regular size“. „Amì Dog small size“ proved to be sufficient in mostly all nutrients with only the nutrient „potassium“ not meeting the minimum recommended levels per kg DM as published by F.E.D.I.A.F (2013).

„Amí wet“ is labeled as a complete vegetable based wet pet food for adult dogs. Composition, analytical constituents and nutritional additives as well as an instruction for use and daily amount is provided on the can. Guaranteed analysis of the company showed no significant deviation to the analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“, and all parameters conformed with the comparison chart of minimum recommended levels (MEYER and ZENTEK, 2010).

Vitamin A, D3 and E are added to the feed, the source of which is not further described. No declaration of Vitamin B12, Folic Acid, L-Carnitine or Taurine can be found.

„Amì wet“ proved to be sufficient in mostly all nutrients with only the nutrient „zinc“ not meeting the minimum recommended levels per kg DM as published by F.E.D.I.A.F (2013). However, when looking at the nutrition of a 9 kg dog, using the recommended daily ration provided on the packaging, demand of all nutrients is satisfied or exceeded.

„Amì Cat“ is labeled as a complete vegetable based pet food for cats of all breeds with no need to add supplements. Composition, analytical constituents and nutritional additives as well as an instruction for use and daily amount is provided on the can. Guaranteed analysis of the company showed no significant deviation to the analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“ other than in the parameter moisture (8% vs. 4,7%). All parameters were conform with the comparison chart of minimum recommended levels (FEDIAF, 2013) Magnesium, Ω-3 and Ω-6 fatty acids are mentioned in the analytical constituents. Vitamin A, D3 and E are added to the feed, the source of which is not further described. Next to trace elements and minerals L-Carnitine and Taurine are mentioned in the nutritional additives in sufficient amount. No delcaration of Vitamin B12 or folic acid can be found.

„Amì Cat“ proved to be sufficient in mostly all nutrients with potassium meeting only

74% of the minimum recommended levels per kg DM as published by F.E.D.I.A.F (2013). Also, when looking at the nutrition of a 4,5 kg cat and using the recommended daily ration provided on the packaging, the demand from all nutrients but Potassium is met. A lower blood potassium level within the group of cats feeding on „Amí Cat“ was not observed in this study.

„Amì Cat“ and „Amì Dog (small and regular size)“ both listed very high addition of sodium selenite (Na_2SO_3) as a source for selenium to the food. Sodium selenite consists up to 46% of selenium (KAMPHUES et al., 2009). FEDIAF (2013) published recommended level per 100 g dry matter of selenium to be 0,03 mg at the minimum, not to exceed the legal upper limit of 0,056 mg for both cats and dogs. (0,3 mg - 0,56 mg per 1 kg DM).

Maximum permitted levels have been determined by the EU. „Legal maximum only applies when the particular trace-element or vitamin is added to the recipe as an additive, but relates to the ‘total’ amount present in the finished product (amount coming from the additive + amount from feed materials)“ (FEDIAF, 2013) As we unfortunately didn’t analyze the amount of Selenium in the finished product, we can only assume the amount by what is originally added to the feed. The apparent excess of over Selenium supplementation 150-times higher than the legal upper limit lists, gives reason to think that even highest losses during process of preservation would still lead to an excessive concentration of selenium in the end product.

The amount of sodium selenite added to Amì Cat is listed as 10 mg/kg, which makes 4,6 mg of pure selenium, and a addition to Amì Dog of 20 mg/kg, which makes a total of 9,6 mg of pure selenium. Seeing as though all dogs and cats feeding on products of „Ami Petfood“ are healthy and (so far) show no signs of selenium intoxication, one could assume that the high number on the packaging might result from a simple labeling mistake. Unfortunately even within a long period of time, the companies were not available for further information on the supplementation of Selenium. („As you can understand I am not allowed to give analysis to anyone. Do not worry! We have been feeding lots of healthy pets for years and you can find good feedbacks everywhere.“ (Ami Pet Food Staff, 2014) Chronic selenium poisoning leads to severe affection of liver and spleen, severe ascites and possible extreme dilatation of blood vessels in the abdominal cavity (MOXON and RHIAN 1943).

A study in 2010 fed dietary concentrations of 8 to 10 µg Se/g DM from Na_2SeO_3 or

organic Selenium (Selenomethionine, which contains 40% pure selenium) to cats. No clinical signs of selenosis or chronic selenium toxicity were observed in the cats or dogs and form of Se had no effect on any of the measurements. Results of the study concluded that cats tolerate greater dietary Se concentrations as they are more efficient at excreting excess Se in the urine and storing less Se in the liver (TODD et al., 2012). „Benevo Duo“ is a wet feed composed to fulfill requirements for both cats and dogs. It is a complete and nutritional balanced adult vegetarian dog and cat food. It is free of all common allergens such as meat fish soya wheat and dairy (can label). Composition, analytical constituents and additives are declared on the can. Guaranteed Analysis provided by the company conformed with the Analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“ and with the comparison chart of minimum recommended levels (MEYER and ZENTEK, 2010). Within the nutritional additives list, only the amount of vitamin D2 and taurine is declared. All other additives are mentioned, however the amount is not specified (Incl. Vit A, E, B3, B5, B2, B7, B6, B12, Folic Acid and trace elements.) „Benevo Duo“ provides sufficient amount of nutrients compared to the minimum recommended levels per kg DM as published by F.E.D.I.A.F (2013). Using the recommended daily ration provided on the can, „Benevo Duo“ does meets only around 80% of the energy and calorie requirements of a 9 kilo dog and only around 80% of the energy, calorie and protein requirements of a 4,5 kilo cat. Animals fed on „Benevo Duo“ should therefore be closely monitored for weight or energy losses. A lower serum total protein in the cats feeding on „Benevo Duo“ could not be observed in this study.

„Vegusto“ is a complimentary wet food for cats. Recommendation to combine or alternate the wet food with dry food for example „Vegusto Cat“ and „Amì Cat“ dry food. 100 % vegan, completely free of animal based ingredients and cruelty-free. „Vegusto“ was fed to 2 participants of this study, but unfortunately didn’t undergo further analysis in this study. However, when approached via Email, the company immediately responded and provided helpful and professional information about analytical constituents of the finished product. Compared to the requirements of a 4,5 kilo cat (Diet Check Munich, NRC 2006) fulfillment of demands was sufficient or nutrients were provided in an excessive amount, while still conformed with the legal maximum allowances (FEDIAF, 2013). Vitamins B1-B3 and B5-B7 as well as Folic Acid were shown to fulfill the requirements.

There was no declaration of Vitamin B12 or Taurine, but declaration of using the supplement „Vegecat™“ by PEDEN to provide sufficient supply. The amount of which was not further described.

„Yarrah Organic“ is labeled as a complete pet food for adult dogs. The recipe is stated to be fully vegetarian/vegan, not containing any meat or animal by products. Composition, analytical constituents and nutritional additives as well as an instruction for use and daily amount is provided on the packaging. Guaranteed analysis of the company showed no significant deviation to the analysis performed by the Veterinary University Vienna and „Futtermittel-Labor Rosenau“. Amount of supplementation of trace elements, Vitamin A (as Retinol), D (as Vitamin D2, ergocalciferol) and E (DL-α-tocoferol acetate) is declared on the packaging.

No declaration or mentioning of Vitamin B12, Folic Acid, L-Carnitine or Taurine can be found on the packaging. However, when approached, the company provided a full list of analytical constituents of the final product and nutritional additives, mentioning L-Carnitine, Taurine and Vitamin B12. Folic acid does not seem to be supplemented.

„Yarrah“ proved to be sufficient in all nutrients, meeting the minimum recommended levels/ kg DM as published by F.E.D.I.A.F (2013) and the requirements of a 20 kg dog.

A study from REISENHOFER (2012) revealed that guaranteed analysis of the vegan dry foods „Benevo“, „Yarrah“ and „Ami Dog“ conformed with the required norm values of the scientific comparison chart. In vegan wet feed the product „Canigourmet“ proved to be conform with the standard value in all parameters. The products „Terra Pura“ and „Yarrah“ showed to be at the limit within the parameter „Crude ash“. Furthermore, the value „moisture“ was shown to be slightly above the recommended value. All other values were within the norm.

ENGELHARD (1999) tested the complete dry food „Yarrah“. Analysis published in the study showed the dry food „Yarrah“ to provide too little iron whilst providing excessing amounts of all other nutrients. Comparison of their own analysis to the official analysis published by „Yarrah“ showed significant difference in zink but no significant differences in all other nutrients. However, when asked about changes in the recipe since 1999, Quality Assurance Manager Arthur Hartman stated that Taurine and L-Carnitine are now added to „Yarrah“.

„Yarrah“ was the only company that provided immediate and helpful customer service, answering all questions professionally without hesitation.

Analysis of the „Yarrah“ in this study showed all parameters were conform with the scientific comparison chart (MEYER and ZENTEK, 2010) as well as with the minimum required allowances published by F.E.D.I.A.F (2013), mainly providing the nutrients excessively. All vegan feeds stated nutritional additives mostly of vitamins and trace elements, some also adding essential amino or essential fatty acids.

Feeding a home prepared diet was not common among vegan cat owners, all cats participating in this study were fed on a commercial diet. However; the book „Vegetarian Cats and Dogs“, by James PEDEN, provides dry kibble and wet food recipes. To make home preparation easier, the books website also offers a prepared dry mix called „Vegecat KibbleMix™“, which needs flour, water and oil adding to it. According to the book, all recipes provided are conform with the AAFCO.

In 2004, GRAY et al published a survey about the nutritional adequacy of two vegan diets, including the diet mentioned above and a canned diet for adult cats called „Evolution diet“. „Vegecat KibbleMix™“s was prepared according to company instructions. Evolution canned diet for adult cats required no additional preparation. The study showed both brands being deficient in taurine and methionine and arachidonic acid, with the „Vegecat KibbleMix™“ diet being additionally deficient in Lysine and Arginine.

The Evolution diet was deficient in several B vitamins as well as retinol, calcium, phosphorus and the overall protein. James PEDEN, the manufacturer of „Vegecat KibbleMix™“ responded to the publication of this study claiming the particular batch was probably made improperly, hinting to many healthy vegan cats he supported for many years. A reevaluation and second analysis of the diet was not performed.

Excessive or deficient intake of iodine may play a role in the development of goitre and hyper-thyroidism in cats (KYLE et al., 1994). The iodine content of the final products unfortunately was not measured in the course of this study. Going only by the information provided on the packaging; regarding the amount of added iodine; the dry cat diet „AMI CAT“ lists 0,4 mg Iodine added per 100g of dry matter. This amount is below the legal maximum of 1,10 mg/100g DM cat food (FEDIAF, 2013). KYLE et al. (1994) suggest that the cat is able to maintain normal levels of thyroid hormone despite prolonged high or low iodine diets.

Only two vegan diets for dogs list the amount of iodine that had been added to the feed. The dry diet „YARRAH“ states an addition of 0,13 mg/100g dry matter.

This amount is below the legal maximum of 1,10 mg/100g DM cat food (FEDIAF, 2013). The dry diet „AMI DOG“ however states an additional amount of 2,7 mg/100g dry matter; hereby widely exceeding the legal maximum. Upon request, no statement regarding this finding was provided by the company.

When it comes to home-prepared diets, dog owners seem to be more open and interested in the idea to feeding their pets a self prepared feed. In this study we looked at an example recipe „Buckwheat and Lentils“, composed and used by one of our participating vegan pet owners. This recipe was formulated and given to a 25 kg Labrador Dog. Comparison to the requirement of a dog of this weight (Diet Check Munich, NRC 2006) showed the diet to be sufficient or providing an excessive amount in most nutrients, but being too low in Vitamin B12 (although supplemented with „Vegedog™“) and Sodium.

Looking at the amino acids and Linoleic acid of this recipe, compared to the minimum required nutrient levels published by FEDIAF (2013), The diet proved to provide sufficient intake in all amino acids except Methionine and Cysteine. Both parameters only reached 70% of the minimum requirement. Requirement of linoleic acid (Ω-6) was met with this self prepared diet. Insufficiency in Vitamin B12 as well as Methionine, Cysteine and sodium, can be easily counteracted by adding an adequate amount of supplementation and adding a controlled amount of table salt to the diet. Nevertheless, an adequate nutrient supply by feeding a self-prepared, home-cooked diet, can only be achieved having profound knowledge of requirements and needs of animals and nutrients in general.

ENGELHARD (1999) proved 10 out of 12 commercially available vegan and vegetarian diets for cats and dogs to be insufficient for cats and dogs nutritional needs. Only two diets could be recommended without reservation. Looking at the publication year of this study however; examined diets would need to be re-examined as recipes and ingredients might have change over the years. In the case of „YARRAH“ a recipe change was confirmed by the company and results in the present study differed from the findings published by ENGELHARD (1999).

In the course of this study, an often asked question was if a vegetarian or vegan diet would be good for kidney disease.

Generally a low protein low phosphorus diet is recommended As a low proteine and low phosphorus diet ist recommended. (ELLIOTT et al., 2000). A vegan or vegetarian diet is often associated with a low-protein diet and therefore considered as an appropriate alternative for kidney disease; However this conclusion can not be made without wide and profound research into this specific topic, taking into consideration the special needs of CKD.

Another point, that should not be dismissed, is the legal situation of feeding cats and dogs on a strictly plant based diet. According to the Austrian animal protection act; the type, consistency, nature, quality and amount of the feed has to conform with the species, age and requirements of the animals. The feed has to be designed and composed in a way, so that animals can satisfy their species appropriate need of activity, that is tied to feeding (§17 (1) TSchG). The German animal protection act states that the person that keeps or cares for a pet hat to nourish the animal according to its species and requirements (§2 (2) TierSchG).

Thinking of the way cats and dogs and their ancestors feed in a natural or wild environment, it is easy to say that a vegan diet is definitely not a species appropriate from of nutrition. However seeing it strict, especially when it comes to texture, it might be arguable if any kind of canned diet fulfills the requirement of a composition and design of food that satisfies species appropriate needs, as it is further described in the Austrian law. All vegan diets for dogs fulfilled nutritional requirements in the main, being in accordance with the legal text of an the age and requirement conforming diet. Although all animals participating in this study were clinically unremarkable and appeared bright and healthy, still the classification of cats and dogs, and the legal definition and description of keeping and feeding them, might make it difficult for veterinarians to openly support and recommend a strictly plant based nutrition.

8. Summary

Feeding cats and dogs a strictly plant based diet rises to the question if adequate supply of nutrients and a healthy lifestyle can be assured.

In this study, 20 dogs and 15 cats underwent a clinical examination and blood assessment. Inclusion criterion to undergo blood assessment was a minimum length of 6 months of exclusively eating a vegan diet for both cats and dogs, with the extra requirements for cats to live indoor only.

During clinical examination of participating vegan cats and dogs, no abnormalities were detected that were to be associated with the individual diet. All examined dogs and cats appeared happy and bright, some fearful, some aggressive. No diseases could be found that were directly and obviously relatable to a plant based died.

Results of blood assessment showed no significant differences in all tested parameters in dogs compared to dogs that were fed a conventional diet. Expected significantly lower values of iron and vitamin B_{12} in vegan dogs could not be observed. Two dogs out of the 20 participating were fed on a home prepared supplemented diet and neither showed any significant deviations. The main finding in this study are significantly lower folic acid values ($p < 0{,}001$) in the group of vegan cats compared to conventionally fed cats. The reason of which is not known and may need further investigation. No other significant deviations to the norm values were found. Expected significant lower values of iron protein or vitamin B_{12} in vegan cats could not be observed. In the main, examined vegan diets fulfilled cats and dogs nutritional requirements.

Two dry dog diets („Amì Dog regular size“ and „Amì Dog small size“) did not fulfill the minimum recommended allowances for potassium per kg DM dog food. One wet dog diet („Benevo Duo“) did not fulfill the energy and calorie requirements of a 9 kilo dog, when obeying the feeding recommendation provided on the packaging.

Two wet diets for cats („Vegusto“ and „Benevo Duo“) did not fulfill the energy and calorie requirement of a 4,5kg cat, when obeying the feeding recommendation provided on the packaging; „Benevo Duo“ furthermore was found to provide insufficient protein supply. The dry cat diet „Ami Cat“ did not fulfill the minimum recommended allowances for potassium per kg DM cat food.

Feeding self-prepared diets was not so much of a subject in cat-owners, but common amongst dog-owners. The recipe presented in this study fulfilled the dogs nutrient

requirement in the main, but was too low in the amino acids methionine and cysteine, vitamin B12 and sodium; nutrient imbalances that can be easily corrected.

Cats are unable to convert carotenoids to vitamin A, depend on dietary intake of arachidonic, taurine, vitamin D, niacin and arginine. Their classification of strict carnivorous as stated in many sources, together with previously mentioned metabolic peculiarities, their adaption for a low-carb diet and a higher protein requirement, might suggest that a vegan or vegetarian diet is not or possibly less advisable for cats. However, all cats, showed no clinical abnormalities seemed bright happy and owners described no acceptance problems of their cats towards the vegan feed. In order to provide adequate nutrient supply and assure a healthy balanced diet, close examination with the subject of vegan nutrition is necessary and implementation of this diet for cats and dogs should not be taken lightly. Supplementation of taurine, l-carnitine, iron, vitamin B12 and vitamin D in both dogs and cats, and additional supplementation of arachidonic acid and vitamin A in cats is recommended. A healthy and balanced vegan nutrition can barely be implemented without supplements.

Long term results, a larger group of animals feeding on a vegan diet for more than 7 years and further tests (taurine, niacin, vitamin A, vitamin D,…) as well as generally a larger number of participants would be needed for significant validity.

With the information given in this study, the overall impression of participating animals and present results of examinations and blood assessments, the insular disapprobation of a vegan diet for cats and dogs can’t be reasoned, but a vegan diet is not species appropriate for cats and dogs and therefore can not be recommended by veterinarians. Also the legal text is not very clear on this specific subject and might make it difficult for veterinarians to actively support and openly recommend a strictly plant based diet.

However; the growing interest and demand for vegan and vegetarian diets for cats and dogs should result in a stronger discussion of this subject among veterinarians.

The strong convictions of vegan pet-owners and the will to put the own philosophy onto their cats and dogs, should lead to taking vegan cat and dog nutrition serious in a modern veterinary clinic. Rather than leaving pet owners to themselves and risking inadequate supply of nutrient, veterinarians can and should provide information on implementation of this diet, nutrient requirement and supplementation. By creating a positive and open basis of discussion, unavailability to medical help and veterinary support can be prevented and a balanced diet and healthy lifestyle assured.

9. Zusammenfassung

Katzen und Hunde rein pflanzlich zu ernähren, wirft die Frage auf, ob eine angemessene und ausreichende Versorgung mit Nährstoffen und ein gesunder und ausgewogener Lebensstil gesichert werden können. In der vorliegenden Studie unterzogen sich 20 Hunde und 15 Katzen einer klinischen Untersuchung und einer Blutabnahme.

Die Bedingungen, um an der Blutuntersuchung teilnehmen zu können, waren die ausschließliche Fütterung von rein pflanzlichen Futtermitteln über eine Mindestdauer von 6 Monaten bei Hunden und Katzen, mit dem extra Kriterium für Katzen, ausschließlich innerhalb einer kontrollierten, geschlossenen Umgebung (Haus, Wohnung) zu leben, wodurch das Ausschließen der Aufnahme tierischer Produkte möglich war. Freigänger-Katzen wurden zu der Blutabnahme nicht herangezogen.

Bei der klinischen Untersuchung von teilnehmenden vegan ernährten Hunden und Katzen wurden keine Veränderungen bemerkt, die mit der jeweiligen Diät in Verbindung gebracht werden könnten. Alle untersuchten Hunde und Katzen präsentierten sich munter und aufmerksam, manche erschienen ängstlich, manche zeigten aggressives Verhalten. Keine Erkrankungen wurden diagnostiziert, die in direktem Zusammenhang mit einer rein pflanzlichen Ernährung gesetzt werden konnten.

Ergebnisse der Blutuntersuchungen von veganen Hunden zeigten keine signifikanten Unterschiede in allen untersuchten Parametern zu Hunden die mit einer herkömmlichen Diät tierischer Inhaltsstoffe gefüttert wurden. Erwartete signifikant niedrigere Eisen- und Cobalaminwerte in vegan ernährten Hunden konnten nicht beobachtet werden. Zwei der 20 Hunde wurden mit einer eigens zusammengestellten und zubereiteten supplementierten Diät gefüttert und zeigten ebenso keine signifikanten Abweichungen.

Blutuntersuchungen der teilnehmenden rein pflanzlich ernährten Katzen zeigten signifikant niedrigerer Folsäurewerte im Vergleich zu Katzen, die mit herkömmlichen Diäten tierischem Ursprungs ernährt wurden. Die Ursache der niedrigeren Folsäurewerte konnte in der vorliegenden Studie nicht geklärt werden und bedarf eventuell weiterführender und umfassenderer Studien. Erwartete signifikant niedrigere Eisen-, Protein- oder Cobalaminwerte in vegan ernährten Katzen konnten nicht beobachtet werden. Bei den Futtermitteln erfüllten die untersuchten pflanzlichen Katzen- und Hundediäten größtenteils die jeweiligen Nährstoffbedürfnisse.

Zwei vegane Trockenfutter für Hunde („Amì Dog regular size“ und „Amì Dog small

size“) erfüllten nicht die Mindestempfehlungen von Kalium pro Kilogramm Trockenmasse Futter. Ein Nassfutter für Hunde („Benevo Duo“) ausserdem nicht den Energie- und Kalorienbedarf eines 9kg schweren Hundes, sofern sich an die Fütterungsempfehlung der Firma gehalten wurde.

Zwei vegane Nassfutter für Katzen („Vegusto“ und „Benevo Duo“) erfüllten ebenfalls nicht den Energie- und Kalorienbedarf, sofern man die Fütterungsempfehlung der Firma, für eine 4,5 kg schwere Katze befolgte. Die Berechnung der „Benevo Duo“ - Ration ergab ausserdem eine unzureichende Proteinversorgung. Das vegane Trockenfutter „Amì Cat“ erfüllte die Mindestempfehlungen für Kalium pro Kilo Trockenmasse Katzenfutter nicht.

Selbst gekochte- und zusammengestellte Diäten zu füttern war seltener ein Thema bei veganen Katzenbesitzern, sehr üblich jedoch bei Besitzern von pflanzlich ernährten Hunden. Das in der vorliegenden Studie präsentierte Rezept einer selbsterstellten Diät erfüllte den Nährstoffbedarf des Hundes zum größten Teil, enthielt jedoch eher niedrigere Mengen der Aminosäuren Methionin und Cystein, Vitamin B12 und Natrium; eine Minderversorgung, die sehr einfach korrigiert werden kann.

Um metabolische Eigenheiten noch einmal herauszuheben, können Katzen Karotenoide nicht zu vitamin A verstoffwechseln und sind abhängig von ausreichender Aufnahme von Arachidonsäure, Taurin, Vitamin D, Niacin und Arginin. Ihre Klassifizierung als strenge Fleischfresser, wie sie in mehreren Quellen genannt wird, zusammen mit den vorher genannten Eigenschaften ihres Stoffwechsels und deren Anpassung an eine kohlenhydratarme und proteinreiche Diät könnten nahelegen, dass eine rein pflanzliche Diät für Katzen nicht oder weniger geeignet beziehungsweise empfehlenswert ist.

Keine der untersuchten Katzen zeigte klinische Veränderungen. Sie präsentierten sich munter und aufmerksam, und Besitzer konnten keine Akzeptanzprobleme veganer Futtermittel bei ihren Katzen beschreiben.

Um eine adäquate Nährstoffversorgung und eine gesunde, ausgewogene Ernährung zur Verfügung stellen zu können, ist eine genaue Auseinandersetzung mit dem Thema der veganen Ernährung notwendig, und die Umsetzung dieser Ernährungsform bei Hunden und Katzen sollte nicht leichtfertig erfolgen.

Ergänzung von Taurin, L-Carnitin, Eisen, Vitamin B12, Vitamin D bei Hunden und Katzen sowie speziell bei Katzen auch die Zugabe von Arachidonsäure und der aktiven Form von Vitamin A ist zu empfehlen.

Die Durchführung einer gesunden, nährstoffreichen veganen Ernährung ist ohne Zusätze kaum durchführbar.

Langzeitstudien, eine größere Gruppe an Tieren, die über einen Zeitraum von über sieben Jahren vegan ernährt werden, und weitere Tests (Taurin, Niacin, Vitamin A, Vitamin D,…) sowie generell eine größere Teilnehmeranzahl wären nötig für eine stärkere Aussagekraft der Studie über vegane Ernährung bei Hunden und Katzen.

Mit den Informationen aus dieser Studie, dem Gesamteindruck der teilnehmenden Tiere und den vorliegenden Ergebnisse der klinischen Untersuchung sowie Blutuntersuchungen, kann die engstirnige Verweigerung oder das Abraten einer veganen Ernährung für Hunde und Katzen nicht begründet werden, jedoch ist eine vegane Ernährung keine artgerechte Ernährung für diese Tiere und kann daher von Tierärzten nicht empfohlen werden. Der Gesetzestext aus dem Tierschutzgesetz ist in Bezug auf dieses Thema nicht sehr deutlich und könnte es für Tierärztinnen und Tierärzte zusätzlich erschweren, offen und bestärkend eine rein pflanzliche Ernährung von Hunden und Katzen zu unterstützen.

Unabhängig davon aber, sollte das zunehmende Interesse an dieser Form der Ernährung und die Nachfrage in einer stärkeren Auseinandersetzung mit diesem Thema unter Tierärztinnen und Tierärzten resultieren. Die starke Überzeugung von veganen Tierbesitzerinnen und Tierbesitzern und der Wille die eigene Philosophie auf die eigenen Hunde und Katzen umzulegen, sollte zu einem Ernstnehmen von rein pflanzlicher Hunde- und Katzenernährung in der modernen Tiermedizin führen. Anstatt Tierbesitzer sich selbst zu überlassen und dadurch eine inadequate Nährstoffversorgung zu riskieren, können und sollten Tierärztinnen und Tierärzte über die korrekte Ausführung und mögliche Risiken dieser Ernährungsweise sowie über Nährstoffbedarf der Tiere und Supplemente informieren. Mittels positiver und offener Gesprächsbasis kann außerdem einer Verschlossenheit gegenüber medizinischer Betreuung und tierärztlicher Unterstützung entgegen gewirkt werden, um zusammen eine ausgewogene Diät und einen gesunden Lebensstil zu sichern.

10. List of tables and figures

11. References

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Bundesgesetz über den Schutz der Tiere, zweites Hauptstück, erster Abschnitt, § 17 (1) TSchG. (Austrian animal protection act)

Tierschutzgesetz, zweiter Abschnitt, §2 (2) (German animal protection act)

12. Appendix

Fragebogen Diplomarbeit „Vegane / Vegetarische Ernährung bei Hund und Katze“

Studiengang Diplomstudium Veterinärmedizin an der Veterinärmedizinischen Universität Wien In Zusammenarbeit mit dem Institut für Tierernährung

Angaben zur Person

Alter (Jahre)

- [ ] 15 - 18
- [ ] 19 - 25
- [ ] 26 - 30
- [ ] 30 - 40
- [ ] 40 - 50
- [ ] älter

Geschlecht

- [ ] männlich
- [ ] weiblich

Ernährung

- [ ] Mischkost
- [ ] Lacto-Ovo-Vegetarisch
- [ ] Vegan
- [ ] Andere
- [ ] Sonstiges:

Angaben zum Tier

Alter

- [ ] 0 - 1
- [ ] 1 - 5
- [ ] 5 - 10
- [ ] 10 - 15
- [ ] älter als 15 Jahre

Gewicht (Hund)

- [ ] < 5
- [ ] 5 - 10
- [ ] 10 - 20
- [ ] 20 - 30
- [ ] 30 - 50
- [ ] > 50

Gewicht (Katze)

- [ ] < 3
- [ ] 3 - 5
- [ ] 5 - 8
- [ ] 8 - 10
- [ ] > 10

Verwendung

- [ ] Zucht
- [ ] Freizeit
- [ ] Sport
- [ ] Sonstiges:

Bekannte Erkrankungen

- [ ] Ja
- [ ] Nein

wenn ja, welche?

Dauermedikation

- [ ] Nein
- [ ] Ja

wenn ja, welche?

Haltung

- [ ] Einzelhaltung
- [ ] Gruppenhaltung
- [ ] Wohnungskatze
- [ ] Freigänger (Katze)

Sonstige Informationen (Betreuung tagsüber bei Verwandten zB,. ...)

Angaben zur Fütterung

Beweggründe

- [ ] Überzeugung

- [ ] Akzeptanzprobleme gegenüber gewöhnlicher Futtermittel
- [ ] Eine Diät wurde aus Krankheitsgründen angeraten
- [ ] Neugier
- [ ] Durch Bekannte / Freunde dazu bewegt worden

Wie haben Sie sich bislang informiert?

- [ ] Fachzeitschriften
- [ ] Internet
- [ ] Freunde / Bekannte
- [ ] Tierarzt / Tierärztin
- [ ] garnicht
- [ ] Sonstiges:

Art der Fütterung

- [ ] ovo-lacto-vegetarisch
- [ ] ovo-vegetarisch
- [ ] vegan
- [ ] Sonstiges:

Ich fühle mich gut informiert über ....

Nährstoffbedarf meines Tieres

- [ ] trifft zu
- [ ] trifft weniger zu
- [ ] trifft garnicht zu

Nährstoffgehalt der Lebensmittel

- [ ] trifft zu
- [ ] trifft weniger zu
- [ ] trifft garnicht zu

ggf. auftretende Mängel einer pflanzlichen Ernährung

- [ ] trifft zu
- [ ] trifft weniger zu
- [ ] trifft garnicht zu

Zeitraum

- [ ] seit Geburt
- [ ] Umstellung erfolgt erst

Seit dem Alter von ....

Verwendete Futtermittel

- [ ] Industriell hergestelltes Futter

Marke :

- [ ] Hausgemachtes Futter

Häufigkeit der Fütterung

- [ ] 1 x / Tag
- [ ] 2 x / Tag
- [ ] 3 x / Tag
- [ ] öfter

Menge der Fütterung

- [ ] 100 - 200 g
- [ ] 200 - 300 g
- [ ] 300 - 400 g
- [ ] 400 - 500 g
- [ ] > 500 g

Wie bemessen sie die Futtermenge?

- [ ] nach Gefühl
- [ ] nach Herstellerangaben
- [ ] nach Appetit
- [ ] willkürlich

Welche Futtermittel werden bei der hausgemachten Fütterung hauptsächlich verwendet

- [ ] Linsen
- [ ] Bohnen
- [ ] Sojaprodukte
- [ ] Seitan
- [ ] Lupine
- [ ] Karotten
- [ ] Erbsen
- [ ] Spinat

- [ ] Rote Rübe
- [ ] Zucchini
- [ ] Eier
- [ ] Reis
- [ ] Kartoffeln
- [ ] Getreideprodukte (Flocken, Nudeln, ...)
- [ ] Milch
- [ ] Topfen
- [ ] Joghurt
- [ ] Käse
- [ ] andere Milchprodukte
- [ ] Pflanzenöl
- [ ] Butter
- [ ] Sonstiges:

Wie ist die Akzeptanz der Futtermittel

- [ ] sehr gut
- [ ] gut
- [ ] weniger gut
- [ ] schlecht

Verträglichkeit der Futtermittel

- [ ] sehr gut
- [ ] gut
- [ ] weniger gut
- [ ] schlecht

Kotkonsistenz

- [ ] flüssig
- [ ] fladenartig
- [ ] weich
- [ ] hart

Kotfarbe

- [ ] rotbraun
- [ ] hellbraun
- [ ] dkl braun
- [ ] schwarzbraun
- [ ] schwarz

Häufigkeit des Kotabsatzes pro Tag

- [ ] 0 - 1
- [ ] 2
- [ ] 3
- [ ] öfter

Allergische Reaktionen

- [ ] Ja
- [ ] Nein

wenn ja, wie äußert sich das?

Füttern sie Ergänzungsfuttermittel

- [ ] Nein
- [ ] Ja

wenn ja, welche?

Wird ihr Tier ausschließlich von Ihnen gefüttert?

- [ ] Ja
- [ ] Nein

wenn nein, werden andere Futtermittel verwendet?

- [ ] Ja
- [ ] Nein

Besonderheiten (Vorlieben, Abneigungen)

Angaben zur Fütterung von Belohnungssnacks (Leckerlies)

Füttern sie Belohnungssnacks?

- [ ] Ja
- [ ] Nein

Marke

andere Snacks

Häufigkeit pro Tag

- [ ] 1 - 5 Stk
- [ ] 6 - 10 Stk
- [ ] 11 - 20 Stk
- [ ] keine Angabe

Anlass

- [ ] beim Einüben von neuen Lektionen
- [ ] bei guter Leistung
- [ ] zu besonderen Anlässen (Weihnachten, Geburtstag, ...)
- [ ] zur Begrüßung / Verabschiedung
- [ ] Sonstiges:

Herkunft der Belohnungssnacks

- [ ] pflanzlich
- [ ] tierisch
- [ ] beides

Werden Belohnungssnacks auch ohne ihr Beisein verfüttert?

- [ ] Ja
- [ ] Nein

wenn ja, welcher Herkunft?

- [ ] pflanzlich
- [ ] tierisch
- [ ] beides
- [ ] weiß ich nicht

Sind Ihnen Veränderungen an ihrem Haustier aufgefallen?

- [ ] Ja
- [ ] Nein

wenn ja, welche?

Datengewinnung
Würden Sie sich bereit erklären ihren Hund / ihre Katze für die Studie zur Verfügung zu stellen? (umfasst eine kostenlose Gesundenuntersuchung (klinische Untersuchung) sowie die Gewinnung von Harn-, Kot-, und Blutproben

- [ ] Ja
- [ ] Nein

Ihr Name

Telefonnummer

Email Adresse

Senden

Geben Sie niemals Passwörter über Google Formulare weiter.

analyzed by IDEXX	Bun	Creatinine	Natrium	Potassium	Phosphate	Bilirubin	ALT	AP	AST
Reference Range	9 - 29 mg/dl	< 1,4 mg/dl	142 - 153 mmol/l	3,9 - 5,8 mmol/l	0,9 - 1,7 mmol/l	< 0,4 mg/dl	< 122 U/l	< 147 U/l	< 59 U/l
Dog 1	13	0,7	147	5,3	1,2	0,2	34	32	41
Dog 2	19	0,7	146	5,6	2,1*	0,1	67	72	95
Dog 3	13	0,8	146	5,9	1,7	0,2	110	49	49
Dog 4	31	0,7	149	4,5	1,4	0,2	34	92	18
Dog 5	16	0,7	146	4,9	1,3	0,2	34	51	17
Dog 6	18	0,9	148	4,5	1,0	0,2	34	48	39
Dog 7	18	0,9	148	4,7	1,7	0,1	48	54	40
Dog 8	13	0,7	150	4,4	0,9	0,1	53	80	28
Dog 9	13	0,7	148	4,5	0,8	0,2	58	148	32
Dog 10	14	0,7	147	5,3	1,4	0,1	598	46	106
Dog 11	25	0,6	147	5,5	1,8	0,2	99	51	53
Dog 12	21	0,6	146	6,0	1,6	0,2	50	31	53
Dog 13	20	1,0	147	4,3	1,6	0,2	41	52	19
Dog 14	13	0,7	146	4,5	1,7	0,2	54	72	21
Dog 15	13	0,6	148	4,9	1,3	0,1	54	69	37
Dog 16	23	0,8	146	5,4	2,4	0,1	41	170	36
Dog 17	12	0,9	142	4,4	2,2	0,2	57	109	28
analyzed by LABOKLIN	3,3 - 8,3 mmol/l	35 - 106 µmol/l				< 3,4 µmol/l			
Dog 18	7,4	115	148	4,5	1,0	2,4	26,1	71	13,6
Dog 19	5,3	94	151	4,6	1,2	1,8	3,8	39	13,3
Dog 20	4,3	85	150	4,3	1,3	1,3	20,3	36	16,2

Total Protein	Albumin	Globulin	Amylase	Lipase	Cholesterin	Fruktosamin	Calcium	Magnesium	Triglyceride
5,4 - 7,6 g/dl	2,8 - 4,3 g/dl	2,4 - 4,3 g/dl	< 1264 U/l	< 298 U/l	< 398 U/l	203 . 377 mmol/l	2,1 - 2,9 mmol/l	0,7 - 1,1 mmol/l	28 - 468 mg/dl
6,2	3,5	2,7	509	45	223	304	2,2	0,8	39
6,1	3,4	2,6	684	28	144	274	2,5	0,9	64
7,0	3,8	3,2	616	67	223	276	2,5	0,9	52
5,5	3,1	2,4	804	92	118	266	2,5	0,8	64
6,0	3,0	3,0	621	72	217	266	2,7	0,7	80
6,0	3,2	2,8	516	25	171	250	2,5	0,9	31
6,5	3,4	3,1	764	34	140	281	2,5	1,0	59
5,3	3,0	2,3	523	64	172	235	2,2	1,0	51
5,9	3,1	2,9	675	64	263	234	2,1	1,0	48
5,7	3,1	2,6	492	62	216	280	1,7	1,0	47
6,5	3,0	3,5	589	33	180	307	2,6	1,1	57
6,7	3,2	3,5	680	56	207	297	2,7	1,2	75
6,3	2,9	3,4	975	22	153	287	2,5	0,8	84
6,8	3,1	3,7	1186	77	178	325	2,6	0,8	142
6,3	3,2	3,1	620	91	151	264	2,2	0,9	33
7,0	3,5	3,5	935	30	216	263	2,4	1,0	66
6,7	3,1	3,6	1345	20	213	272	2,6	0,9	45
					3,1 - 10,1 mmol/l	< 374 µmol/l			< 3,9 mmol/l
6,5	4,1	2,4	836	104	7,1	320	2,7	1,2	0,78
6,3	3,8	2,4	745	56	4,0	320	2,6	1,1	0,36
6,8	4,1	2,7	616	46	4,1	405	2,7	1,0	0,42

Results of Blood assesment - Dogs-2

Leucocytes	Erythrocytes	Hemoglobin	Hematocrit	MCV	MCHC	Thrombocytes	Iron	cPLI	Folic Acid	Vitamin B12	Carnitin
6 - 12 G/l	6 - 9 T/l	15 - 19 g/dl	38 - 55 %	60 - 77 fl	31 - 34 g/dl	150 - 500 G/l	84 - 230 ug/dl	< 200 ug/L	9,3 - 23,8 ng/ml	234 - 812 pg/ml	16 - 42 umol/l
17,8	7,6	17,2	50	66	34	231	130,3	32	11	198	
10,4	7,1	15,3	48	69	32	185	148,3	31	14,1	211	
6,0	7,9	19,1	73	93	26	321	41,1	107	8,8	434	
15,3	7,2	16,5	47	66	35	218	187,5	138	10,9	340	
10,4	6,9	15,9	48	70	33	303	183,6	59		250	
5,9	6,7	15,6	48	72	32	196	161,2	< 30		335	
8,9	8,3	18,6	55	66	34	162		44	8,9	255	
6,3	6,6	15,7	48	72	33	214	237,9	77	8,8	296	35,3
7,1	7,3	17,5	52	71	34	174	202,6	< 30	8,7	224	48,9
7,9	7,9	17,8	58	73	31	188	210,1	43	12,7	280	
12,8	7,1	17,0	54	77	31	159	154,8		8,3	307	
9,3	7,7	18,5	54	70	35	153	126,6			197	
13,3	6,7	15,9	47	69	34	260	113,6	33	15,7	313	
11,9	6,1	14,6	43	72	34	146	107,9	107	15,9	356	
8,1	6,9	17,8	54	78	33	298	211,4	95	12,4	689	46
							149,8	< 30	11,8	236	
11,6	8,0	18,8	56	70	34	200		< 30	4,2	471	
							15 - 45 µmol/l				
6,8	9,1	22,4	55			172	36,8		17,7	254,8	59
4,4	6,9	16,2	50				22,7		13,8	201,4	34
6,9	6,8	16,5	48				23,4		13,1	284,5	26

analyzed by IDEXX	Bun	Creatinine	Natrium	Potassium	Phosphate	Bilirubin	ALT	AP
Reference Range	16 - 38 mg/dl	< 1,9 mg/dl	147 - 159 mmol/l	3,3 - 5,8 mmol/l	0,8 - 2,2 mmol/l	< 0,4 mg/dl	< 175 U/l	< 73 U/l
Cat 1	30	1,0	156	4,7	1,9	0,2	65	67
Cat 2	28	1,6	153	4,7	1,6	0,1	102	40
Cat 3	20	1,3	151	4,5	1,5	0,1	115	56
Cat 4	16	0,7	149	4,7	0,5	0,1	80	29
Cat 5	22	0,7	150	4,2	1,3	0,2	107	36
Cat 6	31	0,8	153	4,5	1,0	0,1	76	42
Cat 7	26	1,0	151	4,1	1,0	0,1	119	63
Cat 8	29	1,2	153	3,8	0,8	0,2	74	42
Cat 9	26	0,8	150	4,8	1,4	0,2	62	25
Cat 10	35	1,1	150	4,5	1,0	0,1	113	29
Cat 11				5,0				
anazlyzed by easyLAB								
Cat 12	28	1	157	4,7	1,7	0,2	77	90
Cat 13	24	0,8	156	4,5	1,7	0,2	87	105
Cat 14	21	0,6	153	4,3	1,4	0,2	67	66
Cat 15	42	1,4	152	4,9	1,6	0,2	71	91

analyzed by IDEXX	AST	Total Protein	Albumin	Globulin	Cholesterin	Fruktosamin	Calcium	Magnesium	Triglyceride
Reference Range	< 71 U/l	5,9 - 8,7 g/dl	2,7 - 4,4 g/dl	2,9 - 5,4 g/dl	< 329 mg/dl	190 - 365 umol/l	2,2 - 2,9 mmol/l	0,6 - 1,1 mmol/l	21 - 432 mg/dl
Cat 1	42	7,1	3,3	3,8	198	210	2,5	1,0	104
Cat 2	38	7,6	3,5	4,1	108	301	2,6	1,1	27
Cat 3	56	9,0	3,6	5,4	132	446	2,4	1,1	42
Cat 4	37	7,1	3,6	3,5	157	267	2,0	1,5	489
Cat 5	24	6,9	3,2	3,7	124	233	2,3	1,0	103
Cat 6	28	6,6	3,2	3,4	122	212	2,4	1,1	53
Cat 7	34	7,5	2,9	4,6	116	220	2,3	1,1	46
Cat 8	26	6,7	3,0	3,7	159	198	2,3	0,9	58
Cat 9	22	6,8	2,8	4,1	100	201	2,3	1,0	55
Cat 10	43	7,1	2,8	4,3	112	214	2,0	1,5	32
Cat 11									
easy Lab									
Cat 12	17	7,3	3,7	3,6	75	260	2,6	0,9	62
Cat 13	19	7,3	4	3,3	93	258	2,6	1	51
Cat 14	22	7,6	3,7	3,9	155	224	2,4	0,9	91
Cat 15	18	7,9	3,2	4,7	147	229	2,4	1,1	51

analyzed by IDEXX	Leucocytes	Erythrocytes	Hemoglobin	Hematocrit	MCV	MCHC	Thrombocytes	Iron	Folic Acid	Vitamin B12
Reference Range	**6 - 11 G/l**	**5 - 10 T/l**	**9 - 15 g/dl**	**28 - 45 %**	**40 - 55 fl**	**31 - 35 g/dl**	**150 - 550 G/l**	**70 - 210 ug/dl**	**11,1 - 21,6 ng/ml**	**269 - 1333 pg/ml**
Cat 1	8,7	7,7	11,3	39	51	29	249	104,8	10,6	634
Cat 2	10,8	8,5	12,1	41	48	30	334	113,4	5,3	1119
Cat 3	6,9	9,6	12,0	40	42	30		95,7	9,0	397
Cat 4	8,7	9,5	12,5	41	43	31	198	89,8		867
Cat 5	6,0	8,8	12,8	42	47	31	129	80,3	10,9	950
Cat 6	12,5	9,6	13,8	40	42	35	299	139,8	15,8	833
Cat 7	6,6	9,6	13,5	44	46	31	235	114,8	7,1	1420
Cat 8	5,4	10,1	13,0	43	43	30	159	88,0	15,7	927
Cat 9	6,5	9,5	12,6	37	39	34	215	130,9	14,8	741
Cat 10	9,9	8,1	9,7	39	47	25	265	224,5	7,0	902
Cat 11								145,4	14,7	496
easy Lab										
Cat 12	7,8	9,4	14	49	52	29	123	80,4	11,1	390
Cat 13	9	10,1	14,8	53	52	28	151	89	12,8	451
Cat 14	5,5	10,5	14,8	51	49	29	219	116,1	9,1	507
Cat 15	8,5	9,6	13,2	46	48	29	430	94,1	12,4	768

12.3. Serum levels of conventionally fed dogs and cats.

	Vitamin B12 pg/ml	Folic acid ng/ml	Iron ug/dl	Totalprotein g/dl		Vitamin B12 pg/ml	Folic acid ng/ml	Iron ug/dl	L-Carnitin umol/l	Totalprotein g/dl
Cat 1	916	16	63	6,34	Dog 1	118	19	194	11	6,63
Cat 2	50	44	146	6,71	Dog 2	287	9	143	22	6
Cat 3	1144	21	55	8,67	Dog 3	172	6	163	39	6,23
Cat 4	421	28	38	8,02	Dog 4	210	13	74	16	6,77
Cat 5	2000	24	109	7,86	Dog 5	15	15	111	50	5,66
Cat 6	36	18	82	6,77	Dog 6	405	4	91	52	6,74
Cat 7	150	14	293	7,66	Dog 7	293	16	96	58	5,98
Cat 8	1321	21	67	7,96	Dog 8	321	15	73	35	7,57
Cat 9	1516	21	50	6,96	Dog 9	271	20	179	49	5,19
Cat 10	87	15	233	7,08	Dog 10	146	12	132	69	6,6
Cat 11	1429	16	92	7,86	Dog 11	653	12	41	37	5,32
Cat 12	369	20	18	7,61	Dog 12	386	9	120	46	6,09
Cat 13	89	17	76	7,31	Dog 13	352	10	137	16	6,53
Cat 14	323	2	133	7,61	Dog 14	183	10	124	58	5,89
Cat 15	370	24	216	9,79	Dog 15	589	14	73	35	6,19
Cat 16	93	17	39	6,81	Dog 16	418	9	219	49	5,52
Cat 17	392	20	61	6,59	Dog 17	248	11	162	69	5,73
Cat 18	357	12	95	6,97	Dog 18	389	17	169	37	6,02
Cat 19	253	14	26	6,05	Dog 19	487	4	165	46	6,02
Cat 20	1327	18	47	5,95	Dog 20	190	13	230	16	7