Welfare assessment in young pet rabbits and guinea pigs in the Netherlands

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Summary

Rabbits and guinea pigs are commonly held pets in the Netherlands. Although they are different species they both die too early in life. Literature describes different diseases and zootechnical issues which can cause welfare impairment and early death in these animals.[4, 5] This study focuses on the most common causes of death in young pet rabbits and guinea pigs related to zootechnical and welfare issues. Necropsy was performed on 92 rabbits and 60 guinea pigs between 2 months and 3 years of age. Owners filled in a specially designed questionnaire regarding the history of disease, housing and feeding conditions. Assessment of the most common causes of death, most common illnesses and possible zootechnical issues has been made.

Of the 92 submitted rabbits, 40,2% (n=37) came from the province Utrecht followed by neighboring provinces. This was probably due to transport that owners had to arrange themselves. Striking was that 26,1% (n=24) of the rabbits were between 2 and 6 months of age. Time and gender distribution did not show many fluctuations. 32,6% (n=30) of the rabbits were euthanized, 58,7% (n=54) was not euthanized and of 8,7% (n=8) of the rabbits this was unknown. Infectious diseases were the main etiology (56,5%, n=52), compared to non-infectious (14,1%, n=13) and unknown (29,3%, n=27). The most common infectious diseases were encephalitozoonosis (26,1%, n=24), coccidiosis (10,9%, n=10) and pasteurellosis (8,7%, n=8). The most common diseases in general are dental disease (54,3%, n=50), pneumonia (30,4%, n=28) and encephalitozoonosis (26,1%, n=24). A remarkable finding was that uterine adenocarcinoma occurred rather frequently in young animals, namely in 10,5% of the female rabbits (does). Castration of does occurred in only 10,5% (n=6) while this is important in preventing uterine adenocarcinoma.[7, 11] This is a lot lower compared to the numbers of castrated males (35,3%, n=12).

As rabbits are social living animals, this is an important factor influencing their welfare. [3-5, 11, 15] The majority (65,3%, n=60) of the rabbits were housed with at least one companion. But social housed rabbits had significantly (p=0,012) more infectious diseases compared to solitary housed rabbits. Rabbits were kept inside (41,3%, n=38), outside (44,6%, n=41) or a combination of inside and outside housing (14,1%, n=13). There was no significant difference between housing locations and the prevalence of infectious disease (p=0,378). As bedding type and cleaning frequency are described as risk factors for developing respiratory disease, this was assessed.[5, 11, 18, 19] There was no significant difference between bedding type and respiratory disease (p=0,179). However, there was a tendency of developing respiratory disease when the cage was cleaned less frequently (p=0,078). Other housing conditions as cage size, materials, enrichment and nutrition could not be assessed, because owners did not fill in the questionnaire appropriately. 43,5% (n=40) of the rabbits were vaccinated against myxomatosis and/or rabbit hemorrhagic disease (RHD), 40,2% (n=37) were not and of 16,3% (n=15) this was unknown.

Of the 60 submitted guinea pigs the majority came from the province Utrecht (35,0%, n=21) followed by surrounding provinces. This was probably due to transport that owners had to arrange themselves. Time, age and gender distribution did not show much variation. 28,3% (n=17) of the guinea pigs were euthanized, 63,3% (n=38) died naturally and of 8,3% (n=5) of the guinea pigs this was unknown. The most common etiology was non-infectious (60,0%, n=35), followed by unknown etiology (21,7%, n=13) and infectious etiology (18,3%, n=11). Most common diseases in general were pneumonia (43,3%, n=26), dental disease (30,0%, n=18) and myocarditis (16,7%, n=10). Remarkable findings in guinea pigs were that calcium deposits occurred in 40,0% (n=24) of the guinea pigs. Ovarian cysts occurred in 16,7% (n=6) of the female guinea pigs (sows) while you expect it primarily in older sows.[7, 22] 2,8% (n=1) of the females were castrated, while this is important for prevention of ovarian cysts.[8] This is low compared to males in which 25,0% (n=6) were castrated.

Guinea pigs are social living animals, so as for rabbits social housing influence welfare.[5, 21, 31, 32] The majority (81,7%, n=49) of the guinea pigs were housed socially. In contrast with rabbits, there was no significant difference in etiology between social and solitary housed guinea pigs (p=0,51). 76,7% (n=46) of the guinea pigs were housed inside, 20,0% (n=12) outside and 3,3% (n=2) a combination of inside and outside housing. There was no significant difference in etiology between inside or outside housed guinea pigs (p=0,74). Type of bedding and cleaning frequency were not related to respiratory disease (p=0,81 resp. p=0,562). As in rabbits, other housing conditions as cage size, materials, enrichment and nutrition could not be assessed, because owners did not fill in the questionnaire appropriately.

In order to prevent the most common diseases that were found in this study, practical recommendations for owners of pet rabbits and guinea pigs were designed.

Introduction

In the Netherlands rabbits (order *Lagomorpha*) and rodents (order *Rodentia*) are commonly held pets. Approximately 980.000 rabbits and 800.000 rodents are held as a pet in the Netherlands in 2003.[1, 2] No data exists about the amount of ferrets kept as pets in the Netherlands. Especially the rabbit is increasing in popularity as a pet, but data of their housing- and welfare conditions are hardly available.[3] It has been suggested that rabbits, rodents and ferrets decease too early in life because of disease, improper housing and feeding conditions or other factors that reduce animal welfare and health.[4, 5] That is why the Veterinary Pathologic Diagnostic Centre (VPDC) of the faculty of Veterinary Medicine in Utrecht assessed the causes of early death and related welfare issues in pet rabbits, guinea pigs, rats and ferrets in the Netherlands. The welfare project started at October 1st 2009 and ended at June 30th 2012. Only four rats and no ferrets were submitted to the welfare project. Thus, this report is only about rabbits and guinea pigs. Welfare recommendations, based on this study as well as available literature, are made to the ministry of Economic affairs, Agriculture and Innovation (EL&I).

Animal welfare

Animal welfare is a very complex concept and no overall accepted definition is used. The Brambell report of 1965 describes 5 freedoms which can be used to assess animal welfare: [6]

1. "Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain full health and vigor." [6]
2. "Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area." [6]
3. "Freedom from pain, injury or disease – by prevention or rapid diagnosis and treatment." [6]
4. "Freedom to express normal behavior – by providing sufficient space, proper facilities and company of the animal's own kind." [6]
5. "Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering." [6]

Using these five freedoms certain welfare requirements can be composed for rabbits and guinea pigs. Commonly reported diseases and welfare requirements will be described in the following paragraphs.

Rabbits

The average life expectancy of a rabbit is eight to twelve years,[1, 3, 7] but the average age as a pet in the Netherlands is a substantially lower. According to questionnaires of Caneel et al. and Schepers et al. pet rabbits deceased at a mean age of 4,2-4,5 years.[1, 3] In the majority of cases the cause of death is unknown,[1] but literature shows contributing factors such a husbandry, nutrition and associated health-problems. Below, common diseases, welfare and zootechnical issues reported in the literature are described.

Common diseases

Not much is known about the prevalence of diseases in young pet rabbits in the Netherlands or other countries. Langenecker et al.,[8] of the clinic for zoo animals, exotic pets and wildlife, Vetsuisse-Faculty of the University of Zurich, assessed the histories of 2125 rabbit patients of all ages between 1994 and 2003 and compared this to studies of four German Clinics (***Table 1***). This is the only known study about frequency of different diseases in pet rabbits and no literature is available about causes of death.

	Own study		**Rheker et al.**		**Kirschbaum et al.**		**Möller et al.**		**Fehr et al.**	
Time period	1994-2003		1990-1999		1992-1993		1981-1983		1998-1999	
Type of practice	Clinic for pets, zoo- and wild animals Vetsuisse-Faculty of the university of Zürich		Clinic for small pets of the veterinary college in Hannover		Clinic for small pets of the veterinary college in Hannover and 3 veterinary clinics.		Veterinary clinic for small animals in Hanau am Main		Clinic for small pets of the veterinary college in Hannover.	
Total numbers	2125		3356		284		130		501	
	Dental disease	14% (n=304)	Dental disease	17% (n=564)	Dental disease	21% (n=60)	Enteritis	15% (n=19)	Dental disease	25% (n=126)
	Castration	13% (n=274)	Castration	12% (n=403)	Elongated nails	10% (n=28)	Eye disease	12% (n=16)	Skin disease	13% (n=66)
	Suspected of *E. cuniculi*	11% (n=233)	Vaccination	5% (n=177)	Gastro-intestinal disease / eye disease	7% (n=20)	Rhinitis / rabbit snuffles	9% (n=12)	Eye disease	11% (n=57)
	Trauma	8% (n=178)	Abscesses	5% (n=162)	Neoplasia	5% (n=15)	Dental disease	8% (n=10)	Musculo-skeletal disease	9% (n=45)
	Abscesses	8% (n=174)	Trauma	2% (n=73)	Abscesses	4% (n=12)	Cystitis / abscesses	6% (n=8)	Respiratory disease	9% (n=45)
	Eye disease	7% (n=152)	Fractures	2% (n=70)	CNS disease / rabbit snuffles	3% (n=9)	Fractures	5% (n=7)	Gastro-intestinal disease	8% (n=41)
	Neoplasia	5% (n=116)	*E. cuniculi*	2% (n=55)	Mites / Fungi skin	3% (n=8)	CNS disease	5% (n=6)	Urinary disease	6% (n=29)
	Fractures	5% (n=97)	Tympani	2% (n=54)	Fracture / myxomatosis / pneumonia	2% (n=7)			Preventive measures	6% (n=28)

Table 1: the most common illnesses in pet rabbits according to Langenecker et al.[8]

Dentition

Problems caused by abnormal dentition are the most important reason for presentation of rabbits at four out of five clinics described by Langenecker et al.[8] In Zurich this occurred in 14% of the rabbits with a mean age of 3,3 years. In the other studies this was 8 to 25% of all the rabbits presented.[8] In the survey of Mullan et al.[9] 29,4% of the rabbits, with a mean age of 2,2 years, had a dental problem. Most of these were subclinical, but some were severe and the majority of owners were not aware.[9]

Rabbits are prone to dental disease, because they have open rooted incisors and cheek teeth that grow continuously.[7, 10, 11] Thus the rabbits need to wear their teeth. Wild rabbits do this by eating abrasive foods, such as grass, bark and roots of trees. This is important to maintain normal occlusion and almost no wild rabbits suffer from dental disease.[11] Pet rabbits do suffer from dental disease, especially pathologic check tooth elongation.[4, 11] Several factors can contribute to this.

Diet is an important factor in the development of dental problems. Diet texture and dental exercise are important,[4, 7, 11] but cannot be the only reason for development of dental disease. Laboratory and commercial rabbits hardly suffer from dental disease, but their diet consists of only pellets in most cases.[11] It is thought that intake of different minerals and vitamins should also be considered.[11] Selective feeding occurs often when rabbits are fed a mixed diet.[4, 9, 11] The pellets, which contain the important vitamins and minerals, especially calcium and vitamin D, are less palatable and are not eaten enough. Calcium depletion can occur with a metabolic bone disease as a consequence. This happens more often in older rabbits, because calcium depletion takes time to develop.[9, 11]

Besides diet it is thought that there are other contributing factors: genetic predisposition, hormonal influence of estrogens, thyroid hormone, corticosteroids, other vitamins and minerals, trauma and additional diseases, such as kidney-, gastro-intestinal-, liver- and pancreas diseases which have an influence on calcium and vitamin D intake, metabolism and excretion.[4, 11] Indoor housed rabbits seem to be predisposed, possibly due to no direct sunlight which is necessary for vitamin D metabolism. If pet rabbits live outside all year and have unrestricted access to grazing and browsing they barely develop dental problems.[11] But rabbits that are kept inside and are fed with a proper diet which is rich of grass, hay and vegetables are less prone to develop dental disease in comparison to those fed a mixed diet with little roughage.[9, 11]

Nervous system

11% of the rabbits in the study of Langenecker et al.[8] were suspected of an infection with *Encephalitozoon cuniculi* (*E. cuniculi*). 91% of these rabbits had signs of the nervous system and 28% had a uveitis. 88% was tested positive using serology. Thus 9,7% of all the rabbits in the study of Langenecker et al.[8] had a positive test result. In only 2 percent of the rabbits in the study of Rheker et al.[8] *E. cuniculi* was “confirmed”. Nervous signs were found in 3-5% of the rabbits by Kirschbaum and Möller respectively. Fehr et al. did not mention nervous signs in their top 8.[8] *E. cuniculi* is mentioned as the most common cause of neurologic disease by many authors.[4, 11]

E. cuniculi is a protozoan parasite which infects the host with spores. These spores infect the lung, kidneys and liver in the acute stadium of the disease. In more chronic cases the brains, kidneys and heart are infected. It can also cause uveitis, abortion and neonatal death.[4] Infections can be asymptomatic or latent.[4, 7, 11] Excretion and transmission occurs especially via the urine for up to three months.[4]

Other infectious neurological diseases, such as toxoplasmosis,[4, 11], rabies and herpes virus are not common.[4] The most common non-infectious neurological disease is vertebral fracture or luxation. This is due to trauma by improper handling or with startled rabbits. There are a lot of other non-infectious neurologic diseases.[4, 11]

Respiratory system

Respiratory diseases are found in 8% of the presented rabbits in the study of Fehr et al. Pneumonia had been found in only 2% of the cases by Kirschbaum et al., rhinitis in 9% of the cases by Möller et al. and rabbit snuffles was found in 3% of the cases by Kirschbaum.[8]

Snuffles is used to describe a rhinitis caused by *Pasteurella multocida* (*P. multocida*), but this is not always the cause of a rhinitis or a respiratory disease.[4, 11] *P. multocida* is a common inhabitant of the nasal cavity and tympanic bullae[7] and is thought to be an opportunistic agent.[11] It can cause an upper respiratory infection, conjunctivitis, otitis, (pleuro-)pneumonia, pericarditis, sepsis, abscesses in the internal organs, bones, joints, subcutaneously and genital organs.[4, 7, 11] Young rabbits who are recently bought from a pet shop or breeder are sensitive. Older rabbits can be infected, but this is due to stress and/or poor husbandry such as high ammonia and dust that irritate the respiratory tract.[11]

Another normal inhabitant of the respiratory system of the rabbit is *Bordetella bronchiseptica* (*B. bronchiseptica*). But this bacterial agent is hardly pathogenic in rabbits. Other possible infectious agents of rabbits are *Staphylococcus aureus, Moraxella catarrhalis, Mycoplasma spp., Chlamydia spp.* and a not very common form of myxoma virus infection.[4] Non infectious respiratory diseases are allergic diseases,[4, 7] trauma,[4, 11] corpus aliena, pleural diseases[11] and several neoplasms, such as a carcinoma of the nose turbinates, thymoma or lymphoma and metastasis.[4, 11]

Gastro-intestinal tract

Enteritis was found in 15% of the rabbits by Möller et al. Gastro-intestinal diseases were found in 7 and 8% of the rabbits by Kirschbaum et al. and Fehr et al. respectively.[8] In other literature many gastro-intestinal diseases are mentioned. Many of these are related to diet,[4, 11], but there are other non-infectious an infectious enteric diseases.[4, 7, 11]The most common mentioned infectious diseases are bacterial enteritis (*Escherichia coli* and *Clostridium spp.*), viral enteritis (Rota- and coronavirus) and parasitic diseases (especially coccidiosis). The most common non-infectious diseases next to diet related diseases are antibiotic enterotoxaemia, gastrointestinal hypomotility and trichobezoars, gastric ulcerations and neoplasie. [4, 5, 7, 11, 12]

Urinary system

Diseases of the urinary system were only in the top 8 of Fehr et al with 6% of the presented rabbits.[8] Urolithiasis and hypercalciuria, kidney failure, encephalitozoonosis and neoplasia are some of the mentioned urinary diseases in the literature.[4]

Remaining organ systems

Other diseases found in the clinics described by Langenecker et al.[8] were skin disease in 13% of the cases, mites in 3%, musculoskeletal disease in 9%, eye disease in 7-12%, trauma in 2-8%, abscesses in 4-8%, fractures in 2-5% and overgrown nails in 10% of the cases.[8]

Myxomatosis and Rabbit Hemorrhagic Disease (RHD)

Myxomatosis and Rabbit Hemorrhagic Disease (RHD) are two important viral diseases of rabbits. Mainly because they have a high mortality rate and there is no effective therapy. Prevention of these diseases by vaccination is essential.[4, 7, 11] According to Schepers et al.[3] and Mullan et al.[9] only 44% respectively 54% of the rabbits were inoculated against myxomatosis. This was 46% respectively 57% for RHD. [3, 9] In the study of Rheker et al. 5% of the rabbits were presented for vaccination. 2% of the rabbits had myxomatosis in the survey of Kirschbaum et al.[8]

Recently, a new vaccine is available in the Netherlands (Nobivac Myxo-RHD). Before this development, rabbits needed to be vaccinated once a year for RHD (with Cunical®) and vaccinated 2 times a year for myxomatosis (with Lyomyxovax®). The proved minimal immunity was only 4 weeks for the Lyomyxovax® vaccine.[13] Other disadvantages were that this vaccine only came in packages of 10 doses and shelf life was only 2 hours after opening. The new vaccine is individual and has to be administered only one a year. A disadvantage of the new vaccine is that rabbits which survived from a myxomatosis infection or have been vaccinated with another vaccine against myxomatosis, possibly do not develop an adequate immune response against RHD.[13]

Uterine adenocarcinoma and castration

Prevention against disease by castration of does is important. Uncastrated does have a high risk of developing uterine adenocarcinoma with ageing.[7, 11] These tumors metastasize very quickly,[7] locally as well as hematogenously to the lungs and other organs.[7, 11] The prevalence is 50 to 80% of the does older than 4 years.[4, 11] In a study of Greene et al. 16,7% of the 2 to 3 year old does already had a uterine adenocarcinoma. Incidence increased with age. At 3-4 years old incidence was 20,8%, at 4-5 years 63,3% and 5-6 years 79,1% .[14]

Only 2 of the does in the survey of Mullan et al. were neutered to prevent uterine adenocarcinoma. In total 41,2% of the does were castrated.[9] In the study of Langenecker et al. there was a neoplasia in 5% of the rabbits. Unfortunately the types of neoplasia are not described. Castration was an important reason to visit the clinics of the studies of Langenecker et al. and Rheker et al. 12% of the presented rabbits came for castration. But gender distribution is not described and males are castrated more often.[8]

Welfare and zootechnical issues

Domesticated rabbits share a lot of the characteristics of their wild counterparts. Although they are tamer, easier to handle [4, 11] and some of them do not dig burrows anymore,[11] survival reactions are still the same. This is primary running to a shelter or freezing to avoid detection. Nevertheless, most pet rabbits are easily distressed by changes in their environment or diet.[4]

Husbandry

Just as their wild ancestors, the European rabbit (*Oryctolagus cuniculus*), domestic rabbits are social living animals.[3-5, 11, 15] Schepers et al.[3] surveyed housing conditions in relation to early death and other welfare parameters via a questionnaire. One important result was that solitary housing was a factor negatively influencing the lifespan of pet rabbits. Socially housed rabbits died at an age of 5,1 years old and solitary housed rabbits died at an age of 3,3 years old.[3] Studies in laboratory rabbits showed that social housed rabbits showed less behavioral[11, 15, 16] and health problems compared to solitary housed rabbits.[11] Wild rabbits live in groups of 2 to 8 adults with their offspring. The males defend the territory and the females are less aggressive to each other. As a consequence, domesticated rabbits must not be kept alone and can be kept as pairs, preferably opposite sexes. Males, but also females can start a fight towards rabbits of the same gender.[11] Small groups of up to 6 to 8 rabbits are also a possibility. In the laboratory these are of the same sex and preferably litter mates. But mixing of a male with several females is also possible if the male and/or the females are castrated if breeding is undesirable.[5, 15] Some pet rabbits are housed with guinea pigs as companionship. This is not recommended because of differences in behavior and nutritional needs. Besides that, *Bordetella bronchiseptica* is pathogenic for guinea pigs, while rabbits can carry this organism with them without becoming ill.[4, 7]

There is no consensus of cage or pen size,[15] but it needs to be high enough to stand up on the hind legs and hop around.[4] Small cages can lead to abnormal behavior (such as restlessness and stereotypes)[11, 15] and health problems (such as skeletal disorders, ulcerative pododermatitis, spinal fractures, osteoporosis and other deformities). Exercise is an important preventive measure for these health issues.[4, 11] Therefore, the accommodation should be as big as possible. ***Table 2*** shows "recommendations by different authorities for minimum cage areas (cm^2) for laboratory rabbits" as stated by Lidfors et al.[15] For pet rabbits larger accommodations are recommended, minimal $1m^2$ to $3m^2$ for an average rabbit. Large and group-housed rabbits need even more space.[4, 5, 11] The height of the accommodation is 40-60cm for laboratory rabbits[15], but rabbits can jump on shelves or raised platforms situated at a height of 2 meters.[4]

Weight (kg)	Swiss Ordinance of Animal Protection 1991	UK Home Office 1989	European Union Council Directive 1986	World Rabbit Science Association 1992
<2	3400	4000	1400	2000
2	4800	4000	2000	2000
3	-	4000	2500	-
3.5	7200	-	-	-
4	-	5400	3000	3000
>5	9300	-	-	-
>5.5	-	-	-	4000
>6	-	6000	-	-

Table 2: "The recommendations by different authorities for minimum cage area (cm^2) for laboratory rabbits" stated by Lidfors et al. [15]

Besides a large cage, Harcourt-Brown[11] advises exercise outside the cage for at least four hours a day.[11] Important is that this area is escape proof,[11] there is enough protection against the sun, predation (such as a cat or dog),[5, 11] wires, toxic plants and other materials.[4] Rabbits are clean animals which deposit there feces and urine in one place and can be trained to use a litter tray.[4, 11, 15] Thus extra exercise outside of the cage is also possible inside the house.

Enrichment objects can be used to prevent abnormal behavior. Boxes or raised shelves can be used as a shelter, look-out or for other recreation.[11, 15] Other examples of enrichment objects are wooden sticks, balls for cats, parrot toys, branches to chew on and drainpipes.[11] Mirrors in the living area increases the amount of time the rabbit spends investigating and feeding in this area. Probably by enriching the visual environment.[15]

Rabbits can be housed inside as well as outside.[4, 5, 11] An advantage of outside housing is the natural supplementation of vitamin D by the sun.[11] But there must be enough protection against mosquitoes, flies and predators.[5] The direct environment of the cage or hutch of the rabbit is important. The cage must be placed in a dry, cool and well-ventilated spot with appropriate protection against rain, wind,[4, 11] draught[5] and sunlight.[4, 5] Optimal temperature is 15-22ºC, with a mean of 18ºC.[11, 15] Rabbits cannot cope with high temperatures (>28ºC[11]), because they cannot pant or sweat effectively.[4, 11, 15] Lower temperatures can be tolerated much better. Important for rabbits kept outside in the winter is acclimatization, a proper shelter with plenty of bedding. [4, 11] In laboratory rabbits a regular dark:light cycle with a light intensity of 200 lux one meter above the ground is recommended. Also a humidity level of 45 to 65 percent is recommended.[15]

Bedding can be an important factor influencing pet welfare, because animals are in close contact with it. For example, rat pups held on cedar-wood shavings had a higher mortality and grew less than rat pups held on crushed corncobs or shredded aspen.[17] Important requirements of bedding are that they absorb moisture from urine and feces to decrease bacterial growth, reduce production of ammonia and CO_2 and build-up of bacterial toxins.[18] If ammonia rises in the cage different problems can develop such as respiratory and eye problems, lethargy and burns on the skin due to contact with soiled bedding.[5, 11, 18, 19] Beddings should also protect the animal from temperature fluctuations, it should be a comfortable substrate and provide a form of enrichments such as digging, nesting, resting and foraging and it may not be toxic or dusty.[18] It is also thought that sawdust, which is commonly made of cedar- and pinewood in Europe, contains toxic substances such as abietic acid and phenols. Abietic acid increases the incidence of neoplasm, liver- and respiratory problems in both rabbits and rodents. The function of the immune system is decreased, more inflammations occur and skin and eye irritation can also exists.[20] Appropriate bedding according to literature are absorbent compressed paper,[12] newspaper or shredded paper covered with hay,[5, 11] wood chips or shavings but not of cedar or pine,[5, 7, 12, 20] garden peat[11] or corn cob.[5] Inappropriate are saw dust and clay.[12]

Nutrition

Appropriate nutrition is important for rabbit welfare. Not only because of the "Freedom from hunger and thirst", but also to prevent disease and express natural behavior. Rabbits are strictly herbivorous and their digestive system is adapted to digest a high fiber diet.[4, 11] Diet fiber stimulates gut motility and other processes in the gut.[4] Wild rabbits graze and forage especially from dusk to dawn.[4, 11] They eat grasses, herbs, succulent buds, young leaves of bushes, weeds, roots and bark of bushes and trees.[4, 15] Sadly, there is only knowledge of short-term feeding for commercial rabbits. No scientific feeding trials exist about nutritional requirements for long-term maintenance of pet rabbits.[11]

As stated before rabbits are selective eaters, [4, 9, 11] with a preference of sugars.[4] Mixed diet, which is given to pet rabbits by many owners, can cause health problems such as dental disease as discussed in the paragraph about common diseases in rabbits. Availability of pellets should be limited, as they are low in fibers and can cause obesity and chronically soft stools.[4, 5, 11] Not more than 2-3% of the rabbit's bodyweight should be fed.[11]

Ad libitum hay and/or grass is needed as a source of fiber.[4, 9, 15] Hay is also diet enrichment and can prevent stereotypic behavior,[3, 15] but not when it is grounded. Thus long fibers are important.[15] A variety of vegetables, such as beet, carrot, collard, broccoli tops, clover, dandelions greens and parsley can be given. Introducing these vegetables to young rabbits should be done gradually.[4]

Other foods, such as snacks, grains or other food high in sugar and starch, are not recommended because it can cause hindgut carbohydrate overload, diarrhea and obesity.[4] Salt licks and/or mineral blocks are not necessary when fed an appropriate diet and the high calcium can be harmful.[11] Relatively large amounts of water are consumed by rabbits, about 50 to 150 ml per kg bodyweight per day.[4, 15] Water should be available continuously.

A lot of diseases have been described for rabbits, but nothing is known about death causes in young pet rabbits. Zootechnical issues as inadequate nutrition and housing probably are contributing to early death in pet rabbits.

Guinea pigs

The average life expectancy of a guinea pig is four to eight years.[1, 7, 12] But there are reports of guinea pigs reaching an age of 10 years old.[1, 21, 22] According to Caneel et al. the mean age in the Netherlands was 4,0 years and 50 percent of the guinea pigs in this survey deceased at an age younger than four years of age.[1] There might be an association between the reason to purchase a guinea pig and their lifespan. Guinea pigs died earlier when the where bought for children. Lack of experience was also a factor negatively influencing the guinea pigs lifespan.[1]

Common diseases

According to the literature there is no knowledge about the most common illnesses in young pet guinea pigs. Just as for rabbits, Langenecker et al.[8] assessed the histories of 2009 guinea pig patients of all ages between 1994 and 2003 and compared this to studies of German Clinics (***Table 3***). Apathy and loss of appetite of unknown reason was most common (14% of the cases).[8] The other illnesses in pet guinea pigs are discussed below.

	Own study		**Rheker et al.**		**Kirschbaum et al.**		**Möller et al.**		**Fehr et al.**	
Time period	1994-2003		1990-1999		1992-1993		1981-1983		1998-1999	
Type of practice	Clinic for pets, zoo- and wild animals Vetsuisse-Faculty of the university of Zürich		Clinic for small pets of the veterinary college in Hannover		Clinic for small pets of the veterinary college in Hannover and 3 veterinary clinics.		Veterinary clinic for small animals in Hanau am Main		Clinic for small pets of the veterinary college in Hannover.	
Total number	2009		2352		323		140		341	
	Unspecified apathy and anorexia	14% (n=289)	Dental disease	16% (n=368)	Mites	22% (n=70)	Dental disease	26% (n=37)	Gastro-intestinal disease	38% (n=130)
	Dental disease	12% (n=251)	Castration	12% (n=281)	Dental disease	9% (n=29)	Mites	11% (n=15)	Dental disease	20% (n=68)
	Castration	10% (n=209)	Abscesses	6% (n=152)	Elongated nails	8% (n=26)	Elongated nails	10% (n=14)	Musculo-skeletal disease	13% (n=45)
	Mites	10% (n=207)	Neoplasia	3% (n=72)	Neoplasia	8% (n=25)	Enteritis	9% (n=13)	Neoplasia	10% (n=34)
	Neoplasia	7% (n=135)	Mites / fractures	2% (n=57)	Gastro-intestinal disease	7% (n=24)	Castration	9% (n=12)	Nervous / sensory organ diseases	9% (n=31)
	Abscesses	6% (n=113)	Pneumonia	2% (n=54)	Eye disease	5% (n=16)	Liver disease	4% (n=6)	Urinary disease	8% (n=26)
	Eye disease	5% (n=109)	Mycosis	2% (n=43)	Fracture	3% (n=9)	Ovary cysts / cystitis/ abscesses / neoplasia	4% (n=5)	Mites	7% (n=24)
	Trauma	4% (n=87)	Trauma	2% (n=41)	Adenitis	2% (n=7)	Eye disease	3% (n=4)	Eye disease	6% (n=20)

Table 3: most common illnesses in guinea pigs according to Langenecker et al.[8]

Dentition

Guinea pigs are prone to dental problems because they have hypsodontic (open rooted) incisors and check teeth. Thus, they grow continuously, but there is also a strong genetic predisposition.[4, 5, 7, 12, 22] Dental problems has been found in 12% of the guinea pigs in the study of Langenecker et al.[8] These guinea pigs had an average age of 3 years and 4 months. Other studies showed a prevalence of dental problems varying from 9 to 20%.[8] Like rabbits, nutrition is a contributing factor for dental disease. Little roughage and fibers, hypocalcaemia and specific for guinea pigs hypovitaminosis C or scurvy with loss of the periodontal ligament. Other causes are congenital defects, trauma, systemic illness that causes anorexia, osteoarthritis of the mandibulary joint, ageing and stress.[4, 5, 7, 10, 22]

Gastro-intestinal system

According to a survey of Fehr et al. and Kirschbaum et al. 38% of the guinea pigs had a gastro-intestinal problem.[8] According to the other comparative studies this was 7-9% and others did not report gastro-intestinal problems in their top 8 of most common diseases.[8] Unfortunately, it is not clear which gastro-intestinal diseases were most common in these studies. The most known gastro-intestinal problems of guinea pigs according to other literature are antibiotic associated enterotoxemia, bacterial enteritis and parasitic diseases[4, 5, 7].

Guinea pigs gastro-intestinal flora is predominantly gram-positive and can be destroyed by i.e. ampicillin, bacitracin, cephalosporins, clindamycin, erythromycin, gentamicin, lincomycin, penicillins, spiramycin and oral tetracyclines.[4, 7] Overgrowth of *Clostridium difficile* and production of its toxin can occur.[4] Bacterial enteritis can be caused by *Escherichia coli*, *Clostridium piliforme*, *Campylobacter* spp., *Salmonella* spp., *Yersinia pseudotuberculosis*, *Pseudomonas aeruginosa* and *Listeria monocytogenes*. Stress and diet can alter normal gut flora, so these pathogenic bacteria can become dominant.[4, 5, 7]Parasitic diseases caused by *Eimeria caviae* and *Cryptosporidium wrairi* are not very common in guinea pigs.[5] They are more common in young animals, especially in combination with stress, overcrowding, poor husbandry and other infections. [4, 5, 7]

Respiratory system

Pneumonia occurred in only 2% of the guinea pigs according to Rheker et al. and was not mentioned by the other comparative studies.[8] However, respiratory disease, especially (bacterial) pneumonia, is mentioned as the most significant disease problem and most common cause of death in guinea pigs in textbooks.[4, 5] *Bordetella bronchiseptica*, a gram-negative rod, is mentioned as the most common cause of bacterial pneumonia. Asymptomatic carriers, such as the rabbit, dog and non-human primates, might play an important role in the transmission of this disease.[4, 5, 7] *B. bronchiseptica* is most common in young animals in combination with suboptimal care.[5] *Streptococcus pneumoniae* is another common bacterial cause of pneumonia[4, 5, 7] which also has much asymptomatic carrier species.[4] It is most common in stressed and/or young animals.[4] Adenovirus of the guinea pig is not common, but has a mortality up to 100%. The virus can cause necrotizing bronchopneumonia in laboratory and pet guinea pigs. Stress, immunodeficiency, a very low or high age are the most important contributing factors.[5]

Ectoparasites

10% of the guinea pigs in the study of Langenecker et al.[8] had mites. In the comparative study the prevalence of mites varied from 2-22%.[8] The most common mites of guinea pigs are *Trixacarus caviae*[4, 5, 7] and *Chirodiscoides caviae*.[4, 5]Other uncommon mites are *Sarcoptes muri*s, *Notoedres muris, Myocoptes musculinus* and *Demodex caviae*. [4, 5] Guinea pigs are also susceptible to other ectoparasites, such as lice (*Gliricola porcelli and Gyropus ovalis*)[4, 5, 7] and fleas (*Ctenocephalides felis*).[4]

Urinary system

In 8% of the guinea pigs in the study of Fehr et al. urinary problems existed.[8] Urolithiasis had a incidence of 4% according to Langenecker et al.[8] It is a common urinary problem of guinea pigs with a mean age of 3 years.[23] According to Peng et al. females older than 3 years are predisposed.[4, 5, 24] But Hawkins et al.[23] did not confirm this gender predisposition in their study. They also found a mean age of three years of the guinea pigs with urolithiasis which varied from 0,5 – 5 years.[23] The etiology of calculi formation is unknown. Possibly an urinary tract infection involving *Escherichia coli* or *Streptococcus pyogenes* plays a role in laboratory guinea pigs. But this has never been reported for pet guinea pigs.[4, 23-25] Infection of the urinary system with gastro-intestinal bacteria might occur more in female guinea pigs because the anus and urethral opening are closer to each other in comparison to males. This might be a reason why females are more prone to developing urolithiasis.[4, 24] But males are more prone to develop an obstruction due to urolithiasis followed by serious illness. This might be a reason why males and females are equally found in the study of Hawkins et al.[23] Both studies had a small research group of 52[23] and 6[24] guinea pigs with urolithiasis. Predisposing factors other than bacterial infection might be decreased water intake, nutritional imbalance and anatomical defects.[5]

Other more or less common urinary tract diseases are urinary tract infection,[4, 24] chronic interstitial nephritis (CIN)[4] and in particular in older guinea pigs kidney failure.[22]

Remaining diseases

The other diseases that were found by Langenecker et al. were neoplasia (7%), abscesses (6%), ophthalmic diseases (5%), and trauma (4%). Liver problems were reported in 4% of the guinea pigs by Möller et al.[8]

Castration and ovarian cysts

10% of the guinea pigs in the study of Langenecker et al. were offered for castration.[8] It was not reported which gender the guinea pigs had or the reason for castration. An important reason to castrate female guinea pigs is the development of ovarian cysts with increasing age.[4, 7, 22] These cysts can develop as early as 10 days of age,[22] but problems develop at a later age.[7, 22] Possible contributing factors can be solitary housing, obesity and hormonal imbalance.[26] Reduced reproductive performance,[22, 27, 28] depression, anorexia and alopecia, gastro-intestinal and respiratory problems can be caused due to increasing size and hormonal activity.[22, 26] Cystic endometrial hyperplasia (CEH), mucometra, endometritis[22, 27, 28] and fibroleiomyomas are associated with ovarian cysts.[27, 28] Ovarian cysts were found in 3 and 4 percent of the presented guinea pigs in the study of Langenecker et al. and Möller et al. respectively.[8] But necropsy of guinea pigs between 1,5 and 5 years of age showed that 76% had ovarian cysts.[4, 28] Nielsen et al.[29] showed a prevalence of 58% in general and 88% in guinea pigs older than 1,5 years and that reproductive status did not affect prevalence or size of ovarian cysts.[29]

Welfare and zootechnical issues

Domesticated guinea pigs (*Cavia porcellus*) have a lot in common with their wild ancestors (*Cavia aperea*).[30] However, a few differences exist. Domesticated guinea pigs show less intraspecific aggressive behavior and have a higher level of sociopositive behavior. Besides this, they express less explorative behavior and are less attentive to their physical environment.[30] Domesticated guinea pigs are less alert and sensitive to an unfamiliar environment in comparison to their wild counterparts.[30] They are gentle animals which rarely bite or scratch.[12] They are still a bit nervous[21] and when excited they can run in circles in their cage[12] or find a hiding place.[5, 30] Guinea pigs develop rigid habits[12] and thus are very sensitive for environmental changes. They can stop eating or drinking in these cases.[12, 21, 30]

Husbandry

Wild guinea pigs are social living animals.[5, 21, 31, 32] They live in male-dominated, polygamous groups of 5 to 10 animals.[5, 21, 30] They eat and rest in groups[5] and develop a stabile hierarchie.[21] It is possible that solitary housing can have a negative effect on lifespan of the guinea pig as it is in rabbits. However this was not proven, but could be assessed with a questionnaire comparable to the questionnaires of Schepers et al.[3] and Mullan et al.[9]. However, it has been demonstrated that boars housed with a sow have a lower cortisol response compared to solitary housed boars when they are composed to a new environment.[21, 30] Because of this, and the fact that wild guinea pigs are social living animals, it is recommended to keep these animals in pairs or groups.[7, 21, 30, 31] Important is that there is enough food, feeding bowls, drinking nipples[31] and space[30] available. Castration of the boars and/or sows in mixed groups is important if breeding is not desired.[7]

It is possible to keep two males as a pair, but especially strangers will start fighting.[5, 21, 31] Keeping two siblings without a female nearby is possible, but it is possible that fighting starts when they reach adulthood.[21, 31] Keeping more than two males together in a group is not recommended because higher frequency of antagonistic behaviors and higher cortisol levels in big groups of males.[30] A pair composed of a male and a female is a good possibility to house guinea pigs. Fighting or threat displays are not seen when keeping a male together with a female.[5, 30] Sows are less aggressive towards each other compared with boars.[31] It is possible to keep adult sows in groups[30, 31], but level of aggressiveness is higher in all female groups compared to mixed groups.[5, 30, 31] Aggressiveness lowers in these groups when a male is added.[30] A small mixed group of more than one male with a few females is not recommended, because of a higher frequency of intensive threatening and fighting behavior among the males. Thus more stress and injuries occur in these groups.[30] Large groups of males and females is preferred by Sachser et al.[30] for laboratory guinea pigs, because subgroups are formed. Males and females which are previously kept solitary or in pairs cannot be introduced in such groups because they do not ‘understand’ the social hierarchy in these large groups. Extreme stress, threatening and fighting behavior and thus injuries occurs if this takes place.[30]

Some guinea pigs are housed with rabbits, but as discussed in the section about welfare issues in rabbits this is not recommended because of differences in behavior and illnesses. Also, a preference test showed that 30 day old guinea pigs that could chose to sit alone or with a rabbit, spend 40% of the time with the rabbit. This was compared to the possibility of a female guinea pig as companionship. Young guinea pigs spend considerably more time (80%) with the sow than with the rabbit.[30]

Housing of guinea pigs can be inside as well as outside.[30, 31] A dry shelter is important when housed outside[30, 31] and heaters can be installed during frost.[30] Cage size needs to be big enough to prevent health issues due to restricted exercise[31], aggressiveness and stress due to overcrowding.[30] As in rabbits there is no consensus of cage size. Cage surface needs to be at least 615,6cm^2, 652cm^2, 700cm^2, 2000cm^2, 2500cm^2 and 9000cm^2 per adult according to different literature. [21, 12, 5, 31, 30, 7] Cage height must be at least 17,5 cm[21], 25cm[12, 31] or 30 cm.[30] At 30 cm adults can fully rise and juveniles can play (e.g. frisky hops)[30], but guinea pigs do not climb so cages do not have to be higher.[12, 30, 31] Rectangular cages are advised, as guinea pigs tend to circle when in panic.[12] Additional floor space to exercise is possible with floor or outdoor grass runs.[31]

As guinea pigs are shy animals they need hiding areas as cage enrichment.[5, 21] Commercial houses, whole or half PVC or plastic drain pipes or nesting boxes[5, 7, 12, 21] and loose hay[5] are suitable for a sense of security. Running wheels are not used, because guinea pigs generally are inactive.[5] Diet can be used as enrichment. Gnawing and wearing down the incisors is important.[5, 21] Laboratory guinea pigs showed less gnawing of cage bars and feed hoppers when they had access to softwood sticks. Porous stones (pumice), young branches of elm, grapevines, maple and birch or bark of apple, peach and pear trees are other possibilities.[30]

Just as in rabbits, environment of the cage of the guinea pigs is important. They need a quiet surrounding as loud noises can cause panic and injuries.[12, 30] Besides this, they need a well ventilated, draught free[5, 30, 31] enclosure with protection against sun[5, 7, 12, 31] and predators.[7] The optimal temperature range is 20-22ºC[31], but can vary from 16ºC to 26ºC.[5, 7, 12, 21, 30] Higher temperatures can cause heatstroke[7, 12, 31] and problems with fertility.[12, 31] A natural or 12:12 dark:light cycle is appropriate for guinea pigs.[12, 30] A humidity between 30-70% is recommended.[5, 7, 12, 30, 31]

Bedding requirements of guinea pigs are comparable to those of rabbits. Beddings like wood shavings, shredded paper or other material of plant origin are mentioned as suitable, but not of pine- or cedar woods.[5, 7, 12, 31] Sawdust is not appropriate, because these fine materials can cause eye problems, respiratory problems and can stick to vulva, scrotum and preputium and cause irritation and obstruction. Straw and hay can cause trauma, especially of the eyes.[31] Cleaning of the cage needs to be done at least once a week[12, 30, 31], preferably twice a week[5], to prevent build-up of ammonia. Build-up of scale in the hutch can occur due to small crystals in the urine of the guinea pig. This can be removed with a weak acid solution.[12, 31]

Nutrition

Nutrition is important for guinea pig welfare as it is for rabbit welfare. Guinea pigs are strictly herbivorous.[5, 12, 31] They eat together, mostly in the evening and at night.[21] As guinea pigs are messy pets, drinking bottles are recommended, although they chew and play with nipples. Feeding bowls are frequently contaminated with feces or bedding, so frequent cleaning is advised.[12] Diet preferences are developed early in life.[5, 31] Thus, guinea pigs are fastidious or fussy eaters.[5, 7, 12, 31] They can stop eating and drinking when there is a change in feeding composition, feeding bowl are drinking system.[7, 12, 21] Dietary changes should be made gradually, as this can cause anorexia and gastro-intestinal problems.[31]

Pellets are preferred above a mixed diet as guinea pigs are selective eaters. Same problems as in rabbits can arise when guinea pigs are fed a mixed diet. [7] Pellets designed especially for guinea pigs are needed, because of the right amounts of vitamin C (see later) and other vitamins and minerals.[5, 12] Feeding a high quality of pellets decreased the incidence of metastatic calcifications in laboratory guinea pigs.[21] In total 60-70 g food/kg body weight/day is eaten by non breeding guinea pigs.[5, 12] The majority of this should be hay and only a small amount should exist of pellets. The recommended amount of pellets is not available in the literature.

According to Laber-Laird et al.[5] feeding only pellets is enough, because it is a complete diet.[5] However, other authors state that an appropriate diet exists of limited amounts of pellets, combined with hay and fresh vegetables.[7, 12, 21, 30, 31] Food intake is not controlled by the amount of calories, but by bulk consumed. Thus, feeding hay decreases the risk of developing obesity.[12] Feeding hay also improves production and growth, prevents dental disease and improves gastro-intestinal tract function.[7, 12] Hay should be given continuously.[12] Alfalfa hay contains high levels of calcium and can cause urolithiasis. Timothy or grass hay does not and is suitable to give ad libitum.[21] As discussed before hay can also function as diet enrichment.[30]

Vegetables can be given as treats[12] and as a source of minerals and vitamins, especially vitamin C.[4, 5, 7, 12, 21, 22] Vegetables with a high liquid content, such as lettuce, are not recommended because of possible gastro-intestinal problems.[21] It has been recommended to give a maximum amount of 10% of the daily intake as vegetables.[12]

Treats as fruit, bread, rolled oats, dry cereals, grains, seeds, candy-style treat foods, table scraps, raisins, figs and hazelnuts have a high sugar or starch content and should be limited or not given at all.[7, 12, 21, 31] Donnelly et al. suggests not more than one tablespoon a day.[21]

Vitamin (Vit.) C deficiency or scurvy is the most important nutritional disease of guinea pigs.[4, 5, 7, 12, 21, 22] Guinea pigs miss an enzyme essential for synthesis of ascorbic acid from glucose. Vit. C is important for synthesis and maintenance of collagen[4, 5, 7, 12, 22] and catabolism of cholesterol to bile acids.[5] As vit. C is not stored, daily intake is essential.[12] Dietary requirement of a non breeding guinea pig is 10-30 mg/kg/day, but up to 50 mg/kg/day for a breeding guinea pig.[5, 7, 12, 21, 22, 31] Stressed or ill guinea pigs need even more.[5, 7] It is not toxic in higher doses and it is excreted in the urine.[5] Commercial pellets containing vit. C need to be stored in a dry, cool and well ventilated environment to reduce the oxidizing of ascorbic acid.[4, 5, 21, 22] It needs to be fed within 90 days after milling, otherwise there is almost no vit. C in the pellets.[4, 5, 12, 21, 22, 31] Other manners to supplement vitamin C is through drinking water, vegetables and fruit or tablets. As vit. C is very instable in water, high concentrated solutions (0,2-1 g vit. C/liter water) need to be made every day. This must be even higher in hard water, with high temperatures and if the solution comes into contact with metals. Thus it is not a reliable manner of supplementing vitamin C.[4, 5, 7, 12, 22] Vegetables rich in vitamin C are kale,[4, 5, 7, 12, 22] parsley,[4, 7, 12] beet greens, [4, 12], red and green sweet peppers[4, 21, 22], spinach,[4] broccoli and many others. [4] Tablets which contain 50 to 60 mg of vitamin C can be given.[12]

As for rabbits a lot of diseases are described for guinea pigs, but nothing is known about diseases and cause of death in young pet guinea pigs in the Netherlands. This study focuses on most common diseases and their relation with zootechnical aspects. Other welfare factors, such as behavior, cannot be evaluated within this study.

Materials and methods

At the start of the welfare project, October 1st 2009, the age limit of rabbits, guinea pigs and ferrets was set between 6 and 36 months and for rats between 6 and 12 months. A year later the lower age limit was decreased to 2 months of age. 92 rabbits, 60 guinea pigs, 4 rats and zero ferrets were submitted to the welfare project from October 1st 2009 until June 30th 2012.

After decease, animals were cooled to 4°C as soon as possible and submitted within 24 hours for necropsy. The necropsy was performed at Utrecht University, Faculty of Veterinary Medicine, at the Veterinary Pathologic Diagnostic Centrum (VPDC). Owners filled in a specially designed questionnaire regarding the history of disease, husbandry and feeding conditions (appendix I). A standard protocol for necropsy at the VPDC (appendix II) and a necropsy protocol of the welfare project (appendix III) were used. This included macroscopic, cytological and histological assessment of various organs and abnormalities. When necessary microbiology was performed. The lung, heart, fat, colon, pancreas, liver, kidney, spleen, adrenals and brain were frozen at -20°C for preservation and additional diagnostics (such as electron microscopy, PCR and bacteriological culture).

Data of the anamnesis forms and results of the necropsies were assembled in a database (Filemaker Pro) designed by Baijens (2008) and exported to Excel® for analysis. Statistical analysis was performed with SPSS 20 using the chi-square test and logistic regression.

The cause of death, natural death versus euthanasia, was determined in all animals. The main etiology and most affected organ systems were assessed. Etiology was classified as infectious, non-infectious and unknown. Each class was divided in subclasses. For infectious causes these were viral, bacterial and parasitic diseases. Different agents were assessed within this subclass. For non-infectious etiology the subclasses were skin, nervous system, dentition, gastro-intestinal system, respiration, circulation, liver and pancreas, blood forming organs, urinary system, reproduction, locomotion, trauma, metabolic and unknown. Most affected organ systems were assessed independent of etiology, e.g. liver and pancreas, spleen, dentition, gastrointestinal, respiratory, circulatory, nervous, urinary and reproductive system. Possible other ailments were assessed, such as skin problems and nutritional problems. These were not likely to be the cause of death, but were related to the health and welfare status of these animals.

Assessment of housing and feeding conditions was performed using the information of the questionnaire filled in by the pet owners. Anamnesis forms were not always complete, so the number of entries varied per question. The following husbandry and feeding related questions were assessed:

1. Solitary and social housing in relation to infectious illnesses.
2. Inside and outside housing in relation to infectious illnesses
3. Bedding type and cleaning frequency in relation to pododermatitis and respiratory problems.
4. Feeding pellets or mixed diet, amounts of hay, vegetables, fruit and treats in relation to dental and gastrointestinal problems.
5. Inoculation of rabbits for Rabbit Hemorrhagic Disease (RHD) and myxomatosis and the prevalence of these diseases.

In order to prevent the most common diseases that were found in this study, practical recommendations for owners of pet rabbits and guinea pigs were designed.

Results

Rabbits

92 rabbits were submitted for necropsy. Time, spatial and age distribution is depicted in *Figure 1*, *Figure 2* and *Figure 3* respectively. Each year was divided into four quarters. The distribution across the country was according to provinces. Age distribution is described in years.

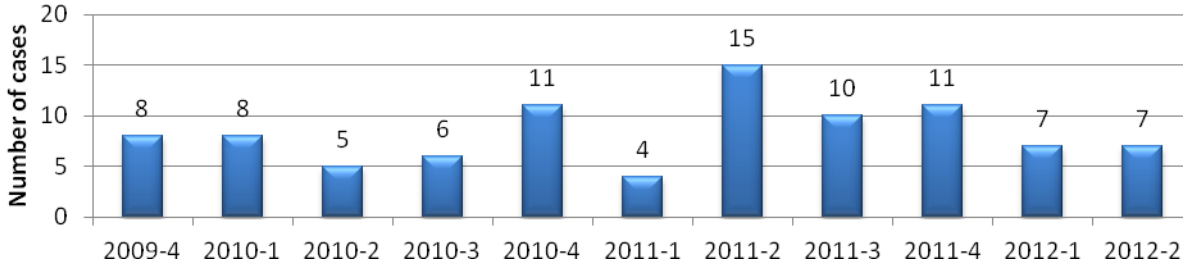

Figure 1: Time distribution of submissions of pet rabbits. The numbers 1 to 4 refer to the quarters of the year (n=92)

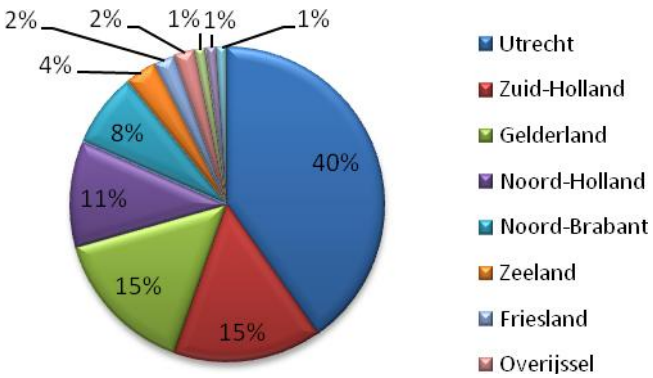

Figure 2: Spatial distribution of submission of pet rabbits according to provinces (n=92)

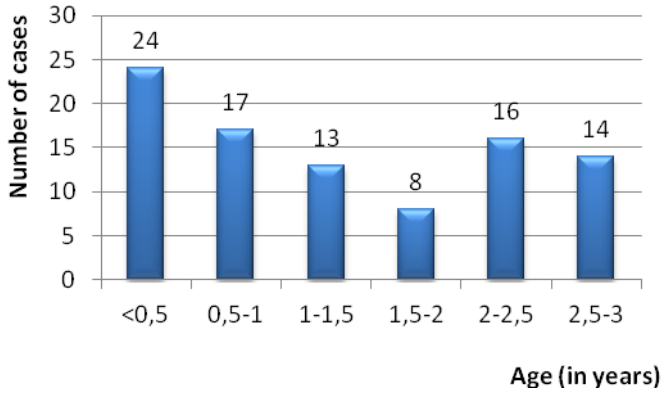

Figure 3: Age distribution of pet rabbits in this study (n=92)

26,1% of the rabbits were less than 6 months old, 18,5% 6 to 12 months, 14,1% 1 to 1,5 years, 8,7% 1,5 to 2 years, 17,4% 2 to 2,5 years and 15,2% 2,5 to 3 years old.

37,0% (n=34) of the rabbits were male, 62,0% (n=57) were female and of 1,0% (n=1) gender was unknown. Of the males 35,3% (n=12) was castrated and 64,7% (n=22) was not. In comparison females were castrated in 10,5% (n=6) and were intact in 89,5% (n=51) (*Table 4* and *Figure 4*).

Female (n=57)		Male (n=34)	
Castrated	10,5% (n=6)	**Castrated**	35,3% (n=12)
Not castrated	89,5% (n=51)	**Not castrated**	64,7% (n=22)

Table 4: Distribution of gender and frequency of castration. One rabbit was left out because gender was unknown (n=91)

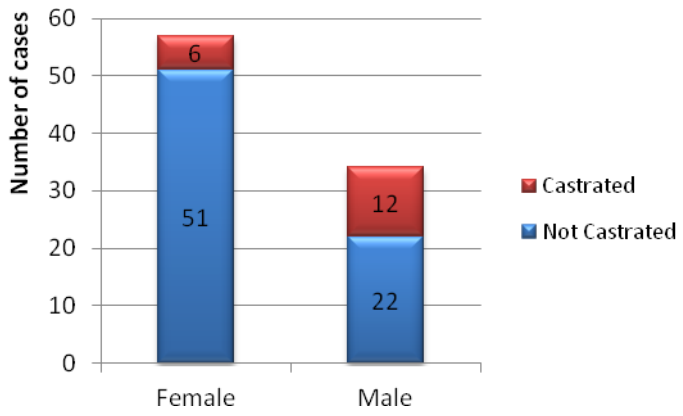

Figure 4: Distribution of gender and frequency of castration. One rabbit was left out because gender was unknown (n=91)

<u>Cause of death</u>

Presented are cause of death (euthanasia or natural death) and etiology of disease (infectious or non-infectious).

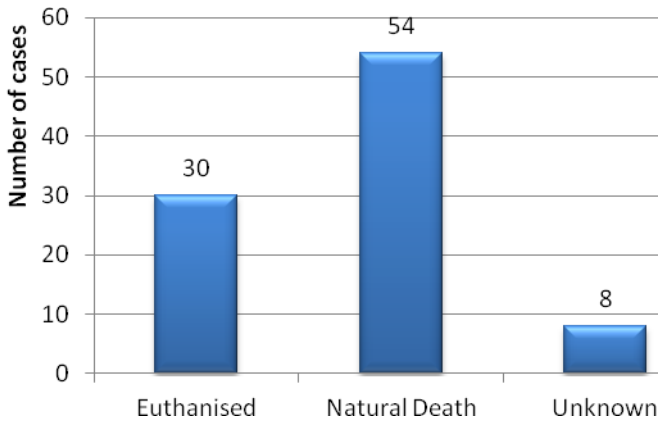

Figure 5: Cause of death typed as natural death and euthanasia in pet rabbits in this study (n=92)

32,6% (n=30) of the rabbits were euthanized, 58,7% (n=54) was not euthanized and of 8,7% (n=8) of the rabbits this was unknown (***Figure 5***).

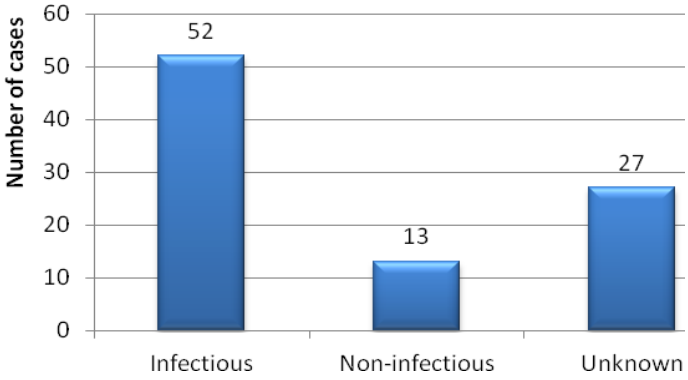

Figure 6: Main etiology of disease in pet rabbits (n=92)

The main etiology was typed as infectious in 56,5% (n=52) of the cases, 14,1% (n=13) for non-infectious and in 29,3% (n=27) of the cases the cause was unknown. (*Figure 6*) Most common infectious agents were assessed (*Table 5*).

Subclass	Number	Agent	Number
Bacterial	17	*Escherichia coli (E. coli)*	1
		Pasteurella multocida (P. multocida)	8
		Unknown bacteria	7
		Clostridium piliforme	1
Viral	10	*Myxoma virus*	4
		Rabbit Hemorrhagic Disease Virus (RHDV)	5
		Shope Fibroma Virus (SFV)	1
Parasitic	37	*Eimeria spp.*	10
		Encephalitozoon cuniculi (E. cuniculi)	24
		Cittotaenia ctenoides (C. ctenoides)	1
		Passalurus ambiguus (P. ambiguus)	2
Total	64	Total	64

Table 5: Most common infectious agents in pet rabbits. Totals do no match with each other, because twelve rabbits had two infectious diseases: 6 rabbits had both Eimeria spp. and E. cuniculi, two E. cuniculi and P. ambiguus, one Eimeria spp. and C. ctenoides, one Eimeria spp. and VHD, one E. cuniculi and unknown bacteria and one rabbit had both unknown bacteria and SFV (n=52)

The most common infectious cause was parasitic in 40,2% (n=37) of all the rabbits, followed by bacterial in 29,3% (n=17) and viral in 10,9% (n=10) of all the rabbits. One rabbit had a bacterial disease combined with a viral disease, one a bacterial disease combined with a parasitic disease and one a viral disease with a parasitic disease.

Of the parasitic agents *Encephalitozoon cuniculi (E. cuniculi)* was most common with an incidence of 64,9% (n=24). This is 26,1% (n=24) of all the rabbits in this study. Pathological findings of rabbits that suffered from *E. cuniculi* are shown in *Table 6*. *E. cuniculi* caused a meningo-encephalitis and a nephritis in 7 cases. The nephritis was chronic interstitial nephritis (CIN) in 4 of these cases. It caused a nephritis and a encephalitis in 5 cases, only a encephalitis in 6 cases, only meningo-encephalitis in 2 cases, a encephalitis combined with a hepatitis and nephritis in 2 cases, only a nephritis in 1 case and CIN with a meningitis in 1 case.

Pathological findings	Number	% of rabbits with E. cuniculi
Nephritis + meningo-encephalitis	7	29,2%
Nephritis + encephalitis	5	20,8%
Encephalitis	6	25,0%
Meningo-encephalitis	2	8,3%
Encephalitis + hepatitis + nephritis	2	8,3%
Nephritis	1	4,2%
CIN + meningitis	1	4,2%
Total	**24**	**100%**

Table 6: Pathology of pet rabbits that suffered from Encephalitozoon cuniculi (n=24)

Other parasitic agents found were *Eimeria spp.* (27,0%, n=10), *Passalurus ambiguus* (*P. ambiguous*, 5,4%, n=2) and *Cittotaenia ctenoides (C. ctenoides*, 2,7%, n=1). *Eimeria spp.* caused typhlitis in one case, colitis in one case, abnormal consistency of the contents of the small and large intestines in two cases, a cholangitis in two cases and hepatitis in two cases. *P. ambiguus* and *C. ctenoides* caused no abnormalities in the intestinal tract. Totals of the parasitic diseases do not match with total of rabbits with a parasitic disease. This is because 6 rabbits had an infection of both *E. cuniculi* and *Eimeria* spp., two both *E. cuniculi* and *P. ambiguus* and one both had *Eimeria spp.* with *C. ctenoides*. *P. ambiguus* and *C. ctenoides* were not the cause of death. Besides this, one rabbit had coccidiosis combined with Rabbit Hemorrhagic Disease (RHD).

The most common bacterial agent was *Pasteurella multocida* (*P. multocida*) with an incidence of 47,1% (n=8) of all the rabbits with a bacterial infection. It caused a pneumonia in 4 cases which was combined with a hepatitis in 1 case and lung edema, emphysema, tracheitis and nasal discharge in another case. A pleuropneumonia was found in 2 cases of which one also had a pyothorax. Otitis media and interna was caused by *P. multocida* in 1 case and sepsis with hepatitis in another case. 5,9% (n=1) had an infection with *Escherichia coli* (*E. coli*) and 5,9% (n=1) had an infection with *Clostridium piliforme* (*C. piliforme*) or Tyzzer's disease. *E. coli* caused a severe enteritis and *C. piliforme* caused typhlitis and a local myocarditis. In 41,2% (n=7) the causative bacteria could not be identified. These bacteria caused a pneumonia in 5 cases of which one was a bronchopneumonia and one was combined with liver necrosis. Liver necrosis was found in 1 case and a preperforative peritonitis with sepsis in another case. Unknown bacteria were found in combination with Shope Fibroma Virus (SFV) in one case and *E. cuniculi* in another case.

Rabbit Hemorrhagic Disease Virus (RHDV) was the most common viral agent with an incidence of 50,0% (n=5) of all the viruses. In all cases there was liver necrosis. In one case this was combined with lung edema and tracheitis. In one case there were also signs of shock. In the last case there also was a hepatitis with fibrosis and bile duct proliferation. Myxomatosis was found in 40,0% (n=4) and caused ocular discharge and conjunctivitis in all cases. One of these cases also had purulent discharge of the right ear and skin abnormalities. Another one of these cases had also inflamed soles of the front paws. The last one these rabbits had alopecia and crustae around the eyes, nose and lips. Shope Fibroma Virus (SFV) was seen in one rabbit (10,0%) and caused fibromas on the head. SFV was found in combination with unknown bacteria in one case and RHD was found in combination with coccidiosis in another case.

Table 7 and *Figure 7* show the major non-infectious death causes organized by organ system.

Organ system	Number of cases	Percentage of cases
Dentition	2	10,5%
Nervous System	1	5,3%
Gastro-intestinal system	3	15,8%
Liver / pancreas	3	15,8%
Reproduction	4	21,1%
Respiration	2	10,5%
Metabolic	1	5,3%
Locomotion	1	5,3%
Urinary system	2	10,5%
Total	**19**	**100%**

Table 7: Most common non-infectious causes of death in pet rabbits organized by organ system. Some rabbits had more than one organ system which was affected. Nine rabbits with a non-infectious death cause had one affected organ systems, two rabbits had two and two rabbits had three organ systems affected by a non-infectious cause (n=13)

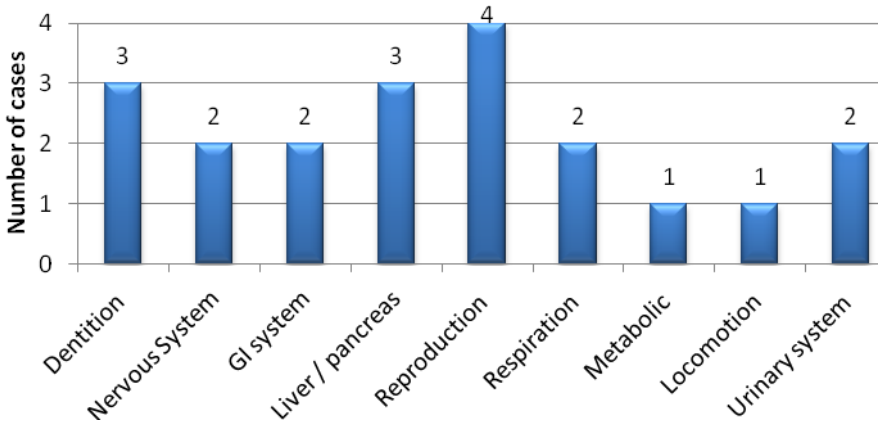

Figure 7: Most common non-infectious causes of death in pet rabbits organized by organ system (n=13)

Nine rabbits had only one organ system that was affected, two rabbits had two and two rabbits had three organ systems affected by a non-infectious cause. 1 rabbit had alveolitis with abscesses, hepatitis and ulcerations of the stomach. One rabbit had an acute hepatitis, lung edema and rachitis. One rabbit had spurs on the teeth with secondary steatosis. One rabbit had a perforation of the jejunum with secondary peritonitis combined with cystic endometrial hyperplasia (CEH) of the uterus.

The most common non-infectious cause of death was a reproductive disease (21,1%). Three of the four rabbits (75,0%) with a reproduction disease had a adenocarcinoma of the uterus. Two of these rabbits also had metastasis of this tumor. One rabbit had a cystic endometrial hyperplasia (CEH) of the uterus, which was probably not the cause of death.

The gastro-intestinal system was affected in three rabbits (15,8%) with a non-infectious etiology of death. In one case there were ulcerations in the stomach, in one case perforation of the jejunum and one case a trichobezoar with an obstruction of the duodenum.

The liver was affected in three rabbits (15,8%) with a non-infectious etiology of death. Two of these cases had a hepatitis. One had secondary steatosis which was probably not the cause of death, but had contributed to death.

Most affected organ systems

The most affected organ systems were determined independent of etiology of death for all the rabbits (*Table 8* and *Figure 8*). Most rabbits had more than one affected organ system, the mean was 2,7 organ systems per rabbit. The six most common affected organ systems are dentition (54,3%, n=50), respiration (41,3%, n=40), gastrointestinal (GI) system (31,5%, n=29), nervous system (31,5%, n=29), liver / pancreas (28,3%, n=26) and urinary system (25,0%, n=23).

Organ system	Number of cases	% of rabbits
Bloodforming organs	6	6,5%
Circulation	11	12,0%
Dentition	50	54,3%
Gastro-intestinal system	29	31,5%
Liver / pancreas	26	28,3%
Locomotion	5	5,4%
Metabolic	4	4,3%
Nervous system	29	31,5%
Respiratory system	38	41,3%
Reproductive system	11	12,0%
Skin	7	7,6%
Urinary system	23	25,0%
Unknown	4	4,3%
Total	**245**	**264,1%**

Table 8: Most affected organ systems in pet rabbits independent of etiology of death. Most rabbits had more than one organ system which was affected. The mean was 2,7 organ system per rabbit (n=92)

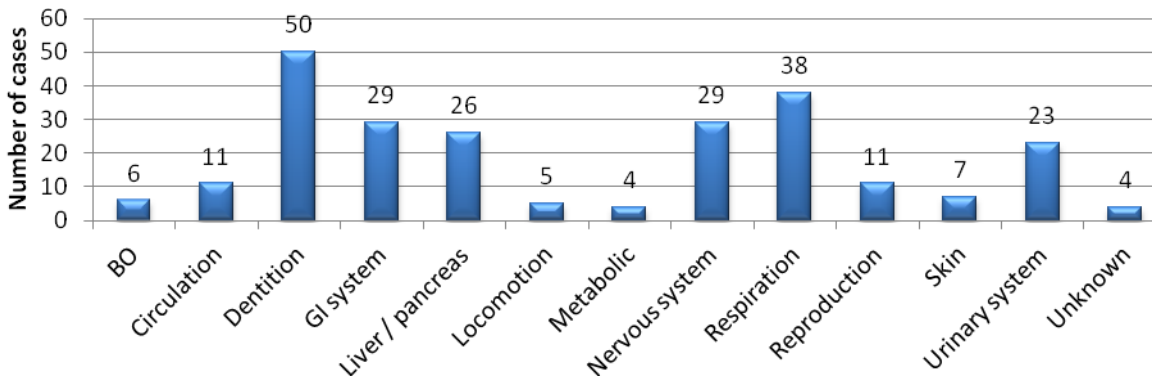

Figure 8: Most affected organ systems independent of etiology of death (n=92). BO = bloodforming organs; GI system is Gastro-intestinal system. Most rabbits had more than one organ system which was affected. The mean was 2,7 organ system per rabbit (n=92)

There were no dental problems with an infectious etiology, 5 (10,0%) of an unknown etiology and 45 (90,0%) of a non-infectious etiology. 45 (90,0%) of the rabbits had spurs on their cheek teeth of which two (4,0%) also had malocclusion and one (2,0%) missed the "peg" teeth bilaterally. The spurs were mild in 28 (62,2%) cases, moderate in 16 (35,6%) cases and severe in one case (2,2%). In four cases (8,9%) there were lesions of the mucosa and/or the tongue caused by the spurs. In four rabbits (8,0%) abscesses around the roots of the tooth existed of which one (2,0%) also had an alveolitis and one spurs (2,0%). One rabbit (2,0%) had brachygnatia inferior and in one rabbit (2,0%) the type of abnormality was not described.

Of the 38 rabbits with an affected respiratory system this was caused by an infectious agent in 9 cases (23,7%), was non-infectious in 8 cases (21,1%) and of unknown origin in 20 cases (55,3%). Of all the rabbits 55,3% (n=21) had a pneumonia which was combined with rhinitis in two cases, calcium deposits in 1 case, with lung edema in 1 case, with epistaxis in 1 case, with emphysema, lung edema, tracheitis, rhinitis and nasal discharge in one case and lung edema, bleedings, tracheitis, rhinitis and nasal discharge in one case. A bronchopneumonia was found in 4 cases (10,5%) which was found in combination with a rhinitis in 1 case and with a tracheitis in another. A pleuropneumonia was found in two cases (5,3%) and in one case this was the cause of a pyothorax. An aspiration pneumonia has been found in one rabbit (2,6%). Lung edema was found in 7 rabbits (18,4%), in combination with a tracheitis in 4 cases and with lung bleedings in 1 case.

29 rabbits had an affected nervous system. The infectious agent *E. cuniculi* was the most common cause in 22 rabbits (75,9%). The etiology was non-infectious in 1 rabbit (3,4%) and unknown in 6 rabbits (20,7%). An encephalitis was found in 12 cases (41,3%), all were caused by *E. cuniculi*. In 13 rabbits (44,8%) a meningo-encephalitis was found and in 10 of these cases *E. cuniculi* the cause and in three cases this could not be confirmed. In the other four cases there were bleedings of the brains (n=2; 6,9%), hyperemic meninges (n=1; 3,4%) and hydrocephalus internus combined with dysautonomia (n=1, 3,4%).

Of the 29 rabbits with gastro-intestinal problems, 14 (48,3%) were infected with a parasitic or bacterial agent. In 8 rabbits (27,6%) there was an non-infectious cause and in 7 rabbits (24,1%) the etiology was unknown. The most common gastro-intestinal abnormality was due to coccidiosis in 7 cases (24,1%). In one of these cases there was a colitis and in one a hemorrhagic typhlitis, in two cases there was an abnormal content of the small and large intestines. In the other cases there were no abnormalities of the intestines. Other parasitic diseases found were the nematode *Passalurus ambiguus* in two rabbits and *Cittotaenia ctenoides* in one rabbit. In these cases there were no other abnormalities of the gastro-intestinal tract. Bacterial diseases were found in three rabbits with gastro-intestinal problems. In one this was caused by *E. coli* which caused a severe enteritis. In one case there was Tyzzer's disease which caused typhlitis. In the last case there was a enteritis with peritonitis and sepsis caused by an unknown bacterial infection. In 5 rabbits (17,2%) there was a peritonitis. This was caused by a stomach ulcer in one case, a preperforative ulcer of the small intestines in 2 cases, a perforative ulcer of the small intestines in one case and an enteropathy in one case. In one rabbit (3,4%) there were ulcerations of the intestines without a peritonitis. Other diseases are mucoid enteropathy in two cases, enteritis in one case, atony in one case, abnormal contents of the small intestines and caecum in one case, a rectal prolapse with diarrhea in one case, a trichobezoar with obstruction of the duodenum in one case and a dysbacteriosis with abnormal motility in the last case.

Of the 26 rabbits of which the liver or pancreas was affected 12 had an infectious disease, 5 a non-infectious disease and of 9 rabbits the etiology was not known. 12 rabbits had a hepatitis that was caused by *P. multocida* in two cases, by *E. cuniculi* in two cases and by *Eimeria stidae* in two cases. In the other cases the cause of the hepatitis was unknown. Necrosis of the liver was found in 10 rabbits. This was caused by RHDV in 4 cases, by unknown bacteria in one case and secondary to hypoxia in three cases. In these three cases one rabbit also had a reaction liver and one had hyperplasia of the bile ducts due to *Eimeria stidae*. Two rabbits had a liver fatness, one a pancreatitis and one *Eimeria stidae* that caused a cholangitis.

23 rabbits had an affected urinary system. Of these rabbits 15 (65,2%) had an infection with *E. cuniculi* causing a nephritis in all cases which was a CIN in 5 cases (21,7%). Other diseases were CIN of unknown origin in 4 cases (17,4%), distended bladder of unknown origin in one case (4,3%), secondary tubular nephrosis in one case (4,3%), thromboembolia in combination with amyloidosis in one case (4,3%) and CIN in combination with urolithiasis in one case (4,3%).

Tumors were classified according to the originating organ system. Adenocarcinoma of the uterus was the only type of tumor found. It was found in 6 does (10,5%), of which 3 probably died of an infectious disease and three died as a consequence of the tumor. Metastasis was found in two cases. One of the rabbits was 12 months old, one 28 months, two 29 months and two were 33 months.

Table 9 shows the 10 most common illnesses of all 92 rabbits in this study. Infectious agents are not in this table, but are shown in *Table 5*.

Illness	Number of cases	Percentage of Rabbits
Dental problems	50	54,3%
Pneumonia with or without concurring diseases (incl. broncho- and pleuropneumonia)	28	30,4%
Lung edema	8	8,7%
Meningo-encephalitis	13	14,1%
Encephalitis	12	13,0%
Hepatitis	12	13,0%
Liver necrosis (sec. to hypoxia)	10 (3)	10,9% (3,3%)
CIN	11	12,0%
Nephritis	7	7,6%
Adenocarcinoma uterus	6	6,5%

Table 9: top 10 of most common affected organ systems in pet rabbits. Most rabbits had more than one organ system which was affected. The mean was 2,7 organ system per rabbit (n=92)

Remaining illnesses

8,7% (n=8) of the rabbits had problems with the skin (*Figure 8*). Three of them had myxomatosis which was also the cause of death. Non-lethal skin problems were chronic dermatitis in two cases of which one was combined with alopecia of unknown cause. Fibromas of the head due to shope fibroma virus in one case, urine scalding in one case and one rabbit had a flea infestation.

Lesions probably due to improper nutrition has been found in six rabbits (6,5%). In five rabbits there were calcium deposits in several organs. In one case this also could be possible because of a underlying renal disease. One case suffered from rachitis.

Two of the rabbits had problems with their feet. These rabbits had myxomatosis, so the sole lesions could also be due to this disease.

One rabbit had amyloidosis, possibly secondary to a renal problem. Amyloidosis was seen in the kidney, muscles, gastro-intestinal tract and adrenal glands.

Husbandry

Group housing

65,2% (n=60) of the rabbits were housed with at least one rabbit (socially) and 34,8% (n=32) were housed individually (***Fout! Verwijzingsbron niet gevonden.***). Group size was 2 in 29 cases, 3-5 in 14, 6-10 in 6, 11-20 in 4, 21-50 in 5 and >50 in 2 cases. *Table 10* and *Figure 10* show the type of housing compared to the etiology of death.

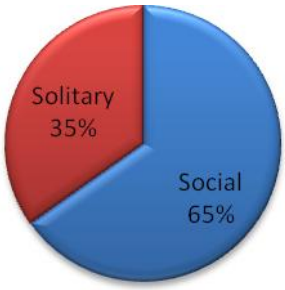

Figure 9: type of housing classified as social or solitary

	Infectious	Non-infectious	Unknown	Total
Social	39	5	16	**60**
Solitary	13	8	11	**32**
Total	**52**	**13**	**27**	**92**

Table 10: type of housing compared to etiology of death (n=92)

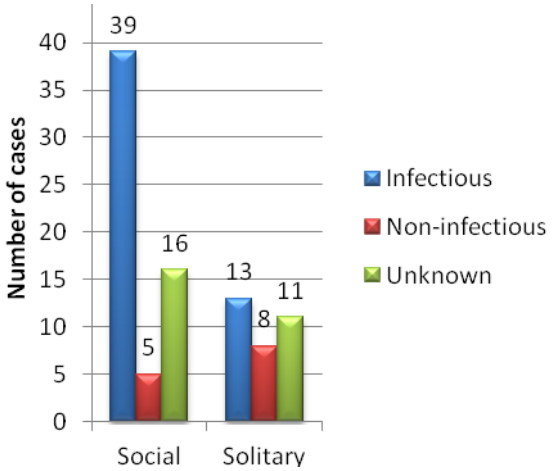

Figure 10: Type of housing compared to etiology of death (n=92)

Of the socially housed rabbits an infectious disease was the cause of death in 65,0% (n=39) compared to 40,6% (n=13) in individual housed rabbits. Non-infectious diseases were the cause of death in 8,3% (n=5) and 25,0% (n=4) for social and solitary housed rabbits respectively. In 26,7% and 34,4% of the cases the cause of death was unknown for social and solitary housing respectively. There was a significant difference between the two groups in the prevalence of infectious and non-infectious diseases (p=0,012).

Location of housing

41,3% (n=38) of the rabbits were housed inside, 44,6% (n=41) outside and 14,1% (n=13) a combination of inside and outside housing. Location of housing was compared to the prevalence of etiology of disease (*Table 11* and *Figure 11*).

	Infectious	Non-infectious	Unknown	Total
Inside	23	4	11	**38**
Outside	22	8	11	**41**
Inside & Outside	7	1	5	**13**
Total	**52**	**13**	**27**	**92**

Table 11: housing location in comparison with the etiology of death. (n=92)

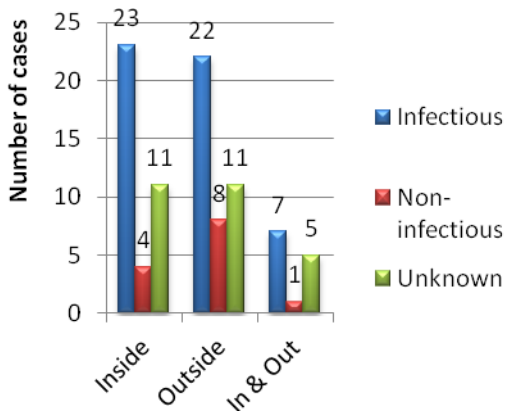

Figure 11: housing location in comparison with the etiology of death. (n=92)

Of the inside housed rabbits 50,5% (n=23) had an infectious etiology, 10,5% (n=4) a non-infectious etiology and in 28,9% (n=11) the etiology was unknown. This was 53,7% (n=22), 19,5% (n=8) and 26,8% (n=11) for outside housed rabbits respectively. And 53,8% (n=7), 7,7% (n=1) and 38,5% (n=5) for inside & outside housed rabbits respectively. There was no significant difference between inside housed rabbits and rabbits who had access to an outside space (p=0,378).

Bedding type

Bedding type was classified as wood shaving, hay, straw, cat litter and other bedding. Other bedding types are papers, earth, pavement, grass, wood, flax, vinyl, hemp fibers, ecobed, sand and rapsodie® (chopped straw). Some rabbits were housed on more than one type of bedding. 4 rabbits (4,3%) were housed on four bedding types, 9 rabbits (9,8%) on three bedding types, 27 (29,3%) on two bedding types and 45 (48,9%) of the rabbits were housed on only one type of bedding. Of 7 rabbits (7,6%) bedding type was unknown. These rabbits were left out in *Table 12* and *Figure 12* which demonstrate the most common bedding types in comparison to respiratory problems.

	No respiratory disease		**With respiratory disease**	
Wood shavings	11	17,7%	18	22,5%
Straw	24	38,7%	29	36,3%
Hay	14	22,6%	8	10,0%
Cat litter	1	1,6%	5	6,3%
Other	12	19,4%	20	25,0%
Total	**62**	**100%**	**80**	**100%**

Table 12: Bedding type in comparison to respiratory diseases. Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study. (n=85)

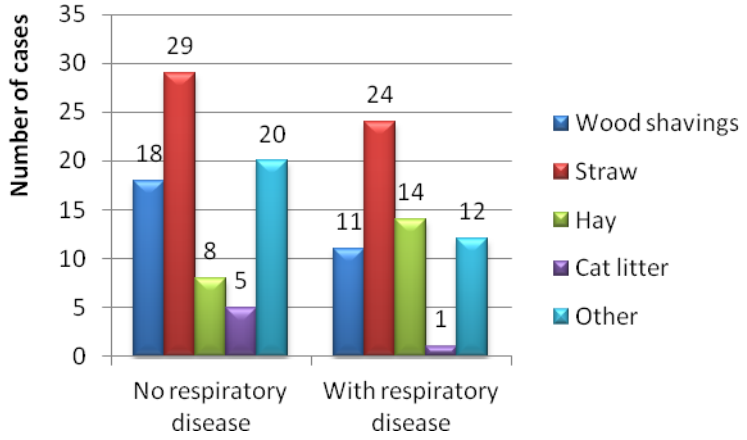

Figure 12: Bedding type in comparison to respiratory diseases . Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study. (n=85)

Of the rabbits with a respiratory disease 22,5% (n=18) was housed on wood shavings, 36,3% (n=29) on straw, 10,0% (n=8) on hay, 6,3% (n=5) on cat litter and 25,0% (n=20) on other bedding types. This was 17,7% (n=11), 38,7% (n=24), 22,6% (n=14), 1,6% (n=1) and 19,4% (n=12) for rabbits without a respiratory disease. No significance difference occurred between the groups and the presence of a respiratory disease (p=0,179). Bedding type could not be compared to the frequency of affected soles. Because of the soles of only two rabbits (2,2%) were affected. Both of these rabbits were kept on a combination of straw and hay.

With the logistical analysis the incidence of respiratory disease was compared to the combination of bedding type and cleaning frequency. There was no significant difference between the group with and without respiratory disease (p=0,175).

Cleaning frequency

Cleaning frequency was filled in by 81 (88,0%) of the owners. Daily cleaning occurred in 7,6% (n=7) of the rabbits. Cleaning occurred 2-4 times a week in 18,5% (n=10) of the rabbits, once a week in 54,3% (n=50), 2-3 times a month in 2,2% (n=2), once a month in 1,1% (n=1) and less than once a month in 1,1% (n=1) of the rabbits. Respiratory diseases were compared to cleaning frequency (***Table 13*** and ***Figure 13***).

Cleaning frequency	Respiratory disease	No respiratory disease
Daily	5	2
2-4x/week	5	12
1x/week	21	29
2-3x/month	1	1
1x/month	4	0
<1x/month	1	0
Unknown	3	8
Total	**40**	**52**

Table 13: cleaning frequency in comparison to the incidence of respiratory disease. (n=92)

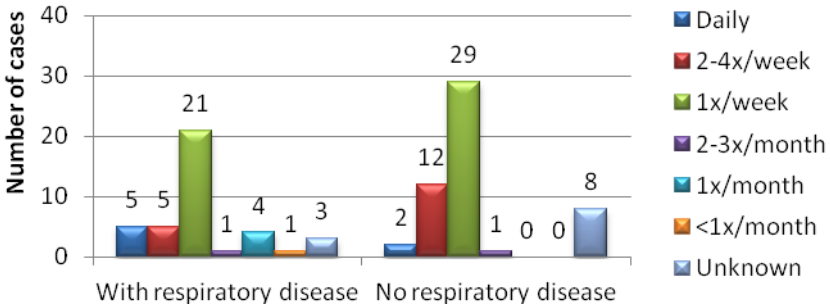

Figure 13: cleaning frequency in comparison to the incidence of respiratory disease. (n=92)

There was no significance difference in cleaning frequency en the occurrence of a respiratory disease (p=0,078). Just as for bedding type cleaning frequency could not be compared to the frequency of affected soles.

Nutrition

Figure 14 demonstrates the feeding composition of the rabbits in this study. Quantities were not assessed in this study.

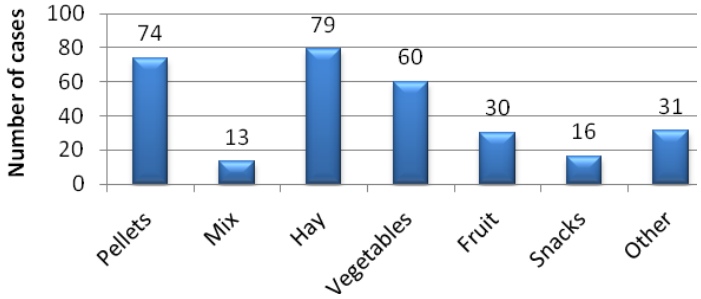

Figure 14: feeding composition of pet rabbits in this study (n=92)

80,4% (n=74) of the rabbits were fed pellets and 14,1% (n=13) were fed mixed feed. Of these rabbits 3,3% (n=3) received both pellets and mix feedings and 8,7% (n=8) received no pellets or mix feedings. 85,9% (n=79) received hay, 65,2% (n=60) vegetables, 32,6% (n=30) fruit, 17,4% (n=16) en 33,7% (n=31) received other feedings. Other feedings that were mentioned were bread, fiber or crispy sticks, grass, corn, barley flakes, branches (such as willow), grain, straw, muesli and roosvicee® in water.

Vaccination status

43,5% (n=40) of the rabbits were vaccinated against the myxoma virus and/or the Rabbit Hemorrhagic Disease Virus (RHDV). 40,2% (n=37) were not and of 16,3% (n=15) the vaccination status was not known (*Table 14* and *Figure 15*). It was not possible to assess vaccinations against these diseases separately.

Vaccination status	Number of rabbits	Percentage
Vaccinated	40	43,5%
Not Vaccinated	37	40,2%
Unknown	15	16,3%
Total	**92**	**100,0%**

Table 14: Prevalence of vaccination against myxomatosis and/or Rabbit Hemorrhagic Disease (RHD) in pet rabbits (n=92)

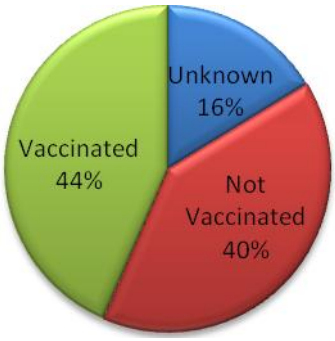

Figure 15: Prevalence of vaccination against myxomatosis and/or Rabbit Hemorrhagic Disease (RHD) in pet rabbits (n=92)

Of the four rabbits with myxomatosis three were not vaccinated and of one this was not known. Of the five rabbits with VHD one was vaccinated and four were not. There is a significant difference between the group of vaccinated rabbits and those that were not vaccinated (p=0,048).

Guinea pigs

60 guinea pigs were submitted for necropsy. *Figure 16*, *Figure 17* and *Figure 18* show the time-, spatial- and age distribution of these guinea pigs respectively. The distribution in time was classified in the four quarters of the year. The spatial distribution was according to the eleven provinces of the Netherlands. Age distribution is described in years.

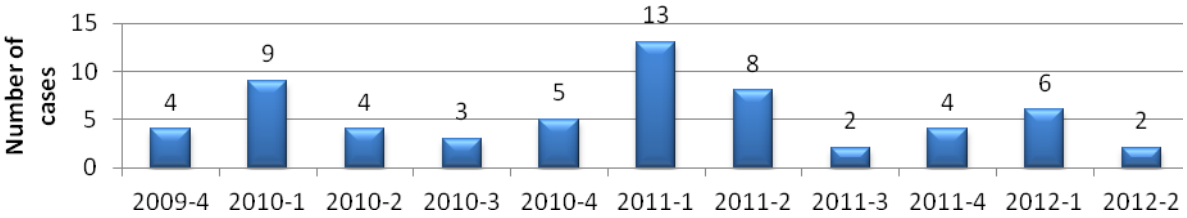

Figure 16: Time distribution of submission of pet guinea pig. The numbers 1 to 4 are the first to fourth quarter of the year respectively (n=60)

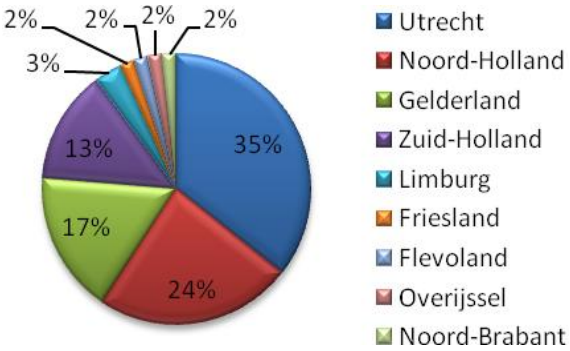

Figure 17: Spatial distribution of submission of pet guinea pigs according to provinces (n=60)

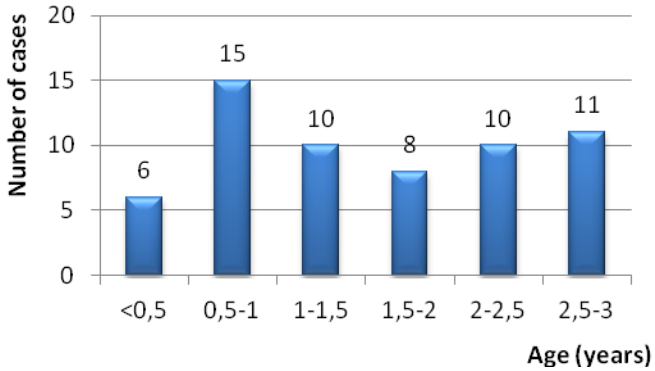

Figure 18: Age distribution of pet guinea pigs (n=60)

10% (n=6) of the guinea pigs were less than 6 months old, 25,0% (n=15) between 0,5 to 1 year, 16,7% (n=10) between 1 and 1,5 years, 13,3% (n=8) between 1,5 and 2 years, 16,7% (n=10) between 2 and 2,5 year sand 18,3% (n=11) between 2,5 and 3 years old.

40,0% (n=24) of the guinea pigs were male and 60,0% (n=36) were female (*Table 15* and *Figure 19*). Of the males 25,0% (n=6) were castrated and 75,0% (n=18) were not. 2,8% (n=1) of the females were castrated, 94,4% (n=34) were not castrated and of 2,8% (n=1) this was unknown.

Female (n=36)		Male (n=24)	
Castrated	2,8% (n=1)	**Castrated**	25,0% (n=6)
Not castrated	94,4% (n=34)	**Not castrated**	75,0% (n=18)
Unknown	2,8% (n=1)	**Unknown**	0,0% (n=0)

Table 15: Distribution of gender and frequency of castration of pet guinea pigs (n=60)

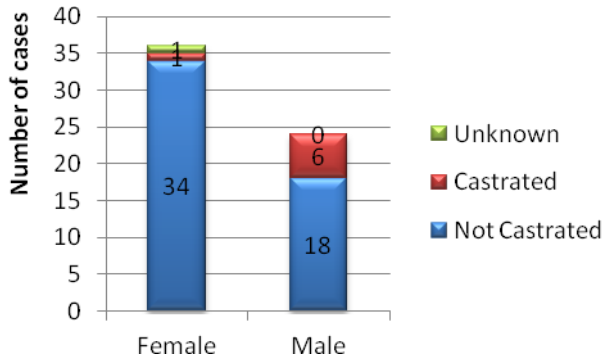

Figure 19: Distribution of gender and frequency of castration of pet guinea pigs (n=60)

<u>Cause of death</u>

This paragraph presents the cause of death (euthanasia or natural death) and the etiology of disease (infectious or non-infectious).

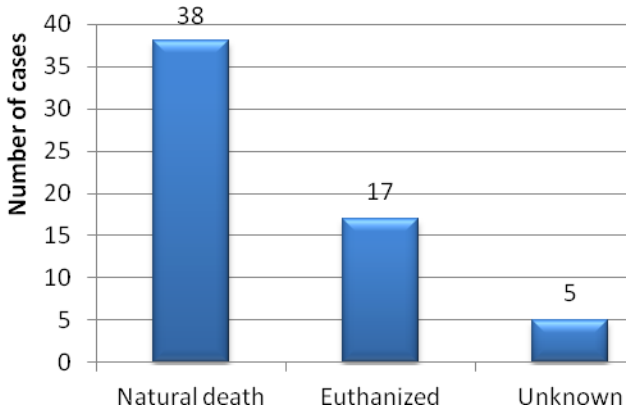

Figure 20: cause of death classified as Euthanized, Not Euthanized and unknown. (n=60)

28,3% (n=17) of the guinea pigs were euthanized, 63,3% (n=38) died naturally and of 8,3% (n=5) of the guinea pigs this was unknown (*Figure 20*).

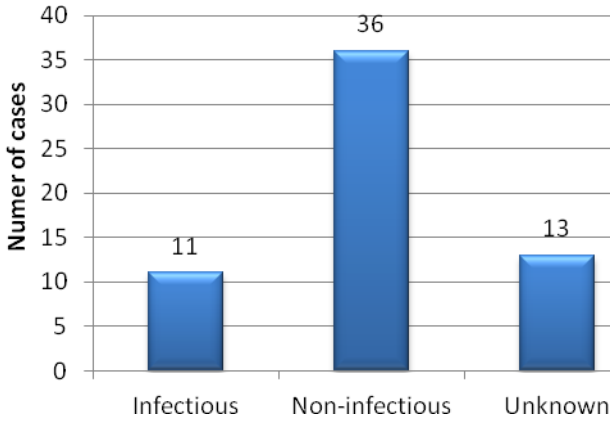

Figure 21: The main etiology classified as infectious, non-infectious and unknown. (n=60)

The main etiology was typed as infectious in 18,3% (n=11) of the cases, non-infectious in 60,0% (n=36) and in 21,7% (n=13) of the cases the cause of death was unknown (*Figure 21*). Most common infectious agents are assembled in *Table 16*.

Subclass	Number	Agent	Number
Bacterial	9	*Bordetella bronchiseptica*	2
		Klebsiella spp.	1
		Acinetobacter baumanii	1
		Unknown bacteria	5
Viral	2	*Adenovirus*	1
		Unknown virus	1
Parasitic	0		
Total	**11**		**11**

Table 16: Most common infectious agents in pet guinea pigs.

81,8% (n=9) of the infectious etiologies were bacterial (*Table 16*). 2 of these cases were caused by *Bordetella bronchiseptica*, 1 by *Klebsiella spp.*, 1 by *Acinetobacter baumanii* and 5 had pneumonia by unknown bacteria. Bacteria probably could not be cultured in these cases, because the guinea pigs were already treated with antibiotics. The guinea pigs with a *Bordetella bronchiseptica* infection both had a chronic active bronchopneumonia of which one also had a tracheitis. *Klebsiella spp.* has caused bronchopneumonia and laryngitis. The guinea pig with *Acinetobacter baumanii* had a severe chronic interstitial pneumonia and a tracheitis.

18,2% of the infectious etiologies were viral. In one case this was an acute enteritis caused by the adenovirus of the guinea pig and the other had a splenitis with viral inclusion bodies (*Table 16*).

The most common non-infectious causes are summarized in *Table 17* and *Figure 22*. They are categorized according to organ system, except for trauma as a cause of death because it was not always clear which organ system was affected. Most guinea pigs had more than one organ system affected. A mean of 1,6 organ system per guinea pig was affected. In one guinea pig (1,8%) the cause of death was unknown.

Organ system	Number of cases	Percentage of cases
Bloodforming organs	2	3,4%
Circulation	8	13,6%
Dentition	6	10,2%
Gastro-intestinal system	2	3,4%
Liver / pancreas	7	11,9%
Locomotion	1	1,7%
Metabolic	5	8,5%
Reproduction	3	5,1%
Respiration	11	18,6%
Trauma	3	5,1%
Urinary system	10	16,9%
Unknown	1	1,7%
Total	**59**	**100%**

Table 17: Most common non-infectious etiologies in pet guinea pigs. Some rabbits had more than one organ system affected. A mean of 1,6 organ system per guinea pig was affected (n=36)

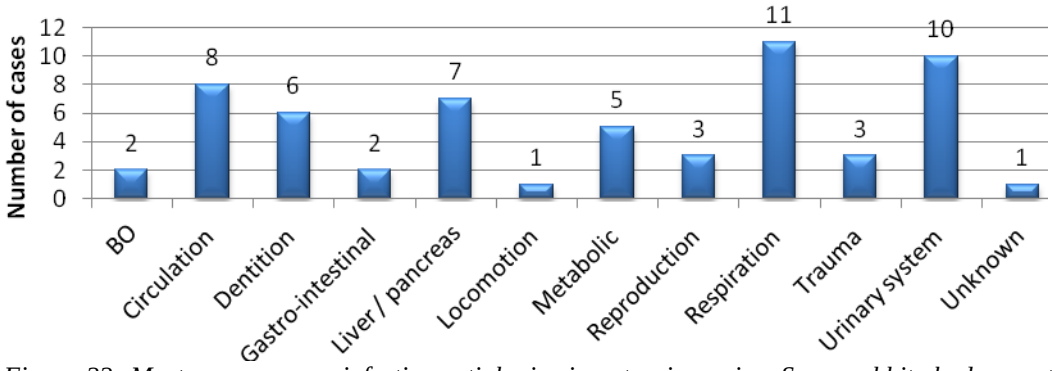

Figure 22: Most common non-infectious etiologies in pet guinea pigs. Some rabbits had more than one organ system affected. A mean of 1,6 organ system per guinea pig was affected (n=36)

The most common non-infectious death cause was respiratory disease (30,6%). Pneumonia was the most common respiratory disease with 7 cases (63,6%), followed by edema in 2 cases (18,2%), bronchopneumonia in 1 case (9,1%) and a combination of pneumonia and lung edema in 1 case (9,1%%). In the last case the pneumonia was probably the cause of death.

The diseases of the urinary systems were found in 27,8% (n=10) of the guinea pigs with a non-infectious death cause. Urinary calculi were found in 5 guinea pigs (50,0%), chronic interstitial nephritis (CIN) in 3 guinea pigs (30,0%) and glomerulosclerosis in 2 cases (20,0%).

22,2% of the guinea pigs had a affected circulatory system. Myocarditis was found in 2 cases (25,0%), decompensatio cordis in 2 cases (25,0%), a combination of these two in 1 case (12,5%), atherosclerosis, Ventricular Septal Defect (VSD) and cardiomyopathy each in 1 case (12,5%).

Most affected organ systems

Table 18 and ***Figure 23*** show the most affected organ systems of all the guinea pigs in this study independent of etiology. In many cases more than one organ system was affected. The mean was 2,8 organ system per guinea pig. In 2 guinea pigs the cause of death was unknown.

Organ system	Number of cases	% of guinea pigs
Bloodforming organs	12	20,0%
Circulation	19	31,7%
Dentition	18	30,0%
Gastro-intestinal system	11	18,3%
Liver / pancreas	23	38,3%
Locomotion	7	11,7%
Metabolic	4	6,7%
Nervous system	1	1,7%
Respiratory system	31	51,7%
Reproductive system	8	13,3%
Skin	4	6,7%
Urinary system	25	41,7%
Unknown	2	3,3%
Total	**165**	**275%**

Table 18: most affected organ systems of all the pet guinea pigs independent of etiology. 2,8 organ system per guinea pig was affected (n=60)

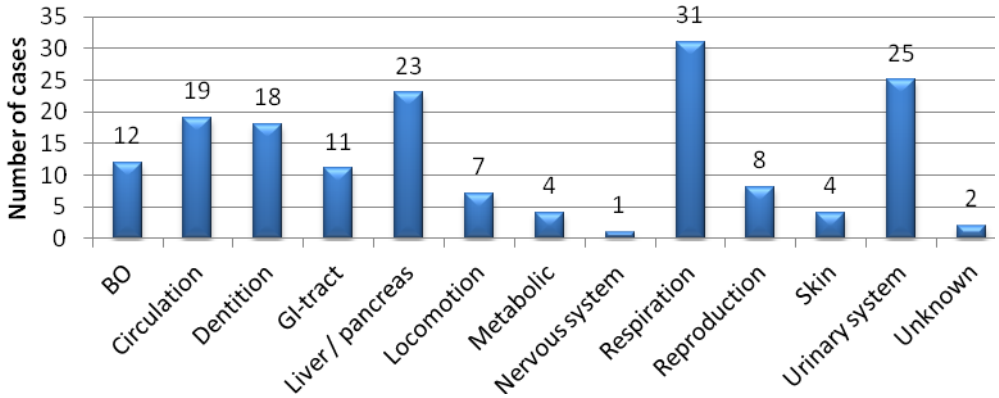

Figure 23: most affected organ systems of all guinea pigs in this study. BO = blood forming organs; GI-tract is gastro-intestinal tract (exclusive dentition). 2,8 organ system per guinea pig was affected. (n=60)

The respiratory system was affected in 51,7% of the guinea pigs (n=31). Respiratory problems were infectious in 29,0% (n=9) and caused by *Bordetella bronchiseptica* (n=2), *Klebsiella spp.* (n=1), *Acinetobacter baumanii* (n=1) and unknown bacteria (n=5). In 45,2% (n=14) of the cases the etiology was non-infectious and in 25,8% (n=8) the etiology was unknown. Pneumonia was seen in 61,2% (n=19) of the respiratory problems. In one case this was in combination with tracheitis, with lung edema in 2 cases and with lung edema and in one case with a rhinitis. 22,6% (n=7) of respiratory problems was a bronchopneumonia. In one case it was combined with tracheitis and in another case with laryngitis. Lung edema was found in 22,6% (n=7) of which this was combined with pneumonia in two cases and pneumonia and rhinitis in one case. In one case (3,2%) metastatic calcifications was found in the lung.

In 33,3% (n=25) of the guinea pigs the urinary system was affected. None of these were infectious, but in one case the etiology was unknown. Metastatic calcium deposits in the kidney were found in 40,0% (n=10) of all urinary problems, followed by urinary calculi with 20,0% (n=5), CIN in 20,0% (n=5) of which 2 guinea pigs also had amyloidosis. Other urinary problems were glomerulosclerosis (8,0%), fibrosis (4,0%), cysts (4,0%) and myoglobin nephrosis (4,0%).

The liver was affected in 38,3% (n=23) of the cases. None had an infectious etiology, 4 unknown and 19 non-infectious. The most common liver problems were liver fatness in 34,8% (n=8), necrosis secondary to hypoxia in 21,7% (n=5), hepatitis in 21,7% (n=5) and fibrosis in 8,7% (n=2) of the cases. Other problems of the liver were amyloidosis, reaction liver, torsion of a liver lobe with 4,3% (n=1) each.

Circulatory problems were found in 31,7% (n=19) of the guinea pigs. None of these diseases were infectious, but four had an unknown etiology and the rest (n=15) had a non-infectious cause. Myocarditis was found in 52,6% (n=10) of which 2 were combined with a decompensatio cordis and one was combined with an endocarditis. Other diseases were decompensatio cordis in 15,8% (n=3), metastatic calcium deposits in 15,8% (n=3), ventricular septal defect (VSD) in 5,3% (n=1), cardiomyopathy in 5,3% (n=1) and atherosclerosis in 5,3% (n=1).

30,0% (n=18) of the guinea pigs had a dental problem. None of these cases were caused by an infection. In 5 cases there was malocclusion and in 4 of these cases spurs and entrapping of the tongue were present. In 12 cases there were spurs on the (pre)molars of which 8 cases were mild, 1 cases was severe and 2 were combined with entrapping of the tongue. In 1 case the incisive teeth were too long. In most cases (94,4%) there were no mucosal or tongue lesions, but in one case (5,6%) there was.

Tumors were classified according to the originating organ system. In three cases (5,0) a neoplasia was the cause of death. Once a teratoma of the right ovary, once an unknown neoplasia of the lymphnoduli mesenterialis and once a B-cell lymphoma of multiple organs.

The most common diseases in this study are summarized in *Table 19*.

Illness	Number of cases	Percentage of guinea pigs
(Broncho) pneumonia with or without concurring diseases	26	43,3%
Dental problems	18	30,0%
Myocarditis	10	16,7%
Metastatic calcium deposits kidney	10	16,7%
Liver fatness	8	13,3%
Lung edema	7	11,7%
Chronic Interstitial Nephritis	5	8,3%
Liver necrosis secondary to hypoxia	5	8,3%
Urine calculi	5	8,3%

Table 19: top 9 of the most common illnesses of pet guinea pigs (n=60)

Remaining illnesses

24 guinea pigs (40,0%) had calcium deposits in one or more organs. Four of these cases had dystrophic calcifications (16,7%). Four cases had metastatic calcifications as a consequence of a renal problem (16,7%) and in 16 (66,7%) guinea pigs there were metastatic calcifications without a renal disease. These are probably due to a nutritional imbalance of vitamins and minerals. Other lesions associated with a nutritional imbalance were found in three guinea pigs (5,0%). One case had an irregular epiphysis in combination with a limited construction of trabecular bone. One case had an irregular contour of the mandibular jaw with severe dental problems. The last case had lesions associated with a vitamin C deficiency, i.e. fractures, bleeding around the knees and bone lesions. Thus, in total 19 guinea pigs had a lesion that was probably due to a nutritional imbalance (31,7%).

Amyloidosis occurred in 6,7% (n=4) guinea pigs. The spleen was affected in all four of the cases and in two it was the only organ affected. The kidney, liver and pancreas were affected in the other two cases and in one of them amyloid deposits were also found in the thyroid gland and gastro-intestinal system.

Ovarian cysts occurred in 10,0% (n=6) of all the guinea pigs. This is 16,7% of all the sows. These cysts were probably not the cause of death in all these cases. Two of these guinea pigs were 11 months, the rest was 15, 19, 32 and 35 months old.

Bumble foot was found in 8,3% (n=5) of the guinea pigs. In one guinea pig there was hyperemia and callus of one sole, in 2 cases all four feet were hyperemic with callus and in 2 cases all four soles were hyperemic with erosive to ulcerative lesions.

6,6% (n=4) of the guinea pigs had skin problems that were not the cause of death, but can affect their welfare. The skin problems were ectoparasites, amyloidosis with endocrine alopecia caused by dysfunction of the thyroid gland, trauma of the skin and mycotic dermatitis.

Husbandry

Group housing

81,7% (n=49) of the guinea pigs were housed socially and 18,3% (n=11) solitary (*Figure 24*). Group size was 2 in 19 cases, 3-5 in 12, 6-10 in 9, 11-20 in 4, 21-50 in 3 and >50 in 2 of the cases. *Table 20* and *Figure 25* show the type of housing compared to the etiology of death.

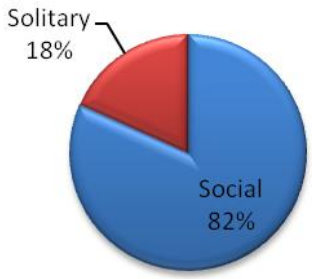

Figure 24: type of housing classified as social or solitary (n=60)

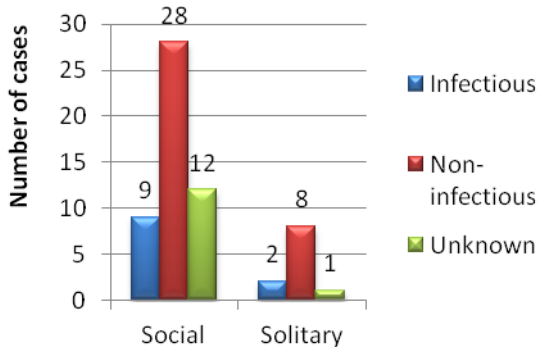

Figure 25: type of housing compared to etiology of death (n=60)

	Infectious	Non-infectious	Unknown	Total
Social	9	28	12	**49**
Solitary	2	8	1	**11**
Total	**11**	**36**	**13**	**60**

Table 20: type of housing compared to etiology of death (n=60)

Of the social housed guinea pigs 18,4% (n=9) had a disease of infectious etiology, 57,1% (n=28) non-infectious and 24,5% (n=12) a disease of unknown etiology. Of the solitary housed guinea pigs this was 18,2% (n=2), 72,7% and 9,1% respectively. There was no significant difference in etiology between social and solitary housed guinea pigs (p=0,51).

Location of housing

76,7% (n=46) of the guinea pigs were housed inside, 20,0% (n=12) outside and 3,3% (n=2) a combination of inside and outside housing. *Table 21* and *Figure 26* show etiology of death compared to housing location.

	Infectious	Non-infectious	Unknown	Total
Inside	8	27	11	**46**
Outside	2	8	2	**12**
Inside & Outside	1	1		**2**
Total	**11**	**36**	**13**	**60**

Table 21: housing location in comparison to the etiology of death (n=60)

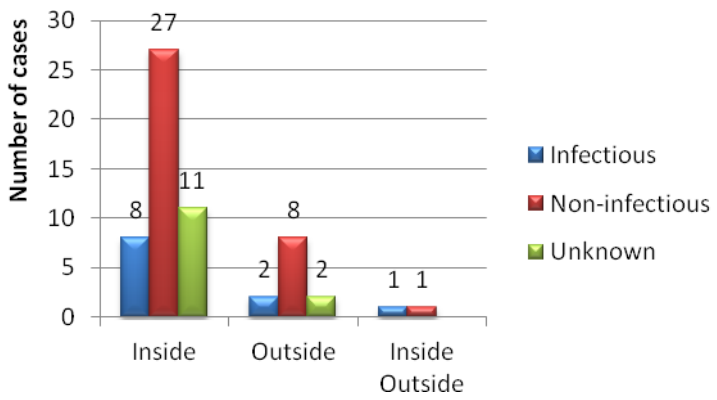

Figure 26: housing location in comparison with the etiology of death. (n=60)

Of the inside housed guinea pigs 17,4% (n=8) had an infectious etiology, 58,7% (n=27) a non-infectious etiology and 23,9% (n=11) an unknown etiology This was 16,7% (n=2), 66,7% (n=8) and 16,7% (n=2) for outside housed guinea pigs and 50% (n=1), 50% (n=1) and 0% for inside & outside housed guinea pigs respectively. There was no significant difference in etiology between inside or outside housed guinea pigs (p=0,74).

Bedding type

Bedding type was classified as wood shaving (56,7%), hay (25,0%), straw (16,7%), cat litter (1,7%) and other bedding (38,3%). Some guinea pigs were housed on more than one type of bedding. Three guinea pigs (5,0%) were housed on three bedding types, 19 (31,7%) were housed on two bedding types, 36 (60,0%) on one bedding type and of 2 guinea pigs (3,3%) the bedding type was unknown. *Figure 27* and *Table 22* demonstrate the most common bedding types in comparison to respiratory problems.

	No respiratory disease		With respiratory disease	
Wood shavings	15	36,6%	19	45,2%
Straw	5	12,2%	5	11,9%
Hay	8	19,5%	7	16,7%
Cat litter	1	2,4%	0	0,0%
Other	12	29,3%	11	26,2%
Total	**41**	**100%**	**42**	**100%**

Table 22: Bedding type in comparison to respiratory diseases (n=58). Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study.

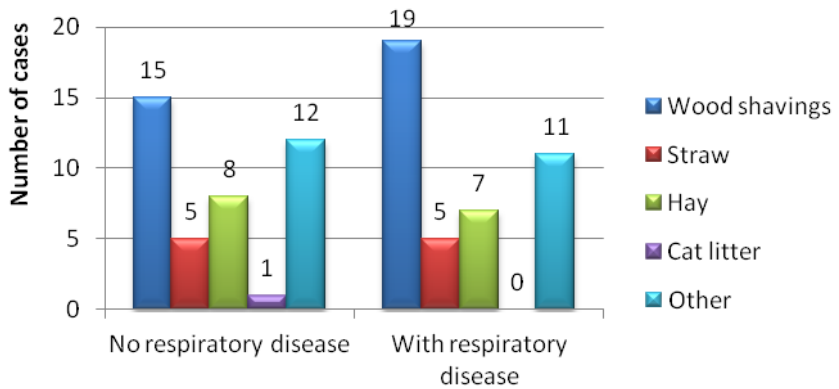

Figure 27: Bedding type in comparison to respiratory diseases (n=58). Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study.

Of the guinea pigs with respiratory disease 45,2% was housed on wood shavings, 11,9% on straw, 16,7% on Hay, 0,0% on cat litter and 26,2% of the guinea pigs were housed on bedding other than the before mentioned bedding types. This was 36,6%, 12,2%, 19,5%, 2,4% and 29,3% respectively for the guinea pigs without respiratory disease. No significant difference exists in occurrence of respiratory disease between the different types of bedding (p=0.81).

Bedding type was also compared to the frequency of affected soles (*Figure 28* and *Table 23*).

	No affected soles		**With affected soles**	
Wood shavings	29	38,2%	5	71,4%
Straw	9	11,8%	1	14,3%
Hay	15	19,7%	0	0,0%
Cat litter	1	1,3%	0	0,0%
Other	22	28,9%	1	14,3%
Total	**76**	**100%**	**7**	**100%**

Table 23: Bedding type in comparison to affected soles (n=58). Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study.

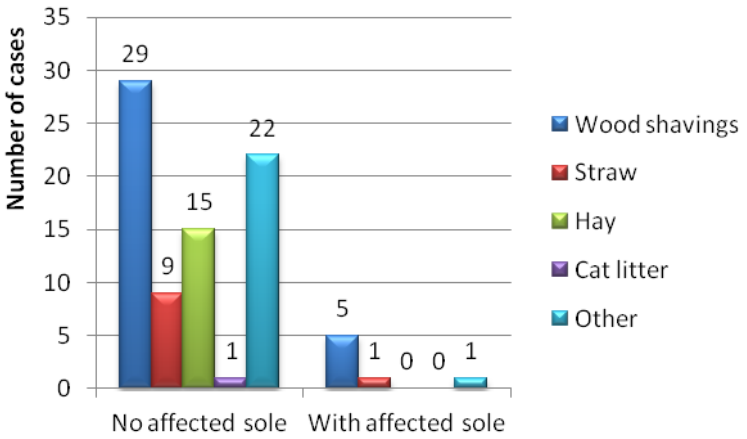

Figure 28: Bedding type in comparison to affected soles (n=58). Some animals were kept on more than one bedding, so the total is larger than the number of animals in this study.

Of the guinea pigs with affected soles 71,4% was housed on wood shavings, 14,3% on hay and 14,3% on other bedding. This was 38,2% on wood shavings, 11,8% on straw, 19,7% on hay, 1,3% on cat litter and 28,9% on other bedding material. Statistical analysis could not be performed because the number of animals with affected soles was too small.

Cleaning frequency

Cleaning occurred daily in 2 cases (3,3%), 2 to 4 times a week in 22 cases (36,7%), once a week in 34 cases (56,7%), 2 to 3 times a month in one case (1,7%) and cleaning frequency was unknown in 2 cases (3,3%). Respiratory diseases and affected soles were also compared to cleaning frequency (*Table 24* and *Table 25*).

Cleaning frequency	No Respiratory disease		Respiratory disease	
Daily	1	3,5%	0	0,0%
2-4x/week	11	37,9%	11	35,5%
1x/week	16	55,2%	18	58,1%
2-3x/month	0	0,0%	1	3,2%
Unknown	1	3,5%	1	3,2%
Total	**29**	**100%**	**31**	**100%**

Table 24: cleaning frequency in comparison to the incidence of respiratory disease in pet guinea pigs (n=60)

Cleaning frequency	No affected soles		With affected soles	
Daily	1	1,8%	0	0,0%
2-4x/week	20	36,4%	2	40,0%
1x/week	31	56,4%	3	60,0%
2-3x/month	1	1,8%	0	0,0%
Unknown	2	3,6%	0	0,0%
Total	**55**	**100%**	**5**	**100%**

Table 25: cleaning frequency in comparison to the incidence of affected soles in pet guinea pigs (n=60)

Respiratory disease did not occur significantly more in animals which case was cleaned less often (p=0,562). Statistical analysis could not be performed because the number of animals with affected soles was too small.

With the logistical analysis the incidence of respiratory disease was compared to the combination of bedding type and cleaning frequency. There was no significant difference between the group with and without respiratory disease (p=0,714)

Nutrition

Figure 29 demonstrates the feeding composition of the guinea pigs in this study. Quantities were not assessed in this study.

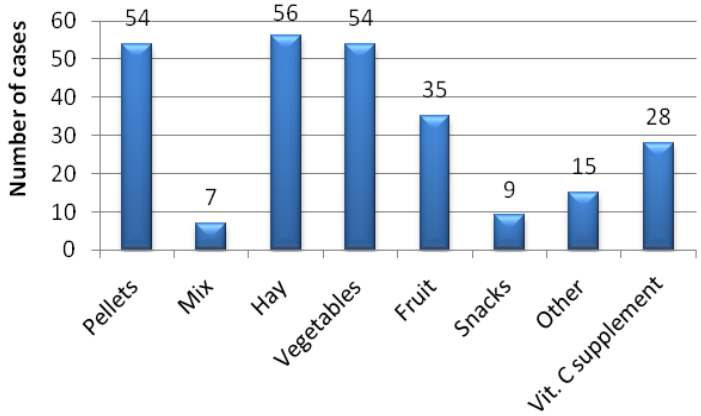

Figure 29: feeding composition of pet guinea pigs. Quantities were not assessed (n=60)

90 percent (n=54) of the guinea pigs were fed pellets and 11,7% (n=7) were fed mixed feed. Of these guinea pigs two were fed both pellets and mixed feet and one guinea pig in this study did not receive any concentrates. 93,3% (n=56) of the guinea pigs received hay, 90,0% (n=54) vegetables, 58,3% (n=35) fruit, 15,0% (n=9) snacks and 25,0% (n=15) received other feeds. Bread, grass, fiber or crispy sticks, mineral stones, herbs, dandelion leaf, plantain and muesli were mentioned as other feeding. 46,7% (n=28) of the guinea pigs received some form of vitamin C supplementation, 36,7% (n=22) did not and of 16,7% (n=10) this was not known. Unfortunately, there was not enough information about quantities of feeding. So no further comparisons of nutrition with gastrointestinal and dental diseases were made.

<u>Vaccination status</u>

Unlike rabbits, no commercial vaccinations are available for guinea pigs in the Netherlands. Therefore, this is not addressed.

Discussion

Limitations of this study

The population of rabbits and guinea pigs in this study may not be representative of the population in the Netherlands. Time distribution fluctuates, but no big peaks are seen for rabbits and guinea pigs. Gender distribution was almost equal for both rabbits as well as guinea pigs. (*Figure 4 and Figure 19*) However, spatial distribution shows more fluctuations. Most rabbits and guinea pigs presented were from the provinces of Utrecht (40% respectively 35%) and surrounding provinces (*Figure 2* and *Figure 17*). Owners had to arrange transport of the animals themselves within 24 hours of decease. This is more difficult and expensive when the owner lives further away. Another reason might be that there is more ignorance of owners and veterinarians in provinces further away from the VPDC.

Striking was that very young rabbits are overrepresented (*Figure 3*). 26,1% (n=24) of the rabbits are younger than half a year, while this group of animals was added a year later (see methods and materials). This suggests that these young rabbits are very vulnerable at this age. Due to weaning at 4 to 6 weeks of age, young rabbits are more susceptible for different infectious diseases as colibacillosis, coccidiosis and pasteurellosis.[4, 11] Thereafter, they are bought and brought into a new environment, possibly with a new diet. All these factors cause stress which predisposes of disease.[5, 12] Another possible reason is that owners want to know if the rabbit was already ill when they bought it so that they can claim costs to the pet stores or breeders.

Most of the animals are sent in by a veterinarian, but not all of the owners will visit a veterinarian when their rabbit or guinea pig is ill. These animals are probably not sent in for necropsy either. Presumably owners that contribute to this study are more concerned with their animal than the average owner. Besides this, animals with an obvious death cause might not be submitted, because the owners and veterinarians are not curious anymore. In other cases, owners might be ashamed to submit their animal if they have the feeling that they did something wrong. Furthermore, if there is a suspicion of an infectious disease in a group, animals probably are submitted earlier to know what is going on and treat the other animals in the group appropriately.

Different pathologist performed the necropsies with help of different students and coworkers. This may lead to inter-observer variation of pathological findings. Also, the database has been filled in by different students which could lead to differences in interpretation. However, one student assessed this database.

This study focuses on cause of death in young rabbits and guinea pigs to assess animal welfare. Other illnesses, such as skin diseases, negatively influence animal welfare but in most cases these are not a cause of death. Thus, these animals are not submitted for necropsy and are missed in this study. In some animals in this study there were non-lethal illnesses, but this was more an incidental finding.

Although there was an extensive anamnesis form, there was too little information about housing and nutrition. A lot of owners did not fill in the form clearly and completely. Quantity of food is mentioned as a hand full, a container, enough for a day, but owners did not measure the exact amount. Same problems existed with the measurements of the housing system.

An important part of animal welfare is the possibility to express normal behavior (see introduction about welfare). Nothing can be said about the expression of normal and abnormal behavior of the animals in this study. Questionnaires and housing visits are possibilities to assess the housing conditions as well as the behavior in living pet rabbits and guinea pigs.

Rabbit

Table 5 and *Table 8* show the most common diseases in pet rabbits. Etiology of death and the top three diseases of rabbits are discussed in this paragraph. The top three diseases are dental disease (54,3%), pneumonia (41,3%) and *E. cuniculi* (26,1%). Furthermore, adenocarcinoma of the uterus is discussed as this occurred in 10,5% of the female rabbits. This was a remarkable finding because rabbits in this study are 3 years or younger. We did not expect this in young animals, because it is a disease that occurs in older rabbits.

Etiology of death

Infectious disease was the most common etiology of death in 60,9% (n=53) of the rabbits (*Figure 6*). Followed by an unknown (24,1%, n=21) and non-infectious cause of death (15,0%, n=13). Most important infectious diseases are encephalitozoonosis, coccidiosis and pasteurellosis. These three diseases are mentioned as common diseases in the literature.[4, 7, 11, 12] These three diseases will be discussed later in this chapter.

Most affected organ systems

The most affected organ systems in rabbits in this study were dentition (54,3%, n=50), respiratory system (41,3%, n=38), nervous system (31,5%, n=29) and gastro-intestinal system (31,5%, n=29). The most common dental abnormality were spurs, the most common respiratory disease was pneumonia and the most common nervous system disease was Encephalitozoonosis. These three diseases will be discussed in the next paragraphs.

Gastro-intestinal diseases were found in 7-15% of the rabbits in the studies described by Langenecker et al.[8] The gastro-intestinal system was affected in 31,5% (n=29) of the rabbits in our study. Higher incidence in this study might be due to the subclinical cases that were also found in this study. The most common gastro-intestinal disease was coccidiosis in 24,1% (n=7) of the rabbits with a gastro-intestinal abnormality and is discussed above. Coccidiosis was not mentioned by Langenecker et al.[8] as a common found disease in pet rabbits. However, in most literature it is mentioned as the most common parasitic disease of the gastro-intestinal tract that is common in rabbits.[4, 5, 11, 12] Our study confirms these statements. Different Eimeria species exists of which *E. stiedae* cause a hepatic infection and different *Eimeria spp.* cause intestinal infections. It occurs more frequently in young rabbits, especially at the weaning age of 5-8 weeks.[4, 5, 11, 12] Risk factors for both these infections are stress,[5, 7] overcrowding,[7, 11] suboptimal diet,[7] poor hygiene,[7, 11] contact with infected wild animals, contaminated feeds and introduction of infected animals.[11, 12] Symptoms that can develop are anorexia, diarrhea or constipation for both types, icterus, distended abdomen with ascites for the hepatic type and dehydration, intussusceptions for the intestinal type.[4, 5, 7, 11, 12] Subclinical infections are also possible.[4, 12] Prevention of coccidiosis is possible with good husbandry, good hygiene, cleaning with for example 10% ammonia solution, avoidance of stress and no introduction of infected rabbits.[5, 11, 12]

Most common diseases

Dental disease

Dental disease was found in 50 rabbits (54,3%). This is probably subclinical in most cases, but it can be a contributing factor in the cause of death. In other rabbits this (probably) is the cause of death. Dental disease has already been discussed in the introduction. Dental diseases were found in 14% of the presented rabbits by Langenecker et al. and in 8-25% in the described studies by Langenecker et al.[8] 29,4% of the rabbits in the survey of Mullan et al. had a dental disease of which most were subclinical.[9] Although it has been suggested that ageing is a risk factor for developing dental disease,[9, 11] this also occurs frequently in young rabbits. In the studies of Langenecker et al.[8] and Mullan et al.[9] the mean age of the rabbits was also very low (3,3 and 2,2 years resp.). Moreover, this study shows that more than half of the rabbits younger than three years had a dental disease. Higher incidence of dental disease in this study can be because diagnosis of dental disease is harder in the living animal compared to postmortem. As said before, poor nutrition is a risk factor which should be considered. Unfortunately, a comparison of nutrition and dental disease was not possible because of the information available was very limited. More research is needed to assess different risk factors for developing dental disease, such as diet, but also genetic predispositions and influence of concurring diseases.

(Broncho-) Pneumonia

Pneumonia, with or without a concurring disease, has been found in 38 rabbits (41,3%). As for dental disease, most of these cases had other diseases besides pneumonia. Pneumonia is not mentioned as a very common disease in rabbits in the literature. An incidence of only 2% was described by Kirschbaum et al.[8] This discrepancy can be accorded to enhanced detection of subclinical cases of pneumonia in the present study. Causes of pneumonia mentioned in literature are mostly infectious. *Pasteurella multocida* is most common, but other bacterial infections have been mentioned.[4, 11] Risk factors for bacterial pneumonia in rabbits is young age, stress, pre-existing diseases, temperature fluctuations, draughts and poor sanitation.[11, 12] Build-up of ammonia can cause irritation of the respiratory tract[5, 11, 19], can be immunosuppressive[5, 31] and causes pneumonia or death in high continuous doses.[19] Appropriate bedding, cleaning frequency and ventilation is recommended to reduce build-up of ammonia.[5, 7, 11] In our study we compared respiratory illnesses in general to bedding type and cleaning frequency. There was no significant difference between bedding type and respiratory disease. A reason might be that wood shavings and saw dust are used in the same group (wood shavings) or that the groups are too small. Respiratory disease in rabbits occurred more when frequency of cage cleaning declined, but this effect was not significant (p=0,078). This might be because of the negative effects of build-up of ammonia as described in the literature. More research is needed to assess the causes of pneumonia and risk factors, such as the influence of husbandry.

Encephalitozoon cuniculi

Encephalitozoonosis was the third most common illness in 24 pet rabbits (26,1%) and is the most common infectious disease. As said before, this protozoan can infect lung, kidneys, brains, heart, eyes and other organs.[4] In our study the kidneys (62,5%) and brains (95,8%) were affected in most cases and in two cases the liver (8,3%) was also affected. *E. cuniculi* was confirmed in 9,7% respectively 2% in the studies of Langenecker et al. and Rheker et al.[8] Incidence of *E. cuniculi* was a lot more in our study. This might be because *E. cuniculi* can be diagnosed solely with postmortem examination.[11] But it is possible that *E. cuniculi* is more common in the Netherlands than in Germany or Switzerland.

Infection is caused by ingestion or inhalation of spores which are excreted by urine of infected rabbits. Vertical transmission is also possible.[4, 7] Young rabbits are more sensitive, because maternal antibodies decline at 4 weeks of age. Other predisposing factors are unsanitary conditions and feeding or drinking bowls contaminated with spore-containing urine.[12]

Prevention of infection with *E. cuniculi* is difficult. As there is no adequate diagnostic test, little information about potential transmission time exists. So, duration of quarantine periods cannot be determined. Also, detection of infected animals is difficult, because there is no adequate diagnostic test.[4] Transmission between rabbits is reduced with good sanitary and hygienic procedures. Most disinfectants are effective, such as amphoteric surfactants, alcohols, quaternary ammonium compound, and phenolic derivatives. [4]

It has been suggested that medicated pellets can prevent infection with *E.* cuniculi.[4, 33] Suter et al.[33] fed fenbendazol medicated pellets to 4 rabbits 7 days before until 2 or 21 days after infection (group A) and compared this to 4 rabbits that were not fed with these pellets (group B). Group A had a negative serology and the parasite could not be isolated from brain tissue. Group B did seroconverse and the parasite could be isolated from the brains.[33] This shows the possibility of medicated pellets as a preventive measurement against *E. cuniculi*. But this is a small group of rabbits, there is a risk of developing resistance against medication as it is not clear if pet rabbits will eat enough of the medicated pellets at the right time.

Vaccination against *E. cuniculi* is not available, but Sobottka et al.[34] described subcutaneous immunization with inactivated spores of different *Encephalitozoon spp*. Seroconversion existed with a titer of 1:1280 3 months after immunization for *E. cuniculi*. Sera of these rabbits strongly reacted with *E. cuniculi* antigens. Vaccination against *E. cuniculi* might be possible, but more research about the humoral and cellular response after immunization with inactivated spores is needed.[34] Also more research is needed for developing an adequate diagnosis tool for the living animal and the different manners to treat and prevent this disease.

<u>Remarkable findings</u>

Uterine adenocarcinoma

10,5% (6/57) of the does had adenocarcinoma of the uterus. As discussed in the introduction this is common in older does with an incidence of 50 to 80 percent in does older than 4 years.[4, 11, 14] In this study, incidence was lower, but rabbits were younger than 3 years. Greene et al.[14] reported an incidence of 16,7% of the animals which is comparable to findings in our study. 3 of the does in our study died as a consequence of this disease and the other three as a result of a different disease (*E. cuniculi* twice and pneumonia once). One of the rabbits was 12 months old, one 28 months, two 29 months and two were 33 months. So in our study it occurred more in relatively older rabbits.

The only known effective preventive measure is castration of the doe.[7, 11] As castration contains a surgical and anesthetic risk, assessment of alternative measures is recommended. Only 10,5% (6/57) of the does in this study were castrated which is a lot lower than the 41,2% described by Mullan et al.[9] Reasons for this difference might be that 26,1% (n=24) of the rabbits in this study is younger than 6 months of age and ovariohysterectomy will be performed when the rabbit is at least 5 months old.[11]

Guinea pig

Table 19 shows the most common diseases of pet guinea pigs in this study. The top three will be discussed in this paragraph and consists of (broncho-)pneumonia (43,3%), dental disease (30,0%) and myocarditis (16,7%). Besides this, two remarkable findings will be discussed. 40,0% of all guinea pigs had calcium deposits and 16,7% of the young sows had ovarian cysts. We did not expect that so many guinea pigs had calcium deposits as some literature describes this as an incidental finding.[4, 22] We also did not expect this many ovarian cysts as it is thought to occur more in ageing sows. [4, 7, 22, 26]

Etiology of disease

In contrast to rabbits, infectious diseases do not play an important role in guinea pigs. 60,0% (n=36) of the guinea pigs deceased because of a non-infectious disease, 18,3% (n=11) of an infectious disease and 21,7% (n=13) of a disease with an unknown etiology. Bacterial pneumonia was the most frequently found infectious disease and is discussed later in this chapter.

Most affected organ systems

The most affected organ systems found in pet guinea pigs were the respiratory system (51,7%, n=31), urinary system (41,7%, n=25) and liver (38,3%, n=23). The most common disease of the respiratory system was pneumonia (83,9% of all respiratory diseases). Pneumonia was also the most common disease in this study and will be discussed later.

Urinary problems were mentioned by Langenecker et al.[8] with an incidence of 8%. It occurred more in this study, possibly due to subclinical cases. Of the urinary problems in this study metastatic calcium deposits in the kidney occurred most often (40,0% of all urinary problems). These calcifications would not be found in the living animals, because diagnosis is made with histology. Calcium deposits have been found in many guinea pigs (n=24) in this study and is a remarkable finding, because some literature describes this as an incidental finding.[4, 22] Because of this, it will be discussed later in this chapter.

Liver problems were mentioned in 4% of the represented guinea pigs by Möller et al.[8] In this study the liver was affected in 38,3% (n=23). Most of these problems were secondary, such as liver fatness and necrosis secondary to hypoxia. These secondary problems are probably not found in the living animal.

Most common diseases

(Broncho-)Pneumonia

Pneumonia was the most common disease in pet guinea pigs in this study with 43,3% (n=26). As mentioned in the introduction incidence of pneumonia was only 2% in the study of Rheker et al.[8], but these probably were only clinical cases. In our study, we also found subclinical cases of (broncho)pneumonia. Bacterial etiology has been suggested to be the most important cause of pneumonia.[4, 5] Bacterial pneumonia was found in 34,6% (9 of 26) guinea pigs with pneumonia. No infectious agent was found in 7 cases (26,9%) and etiology was unknown in 10 cases (38,5%). This suggests that bacterial pneumonia might play an important role. This occurs more in stressed and young, pregnant or ageing animals.[4, 5, 12, 31] Stressors can be nutritional imbalances, draughts, climatic and temperature changes, feeding changes or suboptimal nutrition, overcrowding and occurrence of other diseases.[12, 31] For *B. bronchiseptica* housing with a rabbit or dog is also a risk factor,[4, 5, 7, 12, 31] as well as addition of guinea pigs from numerous sources.[12]

Just as for rabbits build-up of ammonia can cause respiratory disease (see discussion pneumonia rabbit). However, in this study respiratory diseases in general did not occur more with different types of bedding. As in rabbits, this might be because sawdust and wood shavings are assembled in one group or the number of animals per group was too small. In contrary to rabbits, there was no tendency of developing respiratory disease when cage was cleaned less often. In general, cages of guinea pigs were cleaned more often than those of rabbits which can cause this difference.

Risk factors for developing respiratory disease are quite similar for rabbits and guinea pigs according to the literature. This might be the reason why pneumonia is a significant disease in both rabbits (41,3%) and guinea pigs (43,3%). More research is needed to assess the causes of pneumonia and risk factors, such as the influence of husbandry.

Dental disease

As described in the literature dental problems are common illnesses of guinea pigs (30,0%). In most cases dental disease was subclinical or an incidental finding. This explains the higher incidence of dental disease of our study compared to the 9-20% described by Langenecker et al.[8] Nutrition is a major risk factor for development of dental disease, although there are other contributing factors.[4, 5, 7, 10, 22] Unfortunately, we could not compare dental disease with diet, because not enough information was available. As for rabbit, appropriate nutrition should be considered as the major preventive measure for dental diseases. But more research is needed to assess different risk factors for developing dental disease.

Myocarditis

Myocarditis was found in 10 (16,7%) of the guinea pigs and is the third most common disease found in this study. In contradiction, circulatory diseases are not mentioned by Langenecker et al.[8] and other literature.[4, 5, 22, 31] And Harkness et al. states that heart disease is rare in guinea pigs.[12] Heart ailments mentioned in literature are cardiomyopathy,[7] rhabdomyomatosis[12, 27] and myocardial in combination with skeletal muscle degeneration.[27] To the author's awareness there is no knowledge about myocarditis in guinea pigs in the literature. This might be because histology is essential for diagnosis of myocarditis. Histology of the heart is not standard with postmortem examination and the diagnosis is missed in living animals as histology cannot be done.

In other animals myocarditis is caused by a systemic bacterial, viral or parasitic infections which spreads hematogenously in most cases. The myocardium is rarely seen as the primary location of inflammation.[35] In this study in one guinea pig the myocarditis was (probably) primary. But of 90% (n=9) of the guinea pigs with myocarditis other organs were affected. In 2 of these guinea pigs there was a viral infection: one with a splenitis caused by an unknown virus and one with an enteritis and hepatitis caused by an adenovirus. In the other cases no etiologic agent had been diagnosed, but myocarditis occurred in combination with pneumonia (40,0%, n=4), endocarditis (10,0%, n=1), peritonitis (10,0%, n=1) and intussusception of ileum in jejunum (10,0%, n=1). Thus prevalence and causes of myocarditis in guinea pigs are a point of interest and more research is needed.

Remarkable findings

Calcium deposits

Calcifications or calcium deposits has been found in 24 (40%) guinea pigs in this study. 16,7% (n=4) of the calcium deposits were dystrophic, 16,7% (n=4) were metastatic caused by a kidney problem and 66,7% (n=16) were metastatic with a non-renal cause. According to the literature metastatic calcifications are not uncommon in guinea pigs older than a year, especially males.[4, 12, 21, 27, 31, 36, 37] Although some state metastatic calcification is an incidental finding at necropsy and is a subclinical disease,[4, 22] most authors describe clinical signs that can negatively influence guinea pig welfare. Examples are muscle stiffness[4, 12, 21, 22, 27, 31, 37] and wasting.[12, 21] Renal failure,[5, 12, 22] weight loss and sudden death[5, 22, 31] has also been reported. Calcium deposits can be found in the lungs, trachea, stomach, colon, heart, aorta, liver, kidney, uterus and eye.[4, 5, 21, 22, 27, 31]

Diet has been suggested as the major contributing factor for development of metastatic calcifications of a non-renal origin.[4, 5, 21, 22, 27, 36, 37] Diets high in calcium (Ca)[21, 22, 27, 36], phosphate (P) [5, 21, 22, 27, 37], imbalance of the Ca:P ratio [5, 31, 36, 37] and excessive vitamin D[4, 21, 36] are suggested as a possible cause. Low magnesium[5, 21, 22, 27, 36, 37] and potassium[22, 37] might be contributing factors too, as magnesium and potassium are protective against hyperphosphatemia and thus against calcifications.[36] Feeding high quality of commercial guinea pig pellets reduced the incidence of calcium deposits in laboratory guinea pigs[2137] and guinea pigs fed a diet of hay and green leafy vegetables seldom develop metastatic calcifications.[22] Diets should contain 0,9-1,1% calcium, 0,6-0,7% phosphor, 0,3-0,4% magnesium and 0,4-1,4% potassium.[5] Ca:P ratio should be 1,5:1[5, 31] and vit. D less than 1600 iu/kg.[31] However, more research is needed to assess the actual influence of diet on the development of calcium deposits and the effects of calcium deposits on animal welfare.

Ovarian cysts

Ovarian cysts has been found in 10,0% (n=6) of all the guinea pigs. This is 16,7% of the female guinea pigs. Ovarian cysts were found in 3 and 4 percent of the presented guinea pigs in the study of Langenecker et al. and Möller et al. respectively.[8] Higher frequency of ovarian cysts in this study is remarkable, because of the young age of the guinea pigs in this study. This difference might be related to the smaller number of guinea pigs in this study. It can also be caused by the fact that subclinical ovarian cysts might be found earlier at post mortem examinations than in living guinea pigs. Ovarian cysts were identified in 76% of female guinea pigs between 18 months and 5 years at necropsy by Keller et al.[28] This is a lot more than in this study. This is probably due to a higher incidence in older guinea pigs.[4, 7, 22, 26] Reproductive state does not influence development of ovarian cysts.[27, 29]

Castration of the sows is the only effective measurement to prevent development of ovary cysts.[4, 7, 22] Only 2,8% (n=1) of the female guinea pigs in our study was castrated. This is low in comparison with the 10% reported by Langenecker et al. of all the guinea pigs, so it is not comparable.[8] Treatment with a deslorelin implant has been studied, but no effect on size of ovarian cysts was found.[26] More research is needed to assess alternatives of castration to prevent the development of ovarian cysts.

Zootechnical issues

As stated in the introduction zootechnical factors influence animal welfare considerably. Findings in this study are discussed for both rabbits and guinea pigs in this paragraph.

Housing conditions

Rabbits and guinea pigs are social living animals.[3-5, 11, 15, 31, 32] The majority of rabbits and guinea pigs are kept socially. Rabbits were housed solitary in 34,8% of the cases. Mullan et al.[9] stated that 44,1% of the rabbits were kept solitary in 2006 and Schepers et al.[3] stated that 31% of the rabbits were kept solitary in 2009. Thus there is a trend to keep rabbits with at least a companion, but numbers are too small to make definitive conclusions. Guinea pigs were housed socially in 81,7% of the cases. This is much higher than in rabbits. This might be because guinea pigs generally need a bit less space than rabbits, so it is easier to keep them in pairs or groups. No other data about social and solitary housing of guinea pigs are available.

Social housing is beneficial for welfare of rabbits[3, 11, 15, 16] and guinea pigs.[21, 30] But in this study infectious diseases were significantly more common in social housed rabbits compared to solitary housed rabbits (p=0,012). Overcrowding, unstable groups (e.g. male groups) or introduction of new rabbits can cause stress and are predisposing factors for infectious diseases.[5, 11, 12] There probably is no quarantine period before introduction of a possible infected rabbit. In this study socially housed guinea pigs did not suffer more from infectious diseases compared to solitary housed guinea pigs. This difference might be caused by the fact that not many infectious diseases have been found in guinea pigs or numbers of guinea pigs in this study are too small.

Both rabbits and guinea pigs are kept inside as well as outside, but guinea pigs were more frequently housed inside compared to rabbits. 41,3% (n=38) of the rabbits were housed inside, 44,6% (n=41) outside and 14,1% (n=13) a combination of inside and outside housing. This was 76,7% (n=46), 20,0% (n=12) and 3,3% (n=2) for guinea pigs respectively. There are no data available to compare these findings. A comparison with infectious agents are made, because contact with wild rabbits and rodents is a risk factor. There was no difference in incidence of infectious disease in inside and outside housed rabbits and rodents. Probably due to little contact with wild rabbits and rodents.

Cage size could not be determined in most cases in this study. The majority of owners did not fill in the questionnaire or only said it was a large cage. Furthermore, there is no consensus about the minimal cage size as discussed in the introduction. So it is not possible to compare this with the literature.

Bedding and cleaning frequency has already been discussed in the introduction as well as the paragraphs about pneumonia in rabbits and guinea pigs. There is no agreement of suitable bedding. But most authors state that cleaning frequency of the cage must be at least once a week.[3, 5, 11, 12, 15, 30, 31] 82,7% (67/81) of the rabbit owners cleaned the cage at least once a week and this was 98,3% (57/58) for the guinea pig owners. This difference might be because in general guinea pigs are messy pets and rabbits are cleaner. But also because guinea pigs are kept inside more often than rabbits and owners clean the cage when they smell unpleasants odours.

Nutrition

As discussed earlier diet has not been filled in appropriately. Most times the type of food was filled in, such as pellets or mixed diet, hay, vegetables and snacks. But the amount of food was not filled in unambiguous or not at all.

The majority of rabbits (80,4%) were fed pellets and 14,1% of the rabbits were fed a mixed diet. 3,3% were fed a combinations of pellets and mixed diet and 8,7% of the rabbits were did not get any concentratesThis suggests that most owners are aware of what problems can arise when feeding mixed diets. However, amounts of pellets (and mixed feeding) should be limited. It is recommended to feed a maximum of 2-3% of the rabbits' body weight.[11] On the packages of different rabbit feeds in the Netherlands different recommendation are mentioned. This differences might be caused by different energy contents. Because of the context of this study, this has been left out of consideration. Hopefarms® recommends 30-50g/day for dwarf- and small breeds, 50-75g/day for middle size breeds and more than 75 g/day for large breeds. This is comparative to the maximum amount of 2-3% of the bodyweight stated by Harcourt-Brown.[11] Supreme® Science Selective recommends that a mean adult rabbit needs 60-70 g/day, but most owners do not know what a mean adult rabbit is. So under- or overfeeding can arize. Puik® does not mention an amount at all.

The majority of guinea pigs (90,0%) received pellets, 11,7% a mixed diet, 3,3% both pellets and a mixed diet and 1,7% did not get any type of concentrates. Guinea pigs should be fed 6% of their bodyweight in total. The majority of this should be hay and a small amount should be pellets. The recommended amount of pellets is not available in the literature. Different brands recommend different amounts of pellets, probably because different energy contents. Hopefarms® recommends 35-45 g/day divided in two gifts. Science selective recommends 30-50 g/day. When using the same amounts of pellets described for rabbits (2-3%), this is too much as adult guinea pigs weigh 700-1200 grams depending on gender.[4] Thus, an adult boar of 1200 gram may eat a maximum of 36 grams of pellets per day. Recommendations for the amount of pellets seems to be too much. The author recommends to weigh the animals, for example once a week, to monitor for changes in weight which can be caused by the amounts of pellets but also illnesses.

The majority of rabbits (85,9%) and guinea pigs (93,3%) received hay. More than half of the rabbits (65,2%) and the majority of guinea pigs (90,0%) received vegetables. There seems to be a tendency of giving these animals the right diet (hay and vegetables), but hay should be fed ad libitum and vegetables not more than 10% of the diet and quantity of hay and vegetables are not known in this study.

Fruit was given to rabbits in 32,6% of the cases. More than half of the guinea pigs (58,3%) received fruit. Fruit should be limited as they contain high levels of sugars. Especially in guinea pigs, more information should be given to owners about limiting the quantity of fruits should be given.

Treats were given in 17,4% of the rabbits and 15,0 % of the guinea pigs. These treats should not be given on a daily basis, but the amount could not be determined in this study. But there seems to be a trend not to give treats to these animals.

33,7% of the rabbits and 25,0% of the guinea pigs received other feedings such as bread, fiber or crispy sticks, corn, barley flakes, grains, straw, muesli and mineral stones which should be given in very small amounts or not at all. Branches, grass, dandelion leafs and herbs were also mentioned and are appropriate to feed to rabbits and guinea pigs.

As discussed in the introduction vitamin C is essential for the welfare and health of guinea pigs. 46,7% (n=28) of the guinea pigs received some form of vitamin C supplementation, 36,7% (n=22) did not and of 16,7% (n=10) this was not known. There is no consensus in the literature of the amounts of vitamin C needed and how to supplement this. To the authors opinion vitamin C supplementation via pellets or drinking water is unreliable and a lot of vegetables should be given in order to meet the needs for vitamin C. Tablets containing 50 or 60 mg of vitamin C are suggested by Harkness et al.[12] To the authors opinion this is the most reliable manner to supply vitamin C to guinea pigs and when guinea pigs are used to eating these tablets they start to see it as a treat. But as there is no consensus, more research about the amount of vitamin C that should be given.

Although there is some knowledge about nutrition of guinea pigs and rabbits, more research on this topic is needed. Especially long term nutritional requirements are not known.[11] Effects of long-term nutrition on dental disease and other ailments needs to be assessed.

Vaccination of rabbits

51,9% (40/77) of the rabbits were vaccinated against myxomatosis and/or Rabbit Hemorrhagic Disease (RHD) and 48,1% of the rabbits were not. The 15 rabbits of which vaccination status is unknown are excluded in this discussion. This is comparable to data of Schepers et al. and Mullan et al. (see introduction). Vaccinated rabbits in this study suffered significantly less than not vaccinated rabbits (p=0,048). Nevertheless, one of the rabbits that died because of RHD was vaccinated. Reasons for this might be that the owner thought that the rabbit was appropriately vaccinated while the rabbit was not or that the vaccine did not work. It cannot be because the new vaccine (Nobivac Myxo-RHD) did not work, because the rabbit died before this vaccine was available.

Although more research is needed, basic knowledge exists of the different common diseases and zootechnical issues. Optimizing housing conditions, nutrition and care taking can improve welfare and health of pet guinea pigs and rabbits. Informing owners about the requirements of these animals is very important to achieve this. This can be done by the government, veterinarians, breeders, non-profit organization and staff of pet shops.

Suggestions for subsequent similar research

As said before the population of this study is not representative for the Netherlands. The province Utrecht and neighboring provinces are overrepresented. This is probably due to time and costs to transport the animals to Utrecht. If possible (budget wise) this can be made easier for the owner, for example with a transport service.

There was no group of older animals to compare the death causes in young pet rabbits and guinea pigs to. It might be interesting to know the difference between death cause in young pets compared to older pets. At this moment, this can only be done with a retrospective research of the older animals in the archives of the VPDC. But examination of these animals was not so extensive compared to this study, mainly because of the budget of the owners. Besides, no anamnesis form about husbandry is available for these animals. So comparison of the young animals in this study with older animals in the archives has limitations. In subsequent studies older animals can function as a comparison group if enough budget is available to examine more animals.

Different pathologists, co-workers and students worked on this project which can lead to inter-observer variation. This could be minimized by creating more extensive protocols that describe the procedures and forms that are filled in the same. Uniform descriptions of abnormalities simplifies filling in and analyzing the database. For example, the nature and severity of dental problems are described in many different manners. By using a gradation, such as the one mentioned by Harcourt-Brown[11](*Table 26*), a more objective description can be made. When using this gradation, X-rays of the teeth must be added to examine the severity of dental problems.

Grade	Description
1	Normal
2	Root elongation and deterioration in tooth quality. Characterized by: - Incisor ribbing, - Mandibular irregularity, or - Epiphora by dacrocystitis
3	Acquired malocclusion. Characterized by: - Incisor or cheek teeth malocclusion , - Spurs, - Abscesses, or - Loss of alveolar bone
4	Cessation of tooth growth. Characterized by: - Destruction germinal tissue at the apex of the tooth, - Crown break off, - Gum heal, and/or - Periapical abscesses
5	End stage dental disease. Which can be divided in: - Osteomyelitis and abscess formation - Calcification of the teeth and surrounding bone

Table 26: gradation of dental disease in rabbits by Harcourt-Brown[11]

Sometimes the weight of the animal was not filled in. But, especially in rabbits, this cannot be related to the condition of the animals, because rabbit size differs in various breeds. Body Condition Score (BCS) varying from 1 to 5 or 1 to 9 can be used to describe the condition of the animal. As cachexia and obesity are signs of welfare impairment. A clear protocol to determine BCS should be added to the other protocols.

The layout of the database might be changed for a subsequent similar research. Before me, everyone counted the data of this study by hand, but to my opinion this is a waste of time. Therefore Excel® has been used to search and count specific words in the text of the pathologic conclusions, for example the different organ systems and types of agents. If you determine what you want to know beforehand you can also alter the database in Filemaker Pro® for this purpose. For example, now it was only possible to fill in cause of death as infectious, non-infectious and unknown. But it might be useful to add different types of agents (bacterial, viral, parasitic and fungal), with their specific names or different organ systems as used in this study. This makes it easier to export the data from Filemaker Pro® to Excel®.

The anamnesis form must be extended with vaccination for rabbits. In this study veterinarians and sometimes owners were called afterwards, sometimes months to more than a year after submission of the rabbit. The same problem arises when owners did not fill in the anamnesis form completely. Most owners cannot remember everything after a long time, so some of the information was lost. Thus, it is important that owners are called as soon as possible if the anamnesis form was not filled in completely. In the anamnesis form there were no questions about enrichment of the cage, such as a house, pipes or other objects, nor about the possibilities to exercise outside the cage. This is important in rabbits and guinea pigs, especially in smaller cages, and this can be added to the questionnaire.

There was a limited possibility of symptoms that could be filled in. An important missing symptom was nervous signs of rabbits. A possibility for explanation of the symptoms can be used too. A suggestion of the extension of the questionnaire regarding clinical signs is:

- Anorexia
- Depressed water consumption
- Weight loss
- Diarrhea
- Other gastro-intestinal problems
- Depressed growth
- Depression
- Respiratory problems
- Lameness
- Nervous signs
- Reproductive problems
- Urinary problems
- Skin problems
- Sudden death
- Other diseases

Sometimes the anamnesis form was not very clear for owners. An example is that most owners did not realize what pellets were, because the Dutch word ‘hardvoer’ is used more often to describe pellets and mixed diets. This word, a description or pictures could be added to make it easier for owners to understand.

Conclusion

Rabbits and guinea pigs are commonly held pets in the Netherlands. Although they are different species they both die too early in life. Literature describes different diseases and zootechnical issues which can cause welfare impairment in these animals. [4, 5] Although there are some limitations in this study some conclusions can be made.

Rabbit

Like described in the literature, the most common disease of pet rabbits is dental disease (54,3%, n=50). Although subclinical cases were found, problems would develop eventually so this is important for animal welfare. The most important contributing factor for development of dental disease described in literature is nutrition. [4, 7, 9, 11] Unfortunately, we could not compare dental disease with nutrition because of the limited information available about nutrition.

Pneumonia is the second major disease of pet rabbits in this study (41,3%, n=38). In literature, pneumonia has not been described as an important disease[8] in rabbits and when mentioned the cause is bacterial.[4, 7, 11] Risk factors described for bacterial pneumonia are young age, stress, pre-existing diseases, temperature fluctuations, draughts, poor sanitation and high ammonia.[5, 11, 12, 19] These factors could not be assessed in this study. But high ammonia is related to bedding type and cleaning frequency. [5, 7, 11] There was no significant difference between bedding type or cleaning frequency and occurrence of respiratory disease. However, cleaning frequency had a tendency to influence respiratory disease in rabbits (p=0,078).

Infectious diseases are the major cause of death in this study. *Encephalitozoon cuniculi* was the most common infectious agent in this study, followed by *Eimeria spp.* and *Pasteurella multocida*. *E. cuniculi* was the third most common disease in this study (26,1%, n=24). It affected the brains (95,8%) and kidneys (62,5%) most often. Predisposing factors are young age, unsanitary conditions and feeding or drinking bowls contaminated with spore-containing urine. [4, 7, 12] Clinical diagnosis, treatment and prevention of this disease is difficult. [11] The most important preventive measures are good sanitary and hygienic circumstances.

A remarkable finding is that uterine adenocarcinoma occurred in 10,5% (n=6) of the 57 young female rabbits in this study. In three of these cases this was the cause of death and in the other three it was an accidental finding. Castration of does is important for prevention of this disease and is recommended.[7, 11]

Guinea pig

Non-infectious diseases are most important in guinea pigs. The three most common diseases found in this study were pneumonia, dental disease and myocarditis.

Pneumonia is most important disease in guinea pigs according to this study (43,3%, n=26). In the literature it is stated that bacterial respiratory diseases are common in guinea pigs.[4, 5] In this study bacterial pneumonia has been found in 34,6% of the guinea pigs with pneumonia. Predisposing factors are stress, young or old age, pregnancy, nutritional imbalances or changes, draughts, climatic and temperature changes, high ammonia levels, overcrowding, occurrence of other diseases and addition of guinea pigs from numerous resources. [4, 5, 7, 12, 31] As in rabbits no significant difference occurred in this study between incidence of respiratory disease and type of bedding or cleaning frequency.

Dental disease was found as the second important disease in guinea pigs (30,0%, n=18). Literature describes this as an important illness in guinea pigs too.[8] As for rabbits it has been suggested that nutrition is the most important contributing factor for development of dental disease. [4, 5, 7, 10, 22] In this study this comparison could not be made, because of the limited information about nutrition.

Myocarditis is the third most frequent disease in guinea pigs (16,7%, n=10). In much literature circulatory diseases of the guinea pigs are not mentioned or are mentioned as rare. [4, 5, 8, 12, 22, 31] Knowledge about myocarditis in guinea pigs is not available. In other species myocarditis is mostly secondary to a bacterial, viral or parasitic infection somewhere in the body and rarely primary.[35] Primary myocarditis was found in 10% (n=1) of the guinea pigs in this study. In 90% (n=9) of these guinea pigs other organs were also affected. Two of these cases had a viral infection and of the other cases no etiologic agent has been diagnosed. Further research of the occurrence of myocarditis in guinea pigs is necessary.

Calcium deposits were found in a remarkable high frequency (40,0%, n=24). According to literature calcium deposits are not uncommon in guinea pigs older than a year. [4, 12, 21, 27, 31, 36, 37] Nutrition has been suggested as the most important cause for developing calcium deposits. [4, 5, 21, 22, 27, 36, 37] Consistently, in this study 16 (66,7%) of the 24 guinea pigs with calcium had non-renal metastatic calcifications. These were probably caused by a nutritional imbalance. As for dental disease no comparison could be made with nutrition because limited information was available. More research is needed to assess the causes of non-renal metastatic calcifications in (young) pet guinea pigs.

In 16,7% (n=6) of the 36 sows ovarian cysts were found. This is quite high, because the guinea pigs in this study are young. In literature ovarian cysts are described more often in ageing sows with a prevalence as high as 76% guinea pigs with an age between 18 months to 5 years. [4, 7, 22, 26] Castration is the recommended preventive measure. [4, 7, 22]

Zootechnical issues

Although a questionnaire about husbandry and nutrition has been filled in by the owners, limited information was assembled. Therefore, cage size, cage materials and the amount and quality of nutrition could not be assessed.

Group housing could be assessed. Rabbits were housed solitary in 34,8% (n=32) of the cases and 65,2% (n=60) at least with one companion. This was 18,3% respectively 81,7% for guinea pigs. Socially housed rabbits significantly suffered more from infectious diseases then their solitary housed conspecifics. This was not found in pet guinea pigs. Overcrowding, unstable groups and introduction of new animals can cause stress and predisposes for infectious diseases. Introduction of new rabbits that are already infected possibly has disastrous consequences for the population. Quarantine and hygienic measurements are important to prevent infectious diseases.[5, 11, 12]

Both rabbits and guinea pigs were housed inside as well as outside. Rabbits were housed outside more often (44,6%) compared to guinea pigs (20,0%). There was no difference in occurrence of infectious diseases compared to the housing location. Probably due to little contact with wild rabbits and rodents.[11]

Comparing rabbits and guinea pigs

Rabbits and guinea pigs are not only different species, they are of a completely different order (*Lagomorpha* vs. *Rodentia*) and therefore have no fundamental resemblance.[11] Although pneumonia and dental diseases are common in both species and risk factors are probably similar, other common diseases and behavior show many differences.

Recommendations

This chapter summarizes recommendations for housing, nutrition and health care for both rabbits and guinea pigs according to the literature.

Rabbits

Zootechnical issue	Recommendation
Number of animals in group	**Social housing** Recommended: - Pairs: preferably of opposite gender. - Small groups: preferably a male with several females. Consider neutering in these cases. Not recommended: - 2 or more males together with or without females. - With a guinea pig or other species.
Living space and exercise	- Size: as big as possible. Minimal 1-3m^2, large and group-housed rabbits more. - Height: minimal of 40-60 cm. - Exercise outside cage (inside and outside) at least 4 hours a day. But escape-proof, protection against sun, predation, wires, toxic plants and materials.
Enrichment	- Shelter and look-out: box or raised shelve. - Wooden sticks or branches to chew on.
Housing location	Inside or outside, but protection against: - Predation. - Direct sunlight. - Wind and draughts. - Rain.
Temperature	- Optimal 15-22°C. - Lower temperatures can be tolerated, but not higher. - No / minimal temperature fluctuations.
Ventilation	- Well-ventilated area.
Bedding	Recommended: - Absorbent compressed or shredded paper. - Newspaper covered with hay. - Wood chips or –shavings. - Garden peat. - Corn cob. Not recommended: - Saw dust. - Clay.
Cleaning frequency	- Remove droppings and urine daily. - Clean cage fully at least once a week.
Nutrition	- Pellets (no mixed diet!): 2-3% of rabbits bodyweight per day. - Hay and/or grass: ad libitum. - Fresh vegetables: on a daily basis, gradual introduction. - Fruit and treats: none to minimal amounts, <daily.
Water	- Continuous fresh water, refresh daily.
Healthcare	- Vaccination: against myxomatosis and RHD. - Castration of does: to prevent uterine adenocarcinoma. - Quarantine new rabbits. - Monitor body weight weekly. - Monitor length of nails frequently: clip or let it get clipped (for example by a veterinarian) when necessary or unsure. - Monitor behavior and appetite. daily

Guinea pig

Zootechnical issue	Recommendation
Number of animals in group	**Social housing** Recommended: - Pairs: preferably of opposite gender. - Small mixed groups: a male with several females. Consider neutering in these cases. - Large mixed groups: several males with females. No introduction of solitary or pair-housed guinea pigs. Consider neutering in these cases. Not recommended: - Females pairs and groups (but can be possible). - Male pairs and groups. - With a rabbit or other species.
Living space and exercise	- Size: as big as possible, minimal 2500cm^2 per adult. - Minimal height: 30 cm. - Rectangular cage to prevent circling. - Exercise outside cage (inside and outside) is recommended. But escape-proof pen and protection against sun, predation, wires, toxic plants and materials.
Enrichment	- Shelter / hiding areas: Commercial houses, whole or half pipes, nesting boxes or hay. - Wooden sticks or branches for gnawing.
Housing location	Inside or outside, but protection against: - Predation. - Direct sunlight. - Wind and draughts. - Rain. - Loud sounds: startle very easily.
Temperature	- Optimal 20-22°C, but tolerate 16-26°C. - Lower can be tolerated, but not higher. - No / minimal temperature fluctuations.
Ventilation	- Well-ventilated area.
Bedding	Recommended: - Wood shavings. - Shredded paper. Not recommended: - Sawdust. - Straw and hay.
Cleaning frequency	- Clean cage fully at least once a week, preferably twice a week - Clean patches of scale with weak acid solution
Nutrition	- Pellets (no mixed diet!): 2-3% of the guinea pigs bodyweight per day - Hay and/or grass: ad libitum - Fresh vegetables: on a daily basis, gradual introduction - Fruit and treats: none to minimal amounts, <daily - Vitamin C: suppletion with tablet
Water	- Continuous fresh water, refresh daily
Healthcare	- Castration of sows: to prevent ovarian cysts. - Quarantine new guinea pigs. - Monitor body weight weekly. - Monitor length of nails frequently: clip or let it get clipped (for example by a veterinarian) when necessary or unsure. - Monitor behavior and appetite daily.

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Appendices

Appendix I. Questionnaire welfare project rabbit, guinea pig, rat and ferret (translated)

VPDC, Postbus 80158, 3508TD UTRECHT **Tel. 030- 253 3195** Fax: 030-2534774

Practice: …….. Relation number: ……...
Veterinarian: …… Email: ……
Phone number: ……

Owner: ……... Species: ……..
Street: …… Name animal: ……...
Zip code: …… Date of birth: ……..
City …… Gender: M / ex-M / F / ex-F
Tel. Nr.: ……..
Code owner: ……

Cremation ☐ No ☐ Yes, to ……
☐ **Euthanasia/** ☐ **Died naturally** ☐ Date:……..

Onset of illness: .....
Number of animals in group: .....
Number of diseased animals: .....
Treatment: ……....
Duration of treatment: ……....

Clinical signs ☐ Diarrhea ☐ Respiratory problems ☐ Skin problems
☐ Lameness ☐ Depressed growth ☐ Sudden death
☐ Anorexia ☐ Depressed water consumption

Husbandry:
Location: ☐ Inside ☐ Outside
Measurements: L: ..... W: ..... H: .....
Materials: ☐ Wood ☐ Metal ☐ Plastic/Fibreglass
☐ Glass ☐ Other.....
Bedding: .....
Extra ventilation: ☐ No ☐ Yes
Frequency of cleaning: .....
Detergent type: .....

Nutrition
Feeding frequency: ……..
Types of food:
0 Pellets or mix: Brand ..... Amount: .....
0 Hay Brand ..... Amount: .....
0 Vegetables Type ..... Amount: .....
0 Fruit Type ..... Amount: .....
0 Snacks Brand ..... Amount: .....
0 Other Description: ……..
Actual intake .....
Supplements (incl. vitamin C): ☐ No ☐ Yes
Water supply: ☐ Tap water ☐ Bottled water ☐ Rain water ☐ Other
Water Type: ☐ Bowl ☐ Drinking nipple
Frequency of water changes: .....
Anamnesis:
.....
.....
Diagnosis:
.....
.....

Appendix II: Standard necropsy protocol of the VPDC (translated)

Pathology number: Species:
Cassette 1:
Cassette 2:
Cassette 3:
Cassette 4:
Cassette 5:
Frozen:

CYTOLOGY
HC liver:
HC spleen:
HC lung:
HC intestine:
Native preparate intestine:

MACROSCOPY
Date of necropsy: Pathologist./sio: Student:
Chip / brand:
Coat / skin:
Weight:
Age:

Head and neck:
Nose:
Ears / eyes
Oral cavity / dentition:
Tongue:
Brains:
(para)Thyroid:
Pharynx:

Thorax / respiration / circulation
Organ location / effusion:
Trachea:
Pleurae / diaphragm:
Lungs:
Heart en vessels:

Abdomen/ other internal organs
Organ location / effusion:
Esophagus:
Stomach:
Duodenum/ pancreas:
Jejunum / ileum:
Colon and Caecum:
Liver:
Spleen:
Lymph nodes:
Kidneys:
Adrenal glands:
Bladder:
Reproductive system:

Skeletal bones / extremities
Mineralization:
Joints:
Soles:
Temporary conclusion after macroscopic examination:

Appendix III. Necropsy protocol Welfare project (translated)

Welfare project small mammals - Rabbit, guinea pig, rat and ferret		
Macroscopic examination	**Microscopy: put in cassettes**	**Freeze**
Identification chip / tattoo		
Body weight		
Skin, nails	Skin left flank	
Bone (right femur)	Right femoral head, decalcify	
Skeletal muscles	Dorsal back muscles, left	
Eyes	OS and OD (both eyes)	
External ears		
Conchae, larynx	Conchae	
Mouth, teeth		
Pharynx, esophagus	Esophagus	
(para) Thyroid	(para) Thyroid	
Trachea	Trachea	
Lungs	Lung	Lung
Heart and large vessels	Full circle at1/3 height	Heart
		Fat
Intestinal tract	Stomach, duodenum, jejunum, caecum, colon	Colon
Pancreas	Pancreas	Pancreas
Liver and gall bladder	Liver and gall bladder	Liver
Kidney and urinary tract	Kidney, bladder	Kidney
Spleen, lymph nodes	Spleen, Lnn. Mesenterialis	Spleen
Bone marrow (right femur)	Bone marrow right femur, distal and mid-diaphysis	
Adrenal gland	Adrenal gland	Adrenal gland
Brain	Brain	Brain
Pituitary gland	Pituitary gland	
Reproduction organs	Ovaries, uterus Testicles	
Other pathologically changed areas	Other pathologically changed areas	