RABBIT PRODUCTION

Edited and written by

Károly BODNÁR, Ph.D.

2015

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Hódmezővásárhely

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FOREWORD

Domestic rabbits are produced virtually in most of the countries of the world for a number of different purposes. The aim of this textbook or compendium was to give an overview about the domestic rabbit, and its breeding, nutrition, housing, production and health. The material was based on the results of Hungarian and foreign scientists. The textbook is designed and presented as a general volume on domestic rabbits. It is not intended only as a biology book or as one concerned primarily with practical production; elements of both subjects are included.
Complete detail of every subject which may be of interest to each reader could not be included, but the editor/author hopes that useful information is presented for those with diverse interests in rabbits.

Károly Bodnár

1. DOMESTICATION OF THE RABBIT

1.1. The ancestor of the domestic rabbit

The European rabbit is the ancestor of all domestic rabbits.

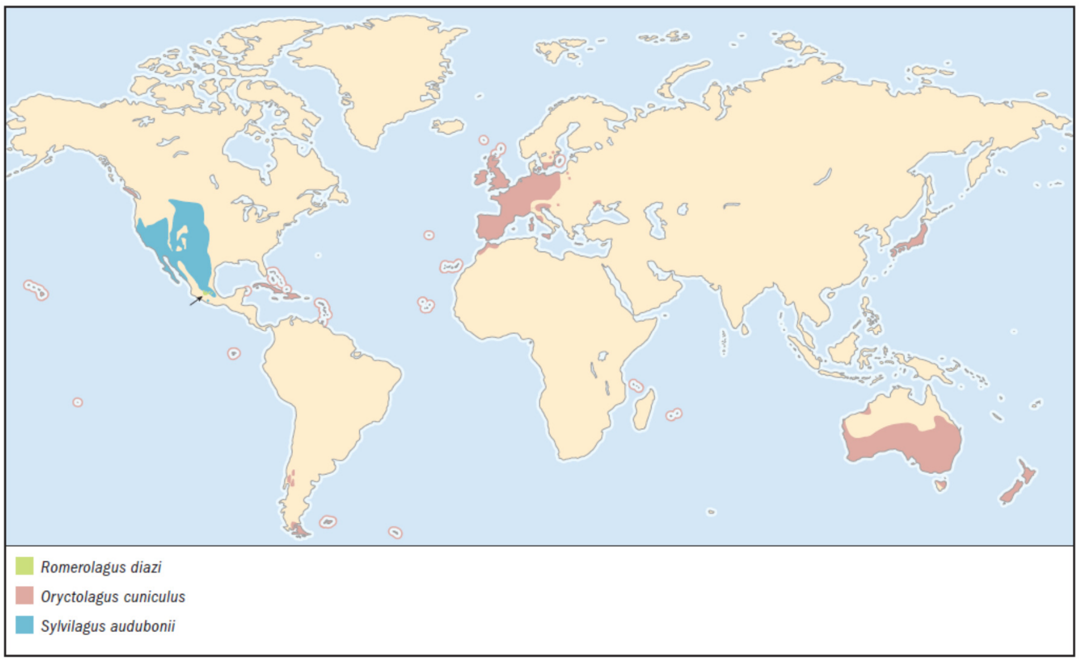
1.1.1. The European rabbit (*Oryctolagus cuniculus*)

Main characteristics:
The European rabbit (Photo 1) is a smallish mammal, although it ranks as medium-sized by *Lagomorph* standards. European rabbits have a body length between 34 and 50 cm, a tail length between 4 and 8 cm and they weigh between 1 and 2.5 kg. They are grey brown in colour (or sometimes black) with a pale coloured underside. As a Lagomorph, it has four sharp incisors (two on top, two on bottom) that grow continuously throughout its life, and two peg teeth on the top behind the incisors, dissimilar to those of rodents (which have only two each, top and bottom). Rabbits have long ears, large hind legs, and short, fluffy tails. Rabbits move by hopping, using their long and powerful hind legs. To facilitate quick movement, a rabbit's hind feet have a thick padding of fur to dampen the shock of rapid hopping. Their toes are long, and are webbed to keep from spreading apart as the animal jumps.

Source: openwalls.com

Photo 1: The European rabbit

Habitat:
The European rabbit or common rabbit (*Oryctolagus cuniculus*) is a species of rabbit native to South-western Europe (Spain and Portugal) and northwest Africa (Morocco and Algeria) (Figure 1). They inhabit headland, grassland, woodland, open meadows and the edges of agricultural land. It has been widely introduced elsewhere, often with devastating effects on local biodiversity. However, its decline in its native range (caused by the diseases myxomatosis and rabbit calicivirus, as well as overhunting and habitat loss), has caused the decline of its highly dependent predators, the Iberian lynx and the Spanish Imperial eagle. It is known as an invasive species because it has been introduced to countries on all continents with the exception of Antarctica and sub-Saharan Africa, and caused many problems within the environment and ecosystems. Australia has the most problems with European rabbits, due to the lack of natural predators there. Predators of the European rabbit include cats, dogs, mustelids, birds of prey and owls.



Source: Grzimek's, 2003

Figure 1: Distribution of European rabbit

Diet:
European rabbits feed on a wide range of vegetation including agricultural crops, cereals, cabbages and young trees (Photo 2). During the winter months they eat grasses, bulbs and bark (Photo 3-4).

Breeding:
European rabbits breed throughout the year and they will produce several litters annually with most being born between February and August. After a gestation period of 28-33 days, they will give birth to 3-12 young. The youngsters are weaned after 28 days and they reach sexual maturity at 4 months old.

Source: Bodnár Károly

Photo 2: Protection of hedge installation against European rabbits (Edgemont, UK)

Source: Bodnár Károly

Photo 3-4: Damage caused by European rabbit in orchard (Geel, Belgium)

Rabbits are social animals, living in medium-sized colonies known as warrens. They are largely crepuscular, being most active around dawn and dusk, although they are infrequently

seen active during the day. During the day, rabbits prefer to reside in vegetated patches, which they use for protection from predators. At night, they move into open prairie to feed. Rabbit populations seem to be greatest in ecotone habitats and less in scrublands or grasslands. Rabbits require at least 55% water content in their diet to reproduce successfully and to maintain a healthy condition. Rabbits are essentially mixed-feeders, both grazing and browsing, but their primary food source is grass. They nevertheless have a diverse diet of grasses, leaves, buds, tree bark, and roots. They will also eat lettuce, cabbage, root vegetables, and grains. Birds of prey are the primary predators of rabbits in scrublands. Rabbits in grasslands are preyed on by carnivores. Ecotone rabbits are preyed on by both. Unlike the related hares (*Lepus spp.*), rabbits are altricial, the young being born blind and furless, in a fur-lined nest in the warren, and they are totally dependent upon their mother. Much of the modern research into wild rabbit behaviour was carried out in the 1960s by two research centres.
Since the onset of myxomatosis, and the decline of the significance of the rabbit as an agricultural pest, few large-scale studies have been performed and many aspects of rabbit behaviour are still poorly understood.

1.1.2. Taxonomic classification

Rabbits belong to the order of mammals called *Lagomorpha*, which includes 40 or so species of rabbits, hares and Pikas. Fossil records suggest that *Lagomorpha* evolved in Asia at least 40 million years ago, during the Eocene period. The break-up of continents during this period may be responsible for the wide distribution of differing species of rabbits and hares around the world, with the exception of Australia. There are currently more than 60 recognised breeds of domestic rabbit in Europe and America, all of them descended from the European rabbit (*Oryctolagus cuniculus*), the only species of rabbit to have been widely domesticated. It is a separate species from other native rabbits such as the North American jackrabbits and cottontail rabbits and all species of hares.

Classification

Domain: *Eukarya*
Organisms in this domain are all eukaryotic, which means they are multicellular, and contain mitochondria along with other membrane bound organelles inside their cells. They also have no cell walls.

Kingdom: *Animalia*
Those who belong to the kingdom Animalia are classified by having the characteristics of being multicellular and heterotrophic.

Phylum: *Chordata*
The European Rabbit belongs to the phylum Chordata, which is in the kingdom Animalia. This phylum is home to both vertebrates as well as invertebrates. Chordates all share characteristics that sets them apart from the rest of the organisms in their kingdom. At some stage in their life, all chordates have a notochord, a dorsal nerve chord, an endostyle (precursor to the thyroid gland), pharyngeal slits, bilateral symmetry, segmented bodies, and a post-anal tail.

Class: *Mammalia*
Members of this class are vertebrates that have fur, females produce milk to feed her young, the middle ear contains three bones, and have a diaphragm.

Order: *Lagomorpha*
Rabbits, hares, and pikas all make up the order lagomorpha. These three groups of animals have four incisors in the upper jaw, and are almost wholly herbivores. Their eyes are set high on the head, giving them a wide field of vision, and have weak but flexible necks.

Family: *Leporidae*
This family contains both rabbits as well as hares. These animals have thick, soft fur, large ears, and limbs adapted for running. Hares generally have longer black-tipped ears, and are larger than rabbits. They are born with their eyes open, have fur, and can run within a few minutes of birth. Rabbits on the other hand are born not to be able to see, and are kept in a fur lined next their first days of life because they are hairless.

Genus: *Oryctolagus*
All European rabbits are classified under this genus.

Species: *Oryctolagus cuniculus*
The European rabbit is the ancestor of all domestic breeds of rabbits. It was eventually given a scientific name in Latin, *Oryctolagus cuniculus. Cuniculus* means underground tunnel/burrow/hole; rabbit. If you put them together you come up with the burrowing rabbit.
This species of rabbits range from about 1.5 to 2.5 kilograms, and can be 38 to 50cm in length, but domestic breeds can be bigger or smaller.

Subspecies of the European rabbit are:

Oryctolagus cuniculus algirus
Oryctolagus cuniculus brachyotus
Oryctolagus cuniculus cnossius
Oryctolagus cuniculus cuniculus
Oryctolagus cuniculus habetensis
Oryctolagus cuniculus huxleyi

1.2. The history of the rabbit husbandry

The exact origin of the European Rabbit, also known as the Old World Rabbit, is unclear, but scientific evidence makes it appear that after the end of the last glacial period, the rabbits were only found on the Iberian Peninsula. Because of their quick breeding habits, they quickly spread west to some Mediterranean countries as well as other parts or Europe.

Rabbits have long been associated with spring and Easter as a symbol of fertility and new birth. In the ancient world, pre-Christian religions would celebrate the spring equinox with live rabbits, as this is the time of year when many wild animals give birth to their young. While the rabbit as an actual representation of deity did not exist on the European continent, in ancient Egypt (Photo 5) there was one such deity by the name of Unut.

Unut was a rabbit headed goddess whose origin dates back to prehistoric Egypt. Also known as Wenut, this deity has an interesting path of evolution, for she was not always known as a rabbit-shaped deity. Prior to her rabbit form which came about at an unknown point during her worship, she was represented in the form of a snake. This seems rather unusual for a reptile to be transformed into a soft, gentle, furry creature, even though snakes too were considered symbols of fertility in ancient Egypt.

Source: Bodnár Károly

Photo 5: Servants with rabbits on Egyptian wall painting
(XVIII. Dynasty, British Museum, London)

The Ancient Greek historian Polybius, was the first to refer to the European Rabbit while writing Corsica. He noted that there were burrowing animals on the island, which resembled small hares. He called these animals *kunikloi*. It is thought however that rabbits entered human history probably when the Phoenicians landed on the shores of Spain.

The European wild rabbit evolved around 4,000 years ago on the Iberian Peninsula, the name 'Hispania' (Spain) is translated from the name given to that area by Phoenician merchants, meaning 'land of the rabbits'. When the Romans arrived in Spain around 200BC, they began to farm the native rabbits for their meat and fur. The Romans called this practice 'cuniculture' and kept the rabbits in fenced enclosures. Inevitably, the rabbits tried to escape and it is perhaps no surprise that the scientific (Latin) name *'Oryctolagus cuniculus'* means 'hare-like digger of underground tunnels'. The spread of the Roman Empire, along with increasing trade between countries, helped to introduce the European rabbit into many more parts of Europe and Asia. With their rapid reproduction rate, and the increasing cultivation of land providing ideal habitat, rabbits soon established large populations in the wild.
Remains of Roman rabbit uncovered in Britain in 2002. The remains of a 2,000-year-old rabbit - found at an early Roman settlement at Lynford, Norfolk - may be the earliest example of rabbit remains in Britain. The bones are similar to those of a small Spanish rabbit, common in Roman times. It is thought rabbits were introduced to Britain following the Roman invasion in AD43. The bones themselves had been butchered, possibly the rabbit was to be eaten by a Roman, and then buried on the site.

Domestication of the European rabbit rose slowly from a combination of game-keeping and animal husbandry. Among the numerous foodstuffs imported by sea to Rome during her domination of the Mediterranean were shipments of rabbits from Spain. Romans also imported ferrets for rabbit hunting, and the Romans then distributed rabbits and the habit of rabbit keeping to the rest of Italy, to France, and then across the Roman Empire, including the British Isles. Rabbits were kept in both walled areas as well as more extensively in game-preserves. In the British Isles, these preserves were known as warrens or garths, and rabbits were known as coneys, to differentiate them from the similar hares (a separate species). The term warren was also used as a name for the location where hares, partridges and pheasants were kept, under the watch of a game keeper called a warrener. In order to confine and protect the rabbits, a wall or thick hedge might be constructed around the warren, or a warren might be established on an island. The Margaret Island in the middle of the Danube in central Budapest (capitol of Hungary) before the 14^{th} century was called *Insula leporum* (Island of Rabbits).

A warrener was responsible for controlling poachers and other predators and would collect the rabbits with snares, nets, hounds (such as greyhounds), or by hunting with ferrets (Photo 6-7). With the rise of falconry, hawks and falcons were also used to collect rabbits and hares.

Source: www.museum-replicas.com

Source: holisticferret.proboards.com

Photo 6-7: Hunting with ferrets (medieval tapestry and nowadays)

While under the warren system, rabbits were managed and harvested, they were not domesticated. The practice of rabbit domestication also came from Rome. Christian monasteries throughout Europe and the Middle East kept rabbits since at least the 5th century. (Pope Gregory stated in a Papal Edict of the year 600 C.E. that foetal rabbits were permissible to eat during the Lenten fast, greatly enhancing their popularity, and it is from this date that the true domestication of rabbits is counted.) While rabbits might be allowed to wander freely within the monastery walls, a more common method was the employment of rabbit courts or rabbit pits. A rabbit court was a walled area lined with brick and cement, while a pit was much the same, only less well-lined, and more sunken. Individual boxes or burrow-spaces could line the wall. Rabbits would be kept in a group in these pits or courts, and individuals collected when desired for eating or pelts. From these pits, which did not allow for easy cleaning, ready handling of rabbits, or for selective breeding, rabbit keepers transitioned to individual hutches or pens, which were originally made of wood but are now more frequently made of metal in order to allow for better sanitation.

1.2.1. Early breeds

Wild rabbits are said to have been first domesticated in the 5th Century by the monks of the Champagne Region in France. Monks were almost certainly the first to keep rabbits in cages as a readily available food source, and the first to experiment with selective breeding for traits such as weight or fur colour. Rabbits were introduced to Britain during the 12th Century, and during the Meddle Ages, the breeding and farming of rabbits for meat and fur became widespread throughout Europe. Sources suggest that some women among the Medieval gentry even kept rabbits as pets. The selective breeding of European rabbits meant that distinct breeds arose in different regions, and the origins of many old breeds can be traced back several centuries. For example; paintings from the 15th century show rabbits in a variety of colours, some even with white 'Dutch' markings; 16th century writings suggest that the Flemish Giant was already being pure-bred under the name Ghent Giant, in the Flemish speaking Ghent area of Belgium; 17th century sources tell of the arrival of 'silver' rabbits in England and France, brought from India and China by seafarers and influential in the Silver and Champagne de Argente breeds; 18th century sources suggest a breed known as Lapin de Nicard once existed in France and weighed as little as 1.5 kg, some consider this to be the forerunner of all dwarf breeds; the English Lop can also be traced back to 18th century records, and is considered the ancestor of all the lop breeds. By the middle of the 19th century, the widespread practice of selectively breeding domestic rabbits had resulted in a large variety of breeds, ranging from the tiny Polish rabbit to the huge Flemish Giant.

Up until the 19th century, domestic rabbits had been bred purely for their meat and fur, but during the Victorian era, many new 'fancy' breeds were developed for the hobby of breeding rabbits for showing. Industrialisation also meant that many people moved from the country to the expanding towns and cities, brought rabbits with them; apart from poultry, they were the only 'farm' animals to be practical to keep in town. Although many of these rabbits were bred for meat, it became increasingly common among the rising middle classes to keep rabbits as pets. Rabbits were connected with the countryside and the animals they had left behind, and became considered almost sentimentally. Rabbit wares were promoted in connection with children, and the romantic attitude towards rabbits persists today in the association of 'bunnies' with newborn babies, and the idea of rabbits as a children's pet. By the 20th century, rabbit breeding had become a popular hobby across Europe, with many rabbit fanciers developing new varieties and colours. Some breeds, such as the Himalayan and Rex, came about as the result of naturally-occuring genetic mutations which were then fixed or enhanced through a selective breeding programme. Others were developed through cross-breeding, particularly with rabbits imported from other countries as a result of increasing travel in Europe. Many breed societies and clubs were established, with some breeds undergoing dramatic swings in popularity, often due to changing fashions for fur and commercial uses. Although the European rabbit arrived in America with European settlers, and established a large wild population, rabbits were mostly hunted in the wild until the late 19th century. Domestic rabbitry did not become popular in the United States until around the turn of the century, when many European breeds began to be imported, and breeders also developed some American breeds.

During the two World Wars, governments in both Britain and the United States encouraged people to keep rabbits as a source of home-produced meat and fur, both for themselves and to help feed and clothe soldiers. After the wars, many people continued to keep rabbits in their gardens, and they become commonplace as household pets. Rabbits have become the third most popular pet after cats and dogs in the UK, unlike cats and dogs however they are traditionally seen as 'childrens pets', and often sadly misunderstood. During the last 30 years or so, attitudes towards rabbits as pets have been undergoing a gradual shift. The promotion of rabbit welfare is fostering a greater understanding of rabbits; from their basic needs to their intelligence, personality and behaviour. Rabbits are increasingly seen in the same way as cats and dogs, as a rewarding companion or family pet, and provided with the same level of care and attention, from routine vaccinations and healthcare, to greater freedom and interaction with their owners.

Rabbits were typically kept as part of the household livestock by peasants and villagers throughout Europe. Husbandry of the rabbits, including collecting weeds and grasses for fodder, typically fell to the children of the household or farmstead. These rabbits were largely 'common' or 'meat' rabbits and not of a particular breed, although regional strains and types did arise. Some of these strains remain as regional breeds, such as the Gothland of Sweden, while others, such as the Land Kaninchen, a spotted rabbit of German, have become extinct. Another rabbit type that standardized into a breed was the Brabancon, a meat rabbit of the region of Limbourg and what is now in Belgium. Rabbits of this breed were bred for the Ostend port market, destined for London markets. The development of the refrigerated cargo ships led to the eventual collapse of the European meat rabbit trade, as the over-population of feral rabbits in Australia could now be harvested and sold. The Brabancon is now considered extinct, although a descendant, the Dutch breed, remains a popular small rabbit for the pet trade.

In addition to being harvested for meat, properly prepared rabbit pelts were also an economic factor. Both wild rabbits and domestic rabbit pelts were valued, and it followed that pelts of particular rabbits would be more highly prized. As far back as 1631, price differentials were noted between ordinary rabbit pelts and the pelts of quality 'riche' rabbit in the Champagne region of France. (This regional type would go on to be recognized as the Champagne D'Argent, the silver rabbit of Champagne.)

Among the earliest of the commercial breeds was the Angora, which some say may have developed in the Carpathian Mountains. They made their way to England, where during the rule of King Henry VIII, laws banned the exportation of long-haired rabbits as a national treasure. In 1723, long haired rabbits were imported to southern France by English sailors, who described the animals as originally coming from the Angora region of Turkey. Thus two distinct strains arose, one in France and one in England.
Commercial rabbit breeders specializing on production of meat and fur primarily breed New Zealand Whites and Californians. Today there are more than 60 recognized breeds of domesticated rabbits that vary tremendously in size, fur type, coloration, and general appearance.

European explorers and sailors took rabbits with them to new ports across the world, and brought new varieties back to Europe and England with them. With the second voyage of Christopher Columbus in 1494, European domestic livestock were brought to the New World. Rabbits, along with goats and other hardy livestock, were frequently released on islands to produce a food supply for later ships. The importations occasionally met with disastrous results. While cattle and horses were used across the socio-economic spectrum, and especially were concentrated among the wealthy, rabbits were kept by lower-income classes and peasants. This is reflected in the names given to the breeds that eventually arose in the colonized areas. From the Santa Duromo Mountains of Brazil comes the Rustico, which is known in the United States as the Brazilian rabbit.
Rabbits are native to Europe, but because of human actions and adaptability today they exist in the wild on every continent except Asia and Antarctica.

1.3. Dedomestication (Feral rabbits)

The European rabbit has been introduced as an exotic animal species into several environments, often with harmful results to vegetation and local wildlife. Such locations include Britain, where they were first introduced by the Romans following their invasion of the British Isles in AD 43; (in November 2004 there were about 40 million European rabbits in the British Isles).
Twenty-four European rabbits were introduced to Australia in 1859 by estate owner Thomas Austin in Victoria. They soon spread throughout the country due to the lack of natural predators, widespread farming producing an ideal habitat, and mild Australian winters allowing them to breed year-round. Australia's equivalent to the rabbit, the bilby (Bilbies are desert-dwelling marsupial omnivores; they are members of the order *Peramelemorphia*. Before the European colonisation of Australia, there were two species. The lesser bilby became extinct in the 1950s; the greater bilby survives but remains endangered.), was quickly pushed out by the rabbits. The bilbies are endangered, but are now making a comeback due to government protection. Between 1901 and 1907, Australia built an immense "rabbit-proof fence" to halt the westward expansion of the introduced rabbit population (Photo 8). The European rabbit can not only jump very high, but also burrow underground, making fencing essentially futile. During the 1950s, experiments with introduction of a virus *Myxomatosis cuniculi* provided some relief in Australia, but not in New Zealand, where the insect vectors necessary for spread of the disease were not present. Myxomatosis can also infect pet rabbits of the same species. Today's remaining wild rabbits in Australia are largely immune to myxomatosis. The rabbit haemorrhagic disease virus, which causes rabbit haemorrhagic disease, has been cleared as a safe form of biological control agent against the European rabbit in Australia.

Source: Bodnár Károly

Photo 8: Electric fence against rabbits (Buckfastleigh, UK)

1.4. Terminology

Rabbits are known by many names. Young rabbits are known by the names 'bunny', 'kit', or 'kitten'. A male rabbit is called a 'buck', and a female rabbit is called a 'doe'. A group of rabbits is known as a 'colony' or a 'nest' or a ‘litter’. Colloquially, a rabbit may be referred to as a "coney" or a "bunny", though the former is archaic. They are sometimes referred to comically as "underground mutton".

2. PRODUCTION GOALS OF THE DOMESTIC RABBIT

The rabbit industry is composed of many groups each with differing production goals (Figure 2). Rabbit production can be commercial, for profit, with the rabbits being used for meat and wool, as pets and for laboratory purposes. Rabbit production can also be a hobby and the rabbits are raised for the show circuit, home consumption, pet sales or as 4H animals.

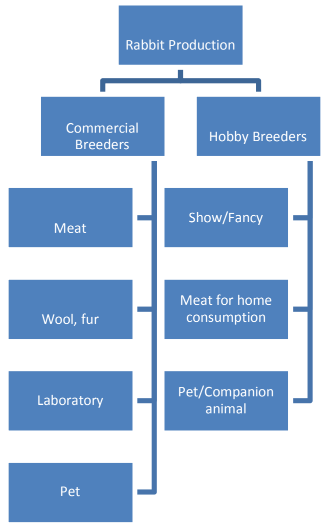


Figure 2: Structure of rabbit production

2.1 Meat rabbits

Meat rabbits have been bred over years with meat production in mind. Their bodies are described as being "commercial" in type, that is, muscular or well-muscled (full of meat).
These breeds are presented as "best choices" if you're interested in raising rabbits for their meat. They are big rabbits with meaty bodies. But after these distinctions, every breed has something different to offer, most notably colours. There are still a few breeds not listed here that you might legitimately consider for raising rabbits for meat. These would be breeds you could say are fairly large, maybe 3.5-5 kg, or so. Consider one of these 'fairly large' breeds if you are particularly intrigued by something about the breed. Recognize that you will probably harvest the rabbits at, say, 2.5 kg instead of 2.7 kg.

2.2. Wool and hair production

Angora hair or Angora fibre refers to the downy coat produced by the Angora rabbit. Angora is known for its softness, thin fibres, and what knitters refer to as a halo (fluffiness). It is also known for its silky texture. It is much warmer and lighter than wool due to the hollow core of the angora fibre. It also gives them their characteristic floating feel.
Angora rabbits produce coats in a variety of colours, from white through tan, gray, and brown to black. Good quality Angora fibre is around 12-16 micrometres in diameter. It felts very easily, even on the animal itself if it is not groomed frequently.

Yarns of 100% angora are typically used as accents. They have the most halo and warmth, but can felt very easily through abrasion and humidity and can be excessively warm in a finished garment. The fibre is normally blended with wool to give the yarn elasticity, as Angora fibre is not naturally elastic. The blend decreases the softness and halo as well as the price of the finished object. Commercial knitting yarns typically use 30–50% angora, in order to produce some halo, warmth, and softness without the side effects of excessive felting.

90% of Angora fur is produced in China, although Europe, Chile and the United States also produce small quantities. In China, there are more than 50 million Angora rabbits, growing 2,500–3,000 tonnes per year. Harvesting occurs up to three times a year (about every 4 months) and is collected by plucking or shearing of the moulting fur.

Most breeds of Angora rabbits moult with their natural growth cycle about every four months. Many producers of the fibre pluck the fur of these breeds. Plucking is, in effect, pulling out the moulted fur. Plucking ensures a minimum of guard hair, and the fur is not as matted when plucked as when it is collected from the rabbit's cage. However, plucking a rabbit is time consuming and can harm the animal, so some producers shear the rabbit instead. While these results in slightly lower quality fleece, as the guard hairs are included, it does take less time and results in more fleeces. Also, not all breeds of Angora moult, and if the rabbit does not naturally moult, it cannot be plucked. German Angoras do not moult.

The premium first quality wool is taken from the back and upper sides of the rabbit. This is usually the longest and cleanest fibre on the rabbit. There should not be hay or vegetable matter in the fibre. Second quality is from the neck and lower sides, and may have some vegetable matter. Third quality is the buttocks and legs and any other areas that easily felt and are of shorter length. Fourth quality is totally unsalvageable, and consists of the larger felted bits or stained fibre. Third and fourth qualities are perfect for cutting up for birds to use in lining their nests. With daily brushing, felting of the fibre can be avoided, increasing the usable portion of fibre.

Angora wool (Photo 9) is commonly used in apparel such as sweaters and suitings, knitting yarn, and felting.

Source: heartshavenfarmkaci.blogspot.com

Photo 9: Angora wool

Hats made from rabbit felt are quite popular (Photo 10-11). In the early part of the 20th century, felt hats were worn by many men all over the world.

Source: www.whoknowsfashion.com Source: www.germansteins.com

Photo 10-11: Felt hats

2.3. Fur (pelt) production

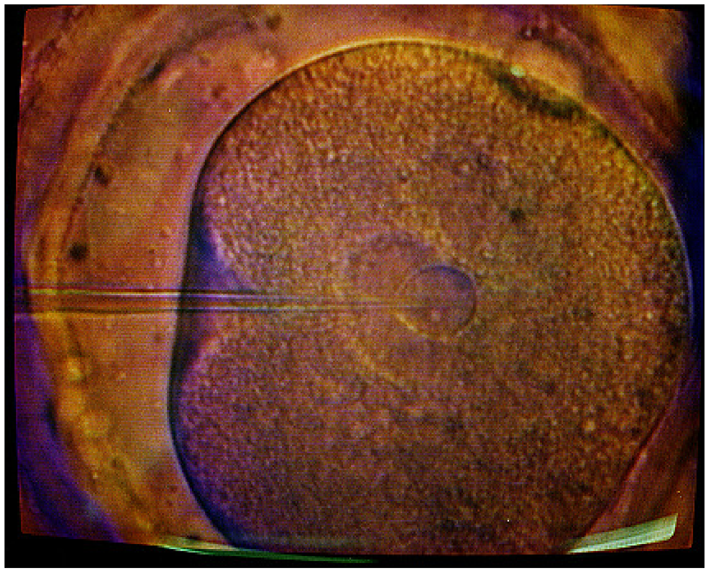
All rabbit breeds produce fur (pelt). Rabbits such as the Rex rabbits, Chinchilla rabbit or Black tan are commonly raised for fur. Each breed has unique colouring and fur characteristics. The rabbit is fed a diet especially balanced for fur production (rich in sulphur) and the pelts are harvested when they have reached prime condition. Rabbit fur is widely used throughout the world in fashion articles (Photo 12-13). China imports much of its fur from Europe and North America (USDA).

Source: www.made-in-china.com Source: www.ushanka.com

Photo 12-13: Fashion articles from fur

2.4. Laboratory rabbit

The rabbit is a test species commonly used in *in vivo* hazard identification tests to determine the developmental toxicity potential of pharmaceuticals, pesticides, and many other chemicals. Rabbit serves as a model organism in developmental biology (Photo 14), surgery, and in studies of many congenital, acquired (cancer and others), and infectious diseases (syphilis).



Source: Bodnár Károly

Photo 14: Gene transfer to rabbit zygote (Kuopio, Finland)

Whilst the quality and quantity of laboratory bred rabbits have improved over the past 40 years or so, their psychological well-being has largely been neglected. Advances have included genetic selection for clearly defined pure-bred strains, such as New Zealand Whites, Dutch and Lops, with traits for docility, reproductive performance and growth as well as a vastly improved health status. Other improvements include a standardized complete diet, and a protected and standardized environment of caging, ventilation, lighting, temperature and humidity. However, such standardized cage designs have evolved mainly for the ease of husbandry and economic considerations, and it is apparent that some of these designs have had undesirable effects on the animals, particularly a reduction in space. Physical and social isolation offers no mental stimulation. Furthermore, the constant feeding of a highly refined pelleted diet is likely to be monotonous. There is evidence that all of these have lead to both physiological and psychological problems. Caged rabbits also show behavioural abnormalities including stereotypes which may be signs of discomfort, mental suffering and distress even though the animals are able to grow and reproduce. There is an ethical mandate to improve the animal's well-being. It is important to minimize suffering not only for welfare reasons, but also because such "suffering" may result in a range of physiological or psychological changes which could add unintentional variables to the experimental design and affect the accuracy and reliability of the scientific results. This in turn may lead to more animals being used in research than is necessary.

2.5. Exhibition

Rabbit shows provide a way to compete with fellow rabbit enthusiasts while gaining valuable rabbit knowledge. Shows can be held at various locations such as fairgrounds or even shopping malls. Some rabbit shows are specific to a competitor’s age range (such as youth and adult shows) or to the rabbit breed(s). Local rabbit shows will tend to be smaller than regional or national competitions.
In the United States the American Rabbit Breeder’s Association (ARBA) is the leading authority on rabbit showing. Though there are several ARBA sanctioned, or approved, shows throughout the United States. There are also several non-sanctioned shows that still follow showmanship regulations, form and procedures such County Fairs. When entering a rabbit show, an exhibitor may be charged an exhibition fee for their animals. Certain shows reward the top competitors and their animals with ribbons, medals, placings and at times even monetary rewards. ARBA has an annual rabbit conference which invites thousands of participants each year.
’Cooped shows’ will last longer than local shows, usually two to 5 days. Rabbits that attend these shows are brought to the shows in carriers and are then placed in coops, or holding cages. These shows allow the rabbits to be observed over a longer period of time offering the judge a better view and the ability to judge the animal in its natural state (Photo 15).

Source: Bodnár Károly

Photo 15: Show of rabbits in cages (Hódmezővásárhely, Hungary)

2.6. Pet

Rabbits can make excellent house pets. They are generally clean and often can be housetrained to use a litter box. They are interesting, docile, interact well with people, and can become quite affectionate. But before acquiring a pet rabbit, there are some things you should consider.
Rabbits can be difficult to handle. Rabbits often resist being picked up, and if not handled correctly, they can become afraid and kick, bite, or scratch. They can also injure themselves trying to escape. This is one of the reasons rabbits may not make ideal pets for small children, who like to hug or cuddle their pet.
Rabbits can be destructive. Rabbits are natural chewers, and they do not know the difference between chewing on appropriate items or inappropriate ones such as electrical cords,

furniture, and books. You will need to "rabbit proof" whatever areas in your house your rabbit is allowed access to. You will need to provide your rabbit with suitable chewing toys and constructive ways to burn off energy.
Unneutered rabbits will usually display territorial marking. Male and female rabbits who are house pets should be neutered. This will decrease the risk of territorial marking and neutered rabbits tend to be easier to litter train. Neutering also decreases aggression and the tendency to chew. Most rabbits are neutered between the ages of 3½ and 6 months. And of course, if neutered, you will not have to worry about them "breeding like rabbits."
House rabbits are not a good "first pet" for children: In addition to being difficult to handle, rabbits may take more time to feel comfortable around people and bond with them. This can require patience, and may be difficult for small children to understand. Although rabbits play, they are less likely to interact with people and toys, unlike dogs and cats that enjoy games of fetch and pouncing on toys manipulated by people. A rabbit will need to be cared for by an adult who can provide the proper diet and sanitation. Rabbits can make excellent and interesting pets for older, quieter children.

Pet shops or pet stores are convenient (Photo 16), may have several different breeds, and also carry many of the supplies you will need. The quality of care, knowledge of the staff, and information on the specific rabbit you would like to purchase can vary considerably from pet shop to pet shop.

Source: Bodnár Károly

Photo 16: Rabbits in pet shop (Plymouth, UK)

3. RABBIT PRODUCTION

Increased awareness of the high potential of meat rabbit production in making a positive impact on the lives of the majority of subsistence, limited-resource rural and periurban populations has contributed to the recent development of numerous national rabbit programmes. While this trend is encouraging, it is imperative that the rabbit project complement the traditional and/or sociological values of the local population and that it be properly introduced with careful planning and design. In many instances a rabbit meat market research and/or feasibility assessment may be warranted. At present, production and survey data are urgently needed from developing countries as well as extension methodologies relevant to rabbit project development. Additionally, applied research must be conducted in developing countries on all aspects of rabbit production breeding and genetics, disease control, economics, housing systems, management, nutrition and reproduction - before sound, general or specific recommendations are made.

In recent years there has been increased awareness of the advantages of rabbit meat production in developing countries (Photo 17-18) as a means to alleviate world food shortages. This is largely attributable to the rabbit's high rate of reproduction; early maturity; rapid growth rate; high genetic selection potential; efficient feed and land space utilization; limited competition with humans for similar foods; and high-quality nutritious meat. According to FAO, by the year 2000 the meat requirements of one-third of the human population will be satisfied by the supply of pork, poultry and rabbit meat.

Rabbits being fed banana leaves in an all wire cage

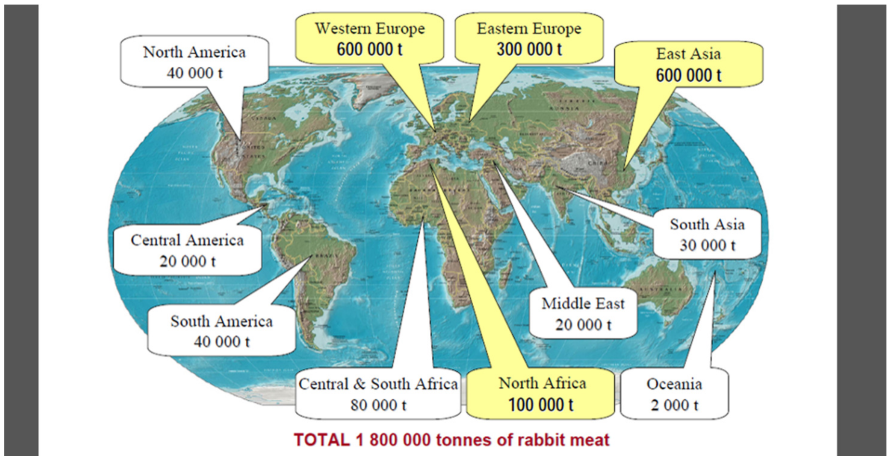
Source: world-rabbit-science.com

Photo 17-18: Rabbit production in developing countries

3.1. World's rabbit meat production

The world's domestic rabbit population, estimated to be 709 million, is comparable to 764 million swine (FAO). Some 82 percent of the world's production of rabbit meat takes place in the developed countries, meaning that approximately only 18 percent of total rabbit meat production occurs in developing states. In developing countries where critical national meat shortages exist, the potential for rabbit production is greatest. A discrepancy is therefore apparent between world distribution of rabbits and those countries needing inexpensively produced rabbit meat.

World's rabbit meat production is continuously increasing; however its rate could be lower or higher (Figure 3). Previously Italy was but now (in the last 10 years) China is the greatest producer (Figure 4). France, Spain and Egypt are also great producers. Hungary is about at the 10th place among countries that produce rabbit meat (Figure 5); although the amount of the production which is only 1% of the world's production does not seem to be important, but it is determinant in the export. Since 97% of the purchased rabbits is exported Hungary is one of the greatest rabbit meat exporter. In consequence of export orientation international markets have a considerable influence on the Hungarian production and price.

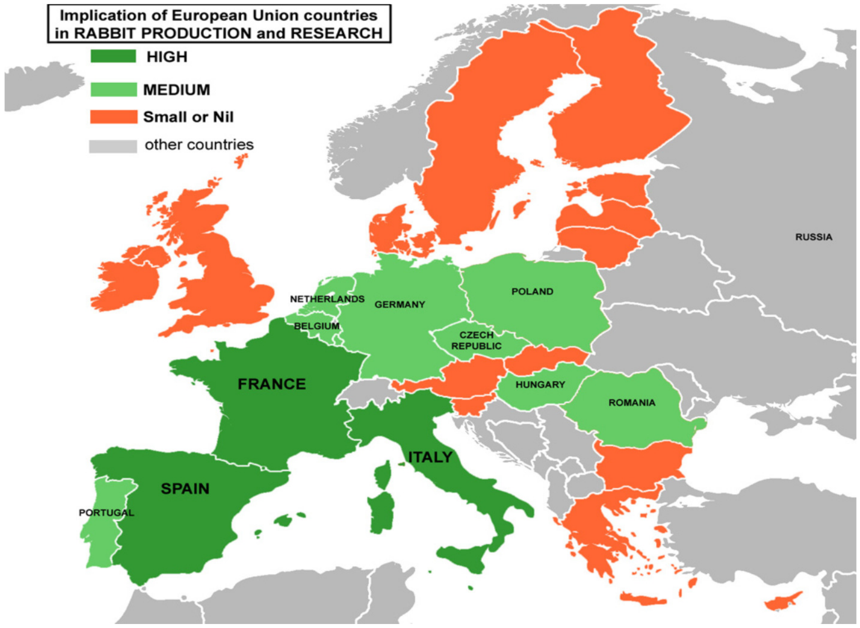


Source: estimation of Lebas, 2009

Figure 3: Rabbit meat production in the great regions of the World

Source: cuniculture.info

Figure 4: Rabbit production in China (Estimated production: 550-600,000 t/year)



Source: cuniculture.info

Figure 5: Status of rabbit production and research in European countries

The highest increase in rabbit meat production can be seen in the production of China. Therefore its role in the world's production and export also increased. Italy is at the second place. Spain fell back to the 5th place in 2005 since its production decreased after 2000. In spite of the continuous decrease in production, Hungary is at the 10th place in the order. In spite of this Hungary has a great importance in export. It is unique that only 3% of slaughtered rabbits is sold in the national market while 97% of it is exported. This is why it is important to know exactly the commerce of the other exporters especially which merchandising in the same markets.

3.2. Hungary's contribution to the rabbit meat market

Previously, 90% of slaughtered rabbits were exported to Italy. The Italian market represents less and less ratio from decreasing export (in 2005 it was 42.2% from 5,331 tons). The reason of this is the decreasing Italian import due to their increasing self-supplying. The Hungarian rabbit meat exported to Switzerland also has an importance (25-30%). Swiss market has become determinant since the built of a Swiss owned slaughterhouse. Export to Germany increases year by year, it is about 20% (in 2005 it was 19.5%). The German purchase lots of rabbits and it seems that Hungarian products are marketable in this market of high standards. Sharing of other countries in Hungarian rabbit meat export is low except Belgium (6.3% in 2005).
Besides being the greatest producer, China is the greatest rabbit meat exporter as well. It is not possible to compete with low prices, but it is probable with quality. On the one hand China exports only frozen meat to Europe, although in many countries chilled meat is preferred. On the other hand, the European consumers' demands on welfare, treatments and traceability are well performed by EU member-states. In 2005 Argentina was the second exporter of rabbit meat in the world. Similar things can be told about Argentina like about China, however, in markets with high quality standards the Hungarian rabbit meat is more preferred.

French rabbit meat export is important as it always was. Spain and Italy have increased their export thus they are also determinants. The Belgian export increases, while the Dutch export is market dependent. With the appearance of BSE the value of rabbit meat rose and the Dutch export started to increase (it was 11.151 tons in 2001), while with the decrease of price the export also decreased. Hungary could compete with other EU states only in price or quality since there are the same EU regulations in all countries.
Countries where Hungary exports rabbit meat are among the greatest importers. Germany is at the first, Italy is at the fourth while Switzerland is at the fifth place. The German import is continuously high while the Swiss and Italian import decrease, which is quite drastic in the latter country. These data prove that it is not possible to improve Hungarian rabbit meat export to Italy and Switzerland.
Three-quarters of the Italian import still come from Hungary. In terms of this position it is very important that one of the Hungarian slaughterhouses is in Italian ownership. Even if this high proportion (75.7% in 2005) remains it is not possible to improve our export since Italy becomes more and more self- supplier to such an extent that Italy is also an exporter.
Sharing of Hungarian rabbits in Swiss import is above 50%. Since stopping the Chinese import the missing amount of rabbit meat has been imported from neighbouring countries such as Germany, France and Italy. Thus, it is not possible to improve our export to this market.
Hungarian rabbit meat export to Germany as well as its sharing in the German import has improved for some years. On the other hand the competition for the market is the highest in this country. Our export to Germany could be increased with higher quality, with dependability and with better satisfaction of consumers' demands.
Besides stagnating or decreasing rabbit production, exporting rabbit meat will be more and more difficult.
Hungarian rabbit meat in these countries could be retaining our export at the present level. In spite of the high competition, Hungarian export to Germany and to Belgium can be improved; however, this needs more efficient market analysis and marketing. Nevertheless, it would be very important to work harder to obtain other markets. In spite of the high quality of Hungarian rabbit meat, competitive and more stable background for producers can only be expected in case of increasing the rabbit meat consumption in Hungary. At the moment it is less than half kg/capita/year.

In 2009, Hungary was at the 14th place ranking among rabbit meat producing countries (5,400 tons). However, since domestic rabbit meat consumption was low (3-4%), and 96-97% of the slaughtered rabbits were sold to international markets, it claimed the 4th place when only the rabbit meat trade was concerned. No data are available about self-consumption levels. According to the database of FAOSTAT, the main present challengers are China, France, and Belgium. Hungarian rabbit meat was exported mainly to Italy (46.3%), Germany (20.3%) and Switzerland (18.8%), while the Russian Federation and the Netherlands significantly increased their import demands. Although Italy increased its imports in total, the share of Hungarian rabbit meat declined (from 75.7 to 55.4% between 2005 and 2009). In contrast, Germany demands far less foreign rabbit meat, but the imports from Hungary have steadily increased (17.8%). The Swiss imports were also shrinking, but the share of Hungarian rabbit meat remains at approximately 50%. Besides stimulating national consumption, Hungarian rabbit meat production and trade could be facilitated by retaining the position in existing markets, also by expanding the exports to those countries where further potential can be exploited due to increased demand. Small-scale rabbit production almost ceased in Hungary and was only 1-2% of the total purchased quantity. The contribution or share of Hycole, Pannon White, Debreceni White, Hyla and Zika were

60.9, 30.5, 4.5, 2.8 and 1.3%, respectively. There are 60-65 large rabbit farms in Hungary producing with about 100,000 rabbit does. Their share by counties is shown in Table 1. The two slaughter houses process 85-90,000 growing rabbits per week. Only the 1-2% of the total rabbit meat production is sold in the supermarkets, in Hungary.

Table 1: Distribution of rabbit does in Hungarian counties

Counties	Does (%)
Bács-Kiskun	31.5
Baranya	6
Békés	1
Borsod-Abaúj-Zemplén	0.7
Csongrád	0.5
Hajdú-Bihar	2.3
Jász-Nagykun-Szolnok	1
Komárom-Esztergom	0.2
Nógrád	8
Pest	30.6
Somogy	4
Szabolcs-Szatmár-Bereg	12
Tolna	1
Vas	0.2
Zala	1
Total	100

Source: Juráskó, 2014

According to the demands of foreign markets, rabbit cages with platforms were established in large numbers, where the kits can be reared at their place of birth. In conclusion, although the promotion of high quality Hungarian rabbit meat is no longer enough to captivate new target markets; innovative approaches are needed in marketing, while reliability and better satisfaction of consumers' demands should be also emphasized.

As China takes the lead and further advances its influence on the rabbit meat market, other countries are in higher competition to increase their share to satisfy world demand. Since, unlike the world trend, rabbit meat production is continuously decreasing in Hungary and rabbit meat imports in some of its most important markets is shrinking. The primary aim would be to retain our position.

Nevertheless, it would be very important to obtain new markets to support the facilitation of Hungarian rabbit meat production and trade. Hungarian exports to its main importers, such as Belgium, the Russian Federation, and Germany could be further improved. Some of these countries would be new markets. However, high quality Hungarian rabbit meat is no longer enough to captivate new target markets; innovative approaches are needed in marketing, while reliability and better satisfaction of consumers' demands should be also emphasized. The aim of the Hungarian Rabbit Breeders' Board is to increase the current growing rabbit production from 4.7 million to 7 million per year until 2020.

4. BREEDS AND HYBRIDS

A breed is a specific group of domestic animals having homogeneous appearance, homogeneous behaviour, and other characteristics that distinguish it from other animals or plants of the same species and that were arrived at through selective breeding. Despite the centrality of the idea of "breeds" to animal husbandry, no scientifically accepted definition of the term exists. A breed is therefore not an objective or biologically verifiable classification but is instead a term of art amongst groups of breeders who share a consensus around what qualities make some members of a given species members of a nameable subset. The hybrid consists of crosses between populations or breeds within a single species. This meaning is often used in animal breeding, where hybrids are commonly produced and selected because they have desirable characteristics not found or inconsistently present in the parent individuals or populations. This flow of genetic material between populations or races is often called hybridization.
There are several breeds all over the world, and in this textbook only some of them are demonstrated.

4.1. Rabbit breeds

Rabbit breeds could be classified by the weight or size of body:

- giant
- large
- medium
- small
- dwarf.

Rabbit breeds could be classified by the quality of hair:

- normal
- angora
- satin
- rex

4.1.1. New Zealand White

New Zealand rabbits (Photo 19) are a breed of rabbit, which despite of the name are American in origin. New Zealand rabbits are available in four recognized colours: (New Zealand white rabbit, New Zealand red rabbit, New Zealand black rabbit, and New Zealand Broken rabbit (colour mingled with white)). Cross breeding can result many different combinations of the three basic pigmentations. There are efforts with certificates of development on a blue variety. The Red has bright golden red fur with a slightly harsher fat. The darker the fur the darker the meat, although all rabbit meat is white meat. One of the larger breed of rabbit, it can weigh anywhere between 4.1-5.4 kg. New Zealand White is a breed that can be used for meat, pelts, show, and laboratory uses. They are quintessential commercial meat rabbits, with the best meat-producing traits bred into the genes through 90 years of selective breeding. Adult New Zealands are less aggressive than other breeds although not all are perfect little rabbits.

Source: Bodnár Károly

Photo 19: New Zealand White rabbit

- Coat - Very dense, thick to the touch with enough resistance to almost resume its normal position. Not too fine and silky, harsh or wiry. Under fur fine soft and dense, interspersed thickly with decidedly heavier guard hairs.
- Type and Weight - Medium length of body, broad and deep throughout with well rounded haunches, front legs to be short, straight and thick. Head bold, broad and rounded, well set in with short neck. Ears in proportion to body, well furred with rounded tips and carried evenly. Small dewlap only permissible in does. Adult buck weight 4.08-4.989 kg. Adult doe 4.53-5.44 kg. Overweight not desirable.
- Colour - Bright clean and white, avoiding yellow coats. Eyes to be pink with good depth of colour.
- Condition - The flesh should be firm and solid over the entire body. Coat should give an even glossy appearance.

4.1.2. Californian

The Cochinelle rabbit was the original name for Californian rabbits (Photo 20), which were developed in California in order to create the ideal meat and fur rabbit. They consist of New Zealand Whites bred to a Chinchilla-colored cross-bred buck. (The breeder spent 7 years crossing Himalayans with Standard Chinchillas before achieving this ideal buck.) Cals are white with black points (Himalayan-marked), and exhibit a meaty commercial body. In the UK, they are also recognized in chocolate, blue and lilac points.

The Californian has the consummate commercial meat rabbit body. It is very muscular, full in the shoulders, and as deep as it is wide in the hindquarters. The usable pelt is completely white, while the points retain the Himalayan coloration. The fur is dense and coarse enough to be described as a fly-back coat, and the undercoat should be very dense.

Senior bucks should weigh 3.6-4.5 kg, with 4 kg being ideal. Senior does should weigh 3.9-4.7 kg, with 4.3 kg being ideal.

Californians have red eyes and very dark, almost black, points - nose, ears, feet and tail. Any color on the usable portion of the pelt is a disqualification from the show table. This can be tricky, since the pigment is temperature sensitive - colder climates may induce ‘smut,’ or coloration, where it does not belong. A molt can, however, remove the tinted fur, which will grow back white once again under correct conditions.

Source: Bodnár Károly

Photo 20: Californian rabbit

4.1.3. Pannon White

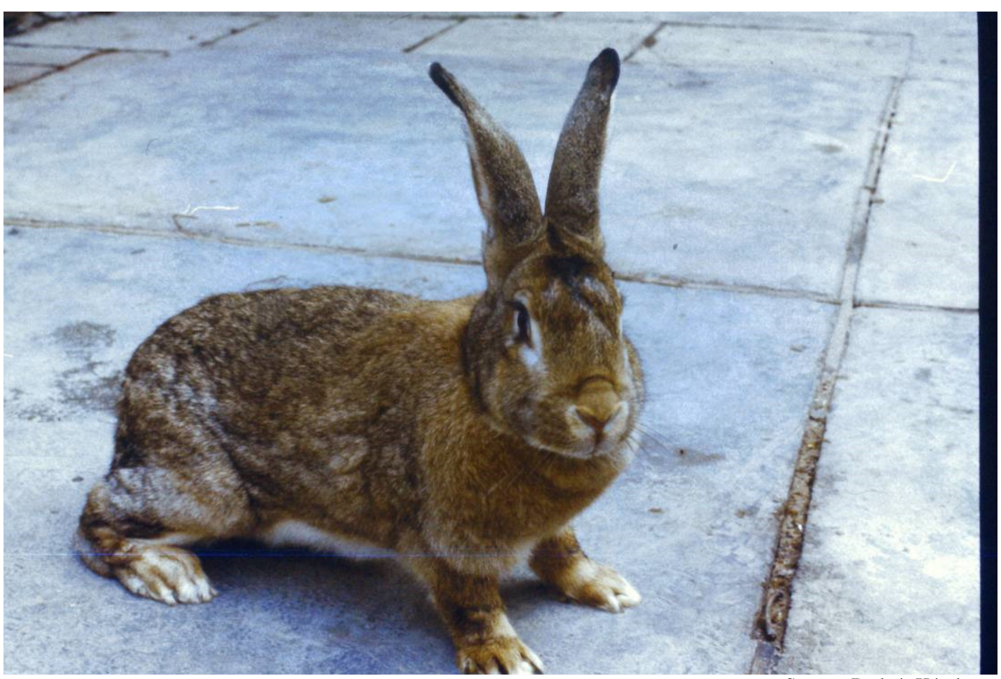
The Pannon White rabbit (Photo 21) breed was developed in Hungary. Using New Zealand Whites and Californians, fryer weight gains and dress-out percentages have been the chief criteria for selective breeding since 1988. They weigh up to 2.3 kg by 10 weeks.
Pannon white rabbit is bred for fattening developed in Hungary 1988. The goal of creation this breed was to create a race for fattening, which will have good fattening characteristics. Good feed conversion, a good percentage of gestation, good number of small rabbits in the litter as well as high yield of meat.
Rabbits this breed has 2.5 to 3 kg of weight in three months. Yield of meat is 60%–62%.
Characteristics of this breed are white colour, relatively small ears and thin skin. The female has a very good percentage of gestation; she can give birth to 8–10 babies, sometimes even more. Baby rabbits are progressing well if they eat food pellets and after three months they are ready for butchering. Weight of an adult rabbit is 4.5–5 kg.

Source: Bodnár Károly

Photo 21: Pannon White rabbit

4.1.4. Hungarian Giant

The Hungarian Giant rabbit (Photo 22) dates to 1920 or before, crossing native Hungarian breeds of rabbits with both the French Lop and The Flemish Giant.
The mature rabbit weighs between 5.5–7 kg. Does are capable of bearing and rearing large litters of up to 16 kits.



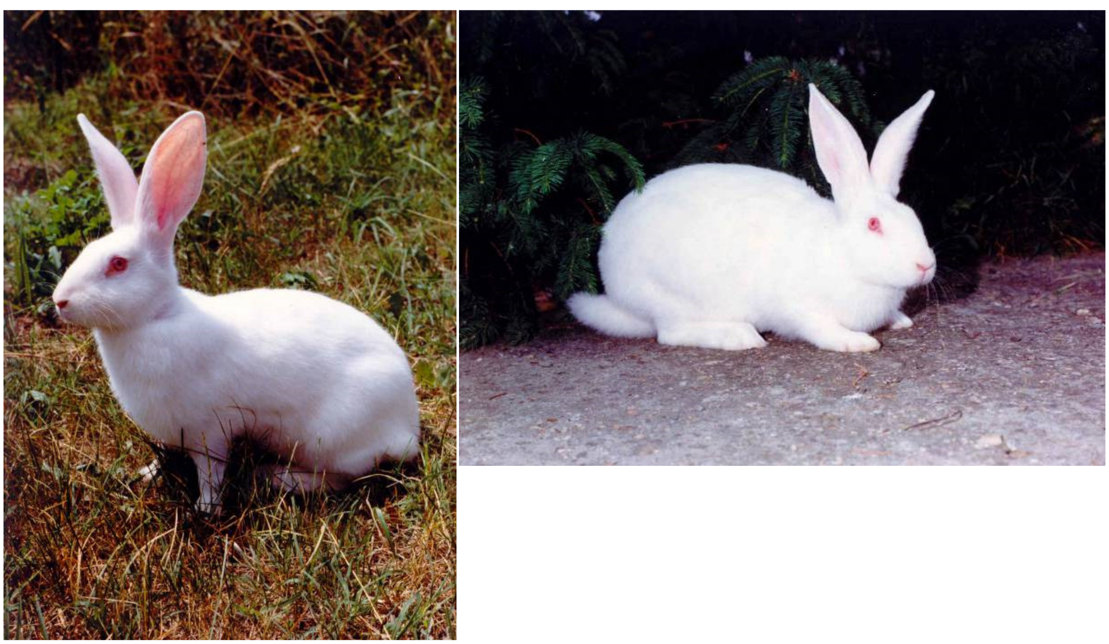
Source: Bodnár Károly

Photo 22: Hungarian Giant rabbit

Hungarian Giant rabbits may play a role mainly in alternative, organic rabbit production systems in which their lower performance and more expensive rearing are offset by a higher selling price.
The ancestors of the Hungarian giant rabbit were two species of Hungarian wild rabbit and the Belgian giant rabbit brought into Hungary. It is fed with hard fodder and large quantities of herbage. It is bred in four colour variations. The ears have blackish shading on the outer edges and on the tips. The fur is even coloured on all parts of the body. It was accepted on the list of indigenous animals in 1994. Today there are only a few hundred of this species remaining.

4.1.5. Bouscat

The Blanc de Bouscat (Photo 23-24) is a white rabbit originally bred in France in 1906. This breed is a large-sized breed (5.0-6.8 kg) and is used mainly for meat production. Albino with a soft silky fur. Body parts of this breed are well-rounded hips with well-filled loin. The ribs are carried forward to combine with shoulders that balance with the rest of the body. The shoulders blend smoothly into midsection, and the midsection smoothly extends into the hindquarters. The body is of medium length with good depth. The top body line rises in a gradual curve from the base of ears to the centre of the hips and then falls in a smooth curve downward to the base of the tail. The sides taper slightly from hindquarters towards shoulders. Back is markedly convex ventrally without being pot-bellied. The skin is smooth.



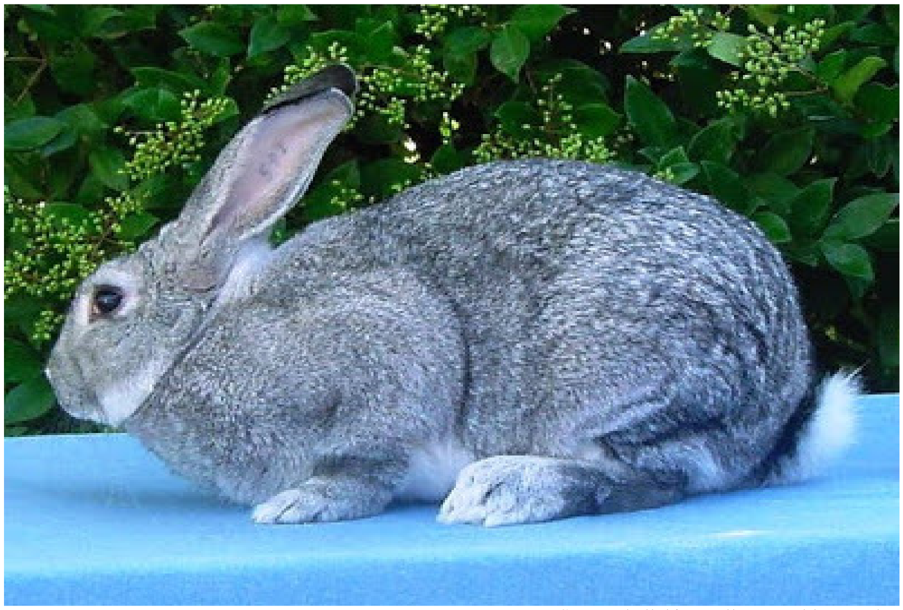
Source: Bodnár Károly

Photo 23-24: Bouscat rabbit

4.1.6. Chinchilla

The Chinchilla rabbit (Photo 25) is a rabbit breed that has been bred to resemble chinchillas. This breed is a medium-sized breed (4.1-5.4 kg) and is used mainly for meat production. The real Chinchilla has a dark slate blue under-colour at base; the intermediate portion is pearl – and should be as light as possible. The top edge has a very narrow black band, above this is

a very light band brightly ticked with black hairs, either wavy or even ticked to make the beautiful Chinchilla surface colour.
The body parts of this breed are well-rounded hips with well-fitted loin and hips. The body is of medium length, with a rather compact and chubby body. The top body line rises in a gradual curve from the base of ears to the centre of the hips and then falls in a smooth curve downward to the base of the tail. The back has a slight gradual arch starting at the ear base. The skin is smooth.



Source: hellokittywallpaperss.blogspot.hu

Photo 25: Chinchilla rabbit

4.1.7. Flemish Giant

The Flemish Giant rabbit (Photo 26) originated in Flanders. It was bred as early as the 16th century near the city of Ghent, Belgium. It is believed to have descended from a number of meat and fur breeds, possibly including the *Steenkonijn* (*Stone Rabbit* – referring to the old Belgian weight size of one stone or about 3.76 kg) and the European "Patagonian" breed (now extinct). It was recognised as a breed in Belgium in 1895.
Its colour depends of the varieties within the breed. Possible colours are: wild grey, hare grey, iron grey, blue grey and fawn. Large size breed. Large and long body. Developed trunk. Imperceptible neck. Low shoulders and plain rump. Basic temperament (for males and females) is docile. This breed seems to have an anti-stress gene.
Use of the breed is meat. Mainly used in semi-professional and family farming for auto-consumption. Rabbits of this breed are also kept as pets. It is common to raise this breed in big cages with straw and forage in outdoor or semi-open air rabbitries.
The growth rate between weaning and 11-12 weeks of age has been estimated at 40.79 g/d, higher than the corresponding figure for the control strain that was 34.75 g/d. The growth rate has a trend to decrease with the age of lower intensity than in the control. The ideal adult weight for females ranges between 8-9 kg, the minimum authorised being 5.5 kg. For males the corresponding figures are: 7.5-8.5 and 7 kg.
As one of the largest breeds of domestic rabbit, the Flemish Giant is a semi-arch type rabbit with its back arch starting at the back of the shoulders and carrying through to the base of

the tail giving a "mandolin" shape. The body of a Flemish Giant Rabbit is long and powerful with relatively broad hindquarters. Bucks have a broad, massive head in comparison to does. Does may have a large, full, evenly carried dewlap (the fold of skin under their chins). The fur of the Flemish Giant is known to be glossy and dense. When stroked from the hindquarters to the head, the fur will roll back to its original position.
A senior doe can take 1 year to reach full maturity. A senior buck can take 1.5 years to reach full maturity. It is not unusual to see a 10 kg Flemish Giant.[

Source: Bodnár Károly

Photo 26: Flemish Giant rabbit

4.1.8. Argente

The Argente rabbit (Photo 27) is one of the oldest breeds of French show rabbits. This breed comes from the local population of rabbits existing at Champagne since the seventeenth century and carrying in homozygosis the silvering gene (si/si). It was recognised as a breed around 1900. At this time there were important migrations to Switzerland and Germany. Use of the breed in a descending order of product importance: meat and exhibition.
Colour is black silver. At birth, Argentes are of a solid colour, with adult colouring beginning to show around four months of age. They are known as excellent pets due to their good nature.
It is a middle size breed (3.6-4.5 kg) with massy and rounded body. Well developed trunk. Imperceptible neck. Low shoulders and raised rump. Dewlap possible in the does. There are several types, from very professional to family-farming. Rabbits of this breed are also kept as pets. The growth rate between weaning and 11-12 weeks of age has been estimated at 37 g/day, higher than the corresponding figure for the control strain. The growth rate has a trend to decrease with the age of lower intensity than that in the control.


Source: Bodnár Károly

Photo 27: Argente rabbit

4.1.9. Dutch

Dutch rabbits (Photo 28) originate with the Brabancon Blue, a marked and smaller version of the Blue Beveren that is now extinct. They looked like Dutch rabbits with a narrow blaze and abbreviated white saddle. Today's Dutch markings and type were standardized in England in the late 1880's.


Source: Bodnár Károly

Photo 28: Dutch rabbits

The Dutch rabbit, easily identifiable by its characteristic colour pattern, was once the most popular of all rabbit breeds. However, after dwarf rabbits were developed, the popularity of

the Dutch rabbit dwindled. Nevertheless, the Dutch rabbit remains one of the top ten most popular breeds worldwide.
"Although the name suggests that the Dutch rabbit is from the Netherlands, it was actually developed in England. During the 1830's rabbits were imported to England from Ostend in Belgium every week for the meat market. Amongst these rabbits was a breed known as the Petit Brabançon, as it originated from Brabant in Flanders. The Petit Brabançon may still be found in paintings from the fifteenth century. The Dutch rabbit has its genetic roots in this old breed. The Petit Brabançon would often display Dutch markings, and breeders in England selected those with even markings, fixing those markings into the breed we know today."
Dutch are popular both as pets and among show breeders.

4.1.10. Angora

Get an overview of angora rabbit history and breeds at Angora rabbits. Angoras are typically very gentle and easy-going. They've had millennia of domestication, and through the ages each animal has been handled frequently in order to be groomed, plucked, sheared, and cleaned.

English Angora
Angoras have been bred for their wool in England for more than 500 years. These are the rabbits with wool and furnishings covering nearly every part of the rabbit. Their silky wool grows to 13 cm or longer, and mats fairly easily. Angoras come in a plethora of colours, and weigh 2.26-3.4 kg. The English Angora (Photo 29) is the smallest of the angora breeds. Acceptable weights are 2.3-3.4 kg. They come in a full rainbow of colours, including broken-white with any acceptable colour. They require significant grooming each week.

Source: Bodnár Károly

Photo 29: English Angora rabbit

French Angora

French Angoras (Photo 30) are considered the original Angora breed. Their faces have short wool however the ears may be tasselled. Wool is to be dense, and up to 11.3 cm or more in length. They come in many colours and weigh between 3.5-4.5 kg.

The use of French Angoras for wool production in France dates to as early as 1845 in the region of Saint Innocent in Savoy, France. A gentleman named Monsieur Lard developed a large angora herd that provided work for many in St. Innocent. But additionally, he and his wife made it possible for others to start their own angora enterprises. Mr. Lard and his wife frequently gave to the village women and to the poor several pregnant rabbits. They paid by returning half the offspring at 12-16 weeks of age. The villagers cared for their own rabbits and reaped the benefits. They sheared the wool, spun the yarn, made garments according to their skills, and sold their products, whether wool, yarn or garment. It was a win-win situation, enabling the enterprising to support the family and the poor to rise out of abject poverty. No wonder France quickly became the global leader of raw angora wool production, holding this distinction until 1965. French Angora rabbits most resemble the angoras of centuries past. This is because they have fur, not wool, on their face, ears and feet. (Compare them to the English Angoras that are woolly everywhere except, possibly, on the tips of their noses.) This is not to say that improvements in wool quality and quantity have not been made. To the contrary, breeders have indeed made great improvements in all aspects of French Angora rabbits. The wool of a rabbit in full show coat has far more height, density and bulk than did angoras of even 80 years ago. The body type is more commercial than is the English Angora. They can be shown in two varieties of white, plus nearly every colour possible, including the broken of these colours.

Source: Bodnár Károly

Photo 30: French Angora rabbit

French Angora rabbits are a dual-purpose breed. They have oval-shaped, commercial bodies that provide plenty of meat, plus the wool for fibre. The wool, with its coarse guard hairs protruding beyond the crimped underwool, is usually low-maintenance, requiring minimal grooming. Expect to find no wool on face, ears (other than minor tufting on some), and feet, up to the ankle joint. Their toenails should match if you plan to show the animal.

4.1.11. Giant Papillion

Giant Papillion (Photo 31) and Chequered Giant have the same genetic background. This breed has been selected for a grouping of up to 8 side spots, instead of a few larger spots. They weigh over 6 kg.

The Chequered Giant can be traced back to large spotted rabbits in France and Germany in the 1800's. Added to the bloodlines of these spotted rabbits were Flemish Giants and French Lops, creating a very large spotted rabbit at first resembling an English Spot, but without the nose markings. Markings have been standardized in the USA as shown, and are accepted in black and blue spots. There are no maximum weight requirements; minimum is 5 kg for a buck and 5.5 kg for a doe.

Source: Bodnár Károly

Photo 31: Giant Papillon rabbit

4.1.12. Rex

The coat of the Rex rabbit (Photo 32-33) is a result of a fur mutation that first occurred in France in 1919. Many of the first Rex rabbits had deformed extremities, earning them the nickname of Wrecks. Today, after years of careful breeding, the deformities are gone. Our Rex rabbits are absolutely stunning in both body type and in density of their plush velvet coats. Rex fur is sought after by furriers as it relieves the pressure on wild species. Rex fur should measure 1.3 cm to 2.2 cm long, with 1.6cm being ideal and have a dense and plush texture that is often described as "velvety. The fur is often very dense and plush because of its short guard hairs and stands almost perpendicular to the skin. The Rex is a medium sized rabbit. Bucks should weigh up to 4.3 kg. Does' weigh goes up to 4.8 kg.

The Rex has a commercial, round body, a slightly broader head than other breeds of rabbit, proportionate and upright ears as well as toe nails that match the colour of its fur on proportionally smaller feet. As with most of larger breeds, the female (doe) has a dewlap, a large flap of skin under the chin.

The Rex mutation also causes the fur to curl in certain areas, but this curling is rarely visible with the exception of areas where the fur is longer, such as behind the ears. Additionally, the mutation causes the whiskers to shorten and curl or not appear.

Source: Bodnár Károly

Photo 32-33: Rex rabbit

4.1.13. Vienna Blue

Blue rabbits have been native to Austria as far back as 1600, being kept by villagers in what is now the Czech Republic. Vienna Blue Rabbit (Photo 34) is a breed raised in Austria around Vienna in 1880 as a result of crossing the Flemish giant with the local breeds. It can weigh up to 4.5-6 kg. Rabbits of this breed have a cylindrical body shape with a well developed frontal part, medium-length upright ears, about 13 cm long, with rounded tips, blue eyes and dark nails.

Source: Bodnár Károly

Photo 34: Vienna Blue rabbit

They grow up quickly and they are well-muscled with very thick fur. The colour of these rabbits is plain dark steel with a shade of blue, sometimes a bit lighter on the belly and chest. The head and ears are the same colour as the body. This breed is characterized by good health and robustness.

Black Viennas were developed at the request of furriers, and more recently, grays and blue grays have been added to the breed.

4.1.14. Tan

Tans originally come from England where they have been shown since the late 1800s. A black rabbit with a yellow belly first appeared in the UK in the county of Derbyshire. The year was 1887, and many rabbit breeders were intrigued with the rabbit. By 1890, at least two "Black and Tan" clubs had formed. Breeders utilized multiple crosses, including the Belgian Hare, to achieve the fiery red belly fur and to establish the body type and size that is standard today.
The Tan rabbit (Photo 35) is a small fancy breed of rabbit shown throughout the world. While originally from England, in recent years they have gained popularity in the United States. Tans come in four varieties: black, blue, chocolate and lilac. Full grown Tans weigh 1.8-2.7 kg.
Tans are a full arched breed. Rabbits with this type show an arch starting at the nape of their neck, running smoothly over their shoulders, midsection and hips. Tans have a very lean, compact, well balanced body. Tans should be short and deep in body type. They are visually striking because of their unique markings, contrast and intensity of their coloration. There are four varieties (colours) in the Tan breed: black, blue, chocolate and lilac. All four varieties have identical patterned markings. The Tan coloration is an intense, deep red colour that is should be even from the chest to tail. The tan belly is the result of the wide band gene, which strengthens the yellow pigment and enhances the ruffs modifiers in the Tan breed.

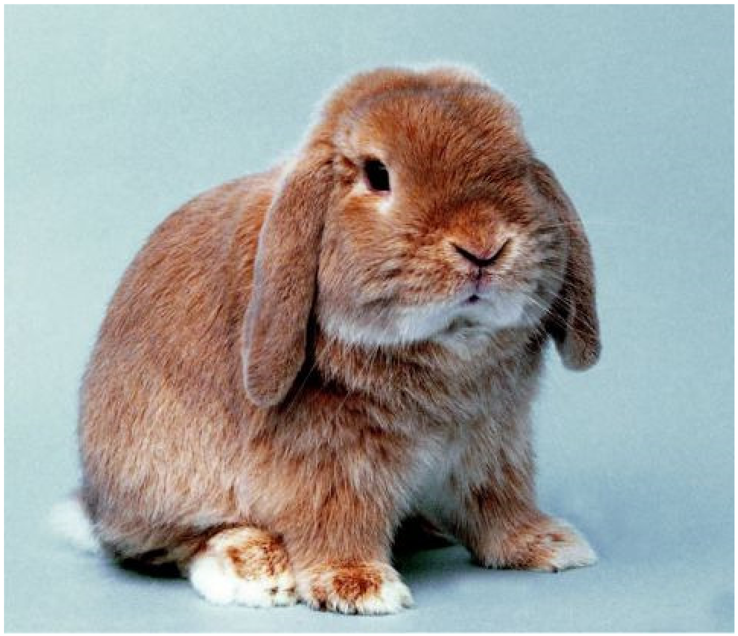
Source: Bodnár Károly

Photo 35: Tan rabbit

4.1.15. Dwarf lop

Body is short with well rounded loins. Deep chest and wide shoulders are giving a cobby well-muscled appearance. It has short strong legs. Maximum weight is 2.381 kg the minimum is 1.93kg. The head is well developed particularly in bucks. Good width between eyes. Full cheeks and broad muzzle are desirable.

The basal ridge of the ears should appear prominent across the top of the skull. Ears should be broad, thick well furred and rounded at ends (Photo 36). They should be carried close to the cheeks giving a horseshoe like outline when viewed from the front. The inside of the ears should not be visible from any angle when carried correctly. The ears are not measured. Eyes are round and bright. Coat should be dense and of good length, rollback with an abundance of guard hairs.



Source: wildpro.twycrosszoo.org

Photo 36: Dwarf lop rabbit

4.2. Rabbit hybrids

4.2.1. Hycole

The selection work carried out for more than 25 years allows providing a female offering the best compromise between health conditions, performance and safety.
Performance targets:

Hycole parent female (Photo 37)

Birth rate	86.9 %
Kits born alive / kindling	10.58
Kits weaned / kindling	9.15
Viability in fattening	97 %
Productivity at 73 days of age	19.8 kg/AI
Annual renewal rate	100 %
Productivity / career	67 rabbits

Hycole White Male (White or white with black extremities) (Photo 38)

Adult weight: 6.5 - 7.5 kg
Excellent conformation
Performance of meat rabbits:
Adapted to slaughter at different ages:
2.35 - 2.40 kg at 65 days
2.80 - 2.90 kg at 78 days
Average ADG greater than 45 grams
Excellent feed conversion ratio in restricted feeding

4.2.2. Zika

Originally, four breed lines were created from the different pedigree rabbits bred for performance. Basic breeding serves to estimate breeding value, analyse populations and examine performance, and selects the best characteristics through which a hybrid rabbit can be created out of the four lines by combination cross-breeding. Our hybrid rabbit demonstrates a significant increase in performance as a result of heterosis and positional effects. The breeding purpose remains the selection of fertile, robust parents which will produce a heavy fattener with the best possible carcass and meat quality.
The most important selection characteristics for all lines are fertility, weight gain, vitality, robustness, longevity and correct appearance.
On the female side, the following characteristics play an important role:

- damming ability;
- milk production;
- fertility of the doe (rate of conception, litter size, litter weight, interval between litters);
- libido of the bucks;
- sperm quality.

On the male side, the characteristics listed below are of central importance:

- rapid growth and weight gain;
- feed conversion;
- calm temperament;
- suitability for group penning;
- carcass quality;
- meat quality.

Numerous comparisons with other lines, together with extensive practical experience have demonstrated the ZIKA hybrid rabbit's high genetic potential:

- the ZIKA hybrid doe has eight litters on average per year, with nine young per litter;
- the fatteners attain a live weight of 3.2 kg at the age of 84 days with a feed conversion of 3:1.

5. BREEDING METHODS

Breeding systems

Purebreeding or straightbreeding is a simpler system than crossbreeding. However, because of hybrid vigor (a major advantage of crossbreeding), it is recommended that meat rabbit breeding (large- or small-scale) use either commercial New Zealand White purebred or Californian X New Zealand White crossbred does. Both breed types of doe have outstanding fertility, mothering instinct, and milk production. One breed weakness of the commercial New Zealand White is lower carcass dressout and a lower proportion of meat to bone. Fryer meat yield can be improved by using purebred Californian or Champagne d'Argent bucks for crossing with commercial New Zealand White purebred or crossbred does. Alternatively, faster gaining and more efficient terminal crossbred fryers that reach market size (2.5 kg) at an early age can be produced by mating purebred Chequered Giant or Flemish Giant bucks to New Zealand White purebred or crossbred does.

The word "terminal" implies that all crossbred offspring are used for meat, with no offspring being saved as replacement bucks or does.

Inbreeding **-** mating closely related rabbits such as brother to sister, father to daughter, or mother to son.

Line breeding **-** breeding of rabbits with common ancestors, such as grandparents.

Out crossing **-** crossing unrelated rabbits into the line.

The essential elements of a program of genetic improvement of meat rabbits, required to satisfy the needs of animals demanded by the producers of rabbit meat in a region or country, are analysed. The three-way crossbreeding scheme is adopted to discuss the programmes. In this context, the development of maternal and paternal lines is one of the central points and a historical enumeration of research or development centres involved in this activity is presented. The principal criteria in founding new lines are discussed and the interest is noted in finding two or three populations, no matter their genetic origin (pure breed, synthetics or crossbred), that are clearly outstanding for the traits important to the desired specialisation of the line. The alternative of applying very high intensities of selection for the traits of interest in very large populations is also commented upon (for example, commercial populations made up by a large number of farms) and examples of founding a line following criteria of hyperprolificacy and another of hyperlongevity are given. Paternal lines are commonly selected for post-weaning daily gain or weight at time of marketing by individual selection. The most common criterion used to select maternal lines is litter size at birth or at weaning, but there are proposals to include traits related with the ability of the doe to nourish the lactating progeny, traits such as weight at weaning, litter weight at weaning or total milk production.

Currently, mixed model methodology (BLUP) is the habitual procedure used to evaluate the animals genetically, using repeatability animal models for litter size and selecting the progeny from the best evaluated matings. The responses reported in paternal lines range between 18 and 35 g/generation for weight at market time and between 0.45-1.23 g/day generation for daily gain, with correlated responses increasing adult weight, intestinal content and feed intake but decreasing feed conversion, dressing percentage and maturity at a fixed weight. The responses estimated in maternal lines range between 0.05-0.13 rabbits born alive or weaned per litter and generation, figures 0.08-0.09 being common. Depending on the lines, ovulation rate or foetal survival was the modified components that explain the responses in litter size. Comparing the responses in crossbreeds with the responses in pure lines, slightly higher responses were obtained for the crossbred does; however, the response was lower than expected for the young issued from the terminal mating, probably due to an interaction between the feed currently used to control enterocolitis and the genetic level for growth traits. Finally, two approaches to diffuse the genetic improvement to the producer are presented which modify the standard pyramid of selection, multiplication and production, aiming to increase the selection effort and minimise the genetic lag between selection and production.

Replacement stock selection
The decision to select young replacement stock should be based on the production records of their parents. Trait averages from buck or doe record forms can serve as a guide in making selection decisions. Important traits include litter size weaned, total litter weight at 21 days of age (an indication of milk production), and fryer weights at 8 weeks of age. Closely inspect each replacement candidate for heavy body weight, desirable meat type, and physical soundness, which includes lack of body defects or blemishes, normal teeth, and thick fur on the foot pads. In a good-quality herd, it is less costly to produce own replacement stock than to purchase new animals.

Breeding tips
A healthy and well-developed commercial doe can be bred at 5 months of age. When mating rabbits, the doe should always be taken to the buck's cage, because the doe is territorial. Especially if a litter is present, the doe is more likely to defend her cage space rather than show an interest in mating. Rabbits being bred should never be left unattended, for two primary reasons:

- the rabbits may fight and even seriously injure one another,
- the manager will not know if a mating took place.

It should take no more than 5 minutes for rabbits to mate. If a successful mating does occur (only one to two services are necessary), the buck snorts and falls to one side of the doe. The buck and doe ear tattoo identification numbers (or names) and the date of mating should then be transferred to record forms. A buck can service one or two does every other day, with a 1-day rest period between matings. Only one buck is needed for every 30 does in a large operation.

It is very important to keep records in the rabbitry, as without them you would not know what rabbits are out of what, the date a doe is due, the age of the rabbit for entering shows, etc.

Pedigrees
Each rabbit should have a complete 3 generation pedigree. This should also include the weight and variety for each ancestor. It's best to buy rabbits that already have pedigrees, however if the rabbit does not have one, start keeping track with the rabbits which already have.

Identification
All rabbits must have a permanent tattoo in their ear (Photo 39) before they can be shown. Tattoos are the way you can tell your rabbit apart from all others on the show table. Usually at least four digits are used, but more numbers or letters are also possible.

Source: Bodnár Károly

Photo 39: Tattoo in rabbit ear

Breeding program

The most common selection criteria used in selection programs for maternal lines are related to litter size at birth or at weaning. In other cases selection programs are practiced for litter size at birth and weight at nine weeks, number of teats, traits related to the ability of the doe to lactate and nourish the progeny (e.g., weight at weaning, litter weight at weaning or total milk production), and in few cases selection for hyperprolificacy and longevity have been introduced recently. Selection for ovulation rate and uterine capacity using new reproductive techniques has been successfully performed, which can be used as an alternative to improve litter size and prenatal survival. For paternal lines, post-weaning daily gain or marketing weight are commonly selected on individual basis. New techniques, such as laparoscopy, ovariectomy, cryopreservation of embryos and semen, TOBEC (Total Body Electrical Conductivity) and X-ray scanning computerized tomography (CT), were used as tools to assist in selection programs. The application of molecular techniques in selection of rabbits so far has had a limited impact on farm animals. Major genes with large effects on litter size components have been identified. Family index or BLUP are the common procedures used to evaluate the animals genetically in selection experiments. Canalization selection model was recently used in evaluation of does and bucks in selection experiments and this model incorporated the classical genetic effects acting on the mean production level, in addition to the other genetic effects acting on the residual variance. Several synthetic maternal, paternal and multi-purpose lines were developed using different criteria and methods of selection. Selection responses were estimated commonly by regressing the estimates of the breeding values on the generation's number, or by using the control populations or the population selected divergently, or by comparing the contemporaries of two different generations using the frozen embryos of the same line. Selection responses obtained in crossbred rabbits could be periodically evaluated by estimating the crossbreeding parameters in the cross (e.g., direct and maternal additive, direct and maternal heterosis, recombination effects, etc.), or by comparing heterosis values obtained from an experiment with those of contemporary commercial farms, or by evaluating the selection responses at different stages of the programme by carrying out contemporary comparisons among purebred and crossbreds.

Studies that have compared selection responses in crossbreds with the responses in pure lines, have observed slightly higher responses in the crossbreds. Direct selection responses per generation estimated for litter size born or weaned were low or slightly moderate and ranged from 0.081 to 0.180 rabbits, while the correlated responses ranged from 0.03 to 0.18 ova for ovulation rate, and 2.0 to 3.7% for prenatal survival. Depending on modified components of litter size, selection for uterine capacity produced responses that were similar to that obtained in direct selection for litter size. Improvement in litter size caused by selection for uterine capacity was not greater than the improvement obtained from direct selection for litter size (approximately 0.1 rabbits per litter per generation). The does selected for litter size at weaning presented significant responses in feed intake (3%) and milk yield (6%). A response of 62 g per litter was recorded when selecting for litter weight at weaning, with a correlated response of 0.17 rabbits for litter size born and weaned. Estimates of direct selection responses per generation were moderate and ranged from 8.7 to 12.6 g for weaning weight, 18 to 68 g for marketing weight, 0.45 to 1.73 g/day for weight gain from weaning to marketing, and 0.05 to 0.27 g feed/g gain for feed conversion from weaning to marketing, which was associated with an increase in correlated responses in adult weight and feed consumption, but with decreasing rate in feed conversion. Selection for growth rate has little or somewhat moderate effects on carcass characteristics and meat quality when rabbits were selected at the same stage of maturity, which was associated with increases in intestinal content and decreases in dressing out percentage and fat deposits, and ultimately in pH in muscle and water holding capacity of the meat. Selection for litter weight at weaning achieved considerable responses in growth rate with maintaining high litter components and feed conversion.

By selection, total fleece weight increased significantly associated with correlated improvements in live body weight and fleece qualities (bristle length and diameter, follicle ratios, compression, resilience, and fibre diameter). Selection responses estimated by different methods were in good agreement to most studies reviewed.

Genetic parameters and trends

The negative genetic correlation (especially in case of the third and fourth parities) between CT-based selection and litter weight at age of 21 days reveals that the prolific performance of Pannon White breed may decrease significantly in the future.

The estimated phenotypic and genetic trends for the CT based muscle thigh volume parameter have clearly demonstrated the success of the breeding program of Pannon White breed.

Inbreeding degradation and pedigree analysis

Because of the special pairing methods the level of inbreeding is low. It was on average about 6.3% in 2008 and 2009. The inbreeding rate is relatively low, approximately 0.5% per year.

The applied pairing system in the Pannon White breed has been effective for the inbreeding rate and for the scale of genetic variance loss. Although the livestock’s population size decrease in 2006 has significantly reduced the genetic variability.

Stability of genetic parameters and breeding values

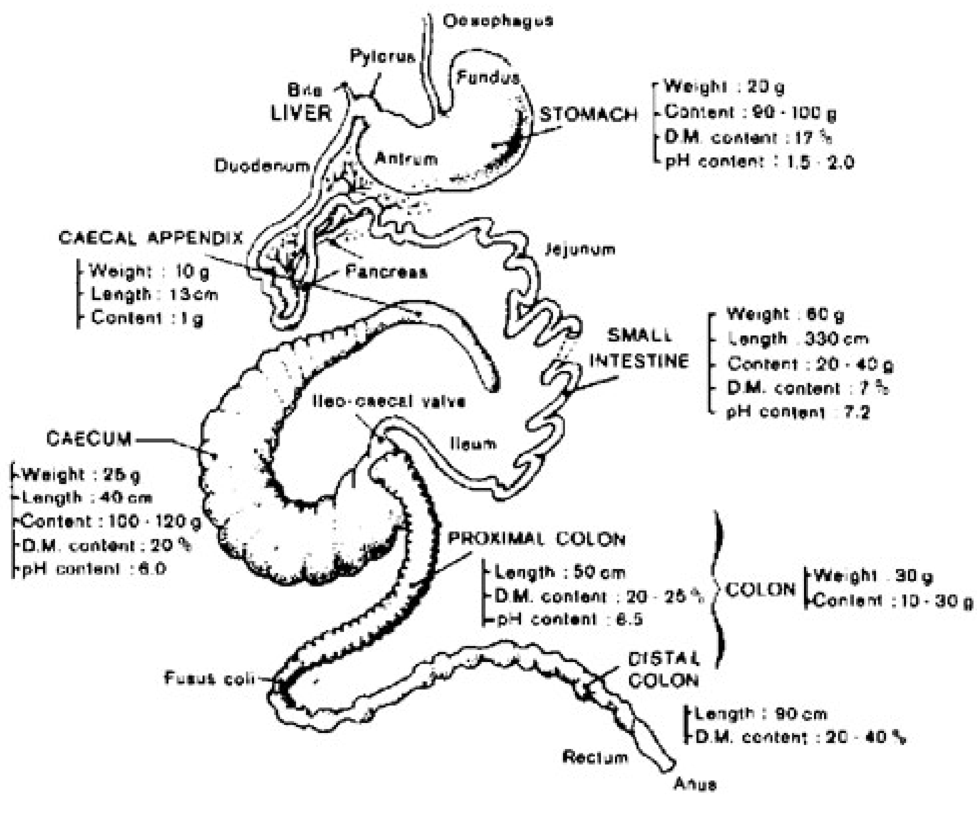
The genetic parameters of the average daily weight gain were stable for different periods. The different part databases were inserted together and because of the decrease of the common individuals. The stability of the breeding values remains unchanged for the practice. From the various databases' most common individuals the rate of the ones with biggest breeding values is relatively low. Preliminary investigations must be done on the stability of breeding values.

6. NUTRITION OF THE RABBIT

The rabbit is a herbivore, or more specifically a folivore animal, designed to exist on a diet of succulent green vegetation. However, its small size means it has a correspondingly high metabolic rate (which limits its ability to exist on a low energy concentration diet), and makes it a highly sought prey (which needs to be agile and athletic to outrun predators). To cope with these problems the rabbit has evolved a digestive tract radically different to that of the better known herbivores such as the horse (a colon fermenter) and the ruminants (gastric fermenters). The rabbit has a system that:

1. allows a high food (and therefore high energy and protein) intake,
2. separates out the digestible and easily fermentable components of the diet, and
3. rapidly eliminates the slowly fermentable fibrous waste that would otherwise have to be carried around.

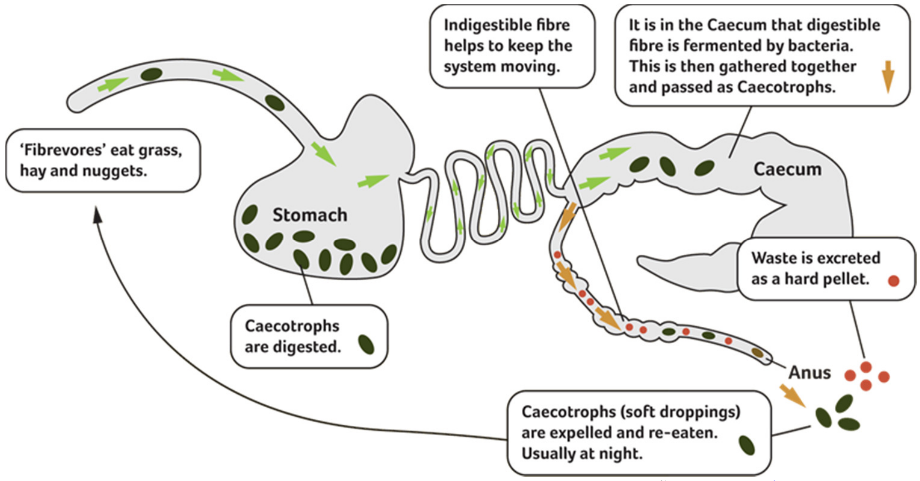
A schematic diagram of the anatomy of the alimentary tract of the rabbit is provided for reference in Figure 6, and an overview of the activity of the digestive system is provided in Figure 7.



[1] Numerical values are those observed in the New Zealand White breed, aged 12 weeks, fed a complete balanced pelleted feed.

Source: www.pet-food-choice.co.uk

Figure 6: Schematic diagram of the anatomy of the gastrointestinal tract of the rabbit.



Source: www.burgesspetcare.co.uk

Figure 7: An overview of the activity of the digestive system of the rabbit.

The system also eliminates the need for having a large absorptive surface area in the large intestine by complete separation of the products of caecal fermentation and the faeces, allowing reingestion and absorption of bacteria and their by-products in the small intestine. Given that the system is geared for rapid elimination of fibrous wastes, it is somewhat ironic that the main driving force for the system is the presence of such indigestible fibre. Lack of this fibre is the most common cause of gastrointestinal disturbance in the rabbit. This chapter aims to review the current understanding of the gastrointestinal physiology of the rabbit, and highlights some areas where the breakdown of the normal physiologic processes leads to disease.

6.1. The digestive system of the rabbit

The digestive system of the rabbit is characterized by the relative importance of the caecum and colon when compared with other species. As a consequence, the microbial activity of the caecum is of great importance for the processes of digestion and nutrient utilization, but also in the control of digestive pathologies. Furthermore, caecotrophy, the behaviour of ingestion of soft faeces of caecal origin, makes microbial digestion in the caecum more important for the overall utilization of nutrients by the rabbit. Additionally,
the rabbit has developed a strategy of high feed intake (65–80 g kg^{-1} body weight (BW)) and a rapid transit of feed through the digestive system to meet nutritional requirements.

6.1.1. The oral cavity

Ingestion
Rabbits in the wild selectively eat young succulent shoots. To pick off such shoots they utilize the chisel-like incisors (Figure 8) to cut off the short pieces of vegetation. This is enabled by the long diastema, rostrally positioned incisor teeth and cleft upper lip (''hare-lip''). Location of food is by means of sensitive vibrissae on the lips, because ocular position in rabbits prevents visualization of objects directly in front of the mouth. The lips themselves are highly mobile, and in captivity (where the diet is composed primarily of long stem hay,

vegetable pieces, and pelleted or other particulate foods) the incisors themselves are largely superfluous. Therefore, captive rabbits can cope well with the removal of the incisor teeth.

$$\begin{array}{cccccccc} \mathbf{M} & \mathbf{P} & \mathbf{C} & \mathbf{I} & \mathbf{I} & \mathbf{C} & \mathbf{P} & \mathbf{M} \\ \hline \mathbf{3} & \mathbf{3} & \mathbf{0} & \mathbf{2} & \mathbf{2} & \mathbf{0} & \mathbf{3} & \mathbf{3} \\ \hline \mathbf{3} & \mathbf{2} & \mathbf{0} & \mathbf{2} & \mathbf{2} & \mathbf{0} & \mathbf{2} & \mathbf{3} \end{array} \; \mathbf{= 28}$$

where:

I – incisor
C – canine
P – premolar
M – molar

Source: www.cakitches.com

Figure 8: Teeth of the rabbit (Left: toothing structure; Right: teeth in situ)

Chewing

Once ingested, the food material is ground down by the cheek teeth (premolars and molars). The teeth in each arcade are arranged in extremely close proximity to one another, and act as a single occlusal surface rather than as individual teeth. The margins of each tooth, and the ridge running from the labial to the vestibular surface across the occlusal surface of each tooth, are composed of enamel. The ‘‘valleys’’ in between these structures are formed from ‘‘softer’’ dentine. The continual attrition that occurs due to tooth-food and tooth-tooth abrasion maintains this file-like occlusal plane on each arcade, and provides an excellent grinding surface. The movements of the jaws and teeth during mastication have been described and illustrated, as have the coordinated tongue movements during the process. Masticatory actions are divided into three types:

1. Type I actions are those involved in the slicing actions of incisor use during prehension.
2. Type II actions constitute the main part of the masticatory cycle, providing the chewing and grinding actions necessary for processing of the food and reduction of long stem herbage to shorter particles. Only one side of the mouth is used for this type of mastication at any one time, and the mandible is always moving towards the midline at the stage when pressure is being applied to the ingesta.
3. Type III actions are those involved in forming a bolus of food ready for swallowing. Up to 120 jaw movements per minute have been reported following ingestion of fresh food.

When caecotrophs are ingested type II masticatory actions do not take place and the caecotrophs are swallowed intact.

Salivary secretion

The rabbit has four major pairs of salivary glands: the parotid, mandibular, sublingual, and zygomatic. Amylase and galactosidase are produced in the saliva, which is produced continuously by the mandibular glands, and in response to food intake by the others. Lipase and urea (prominent in human and ruminant saliva respectively) are only present in trace amounts in rabbit saliva. Potassium and bicarbonate ions are also important constituents of saliva.

6.1.2. Oesophagus

The oesophagus serves as a transport duct from the oral cavity to the stomach. The structure and function of the rabbit oesophagus differs little from that of other nonruminant species, and has little or no effect on digestion.

6.1.3. Stomach

The stomach of the rabbit is a thin-walled, pouch-like organ. It comprises 15% of the gastrointestinal tract volume. There is an extremely well developed cardiac sphincter that precludes true vomiting. The cardiac portion of the stomach is thin walled, nonglandular, and intrinsically immobile. Churning of the food material within the cardia is thought to occur indirectly because of large intestinal movements and locomotory movements of the rabbit rather than because of intrinsic gastric motility. The stomach is normally never empty. In fact, after a 24-hour fast the stomach of an adult rabbit has been shown to still be 50% full, usually with a mass of food material and hair surrounded by fluid. The fundus is the major secretory portion of the stomach, and has parietal cells (which secrete hydrochloric acid and intrinsic factor) and peptic cells (which secrete pepsinogen, the precursor of pepsin). The pyloric region has a much thicker muscular wall.

Preweaning gastric physiology and changes at weaning
Suckling rabbits have a gastric pH of 5–6.5. Ingested milk forms a semisolid curd within the stomach, which is gradually passed into the small intestine over the 23.5 hours between feeds. The curd formation is due to the action of a rennin-like enzyme. In other animal species, prolonged gastric retention of this curd would be expected to allow marked proliferation of bacteria. However, rabbits at this age have protection against infection conferred by a substance known as ‘‘Stomach oil’’ or ‘‘Milk oil’’—an antimicrobial fatty-acid product (octanoic and decanoic acids) of the action of the suckling kit’s digestive enzymes on substances in the mother’s milk. Even if bacteria did grow, rabbit kits also have passive maternal antibody protection (obtained via the placenta before birth, and in the first milk meal after birth) against infectious organisms. These factors maintain the gastrointestinal system of the preweaning rabbit in an almost sterile state. Rabbit kits fed on milk substitutes or milk of another species fail to develop this antimicrobial substance, and severe bacterial enteritis is common in handreared kits. Rabbit kits are entirely dependent on milk until 10 days of age. As the youngsters age, they begin to ingest maternal caecotrophs. Because the caecotrophs remain intact for long periods in the stomach within their mucinous coating, the microbial contents may remain protected from the ‘‘stomach oil’’ long enough to pass through into the intestine and colonize the developing hindgut. By 15 days of age some solid material is being consumed. By day 20 solid materials form the majority of the food intake and caecotrophy has begun, and by day 30 milk intake is minimal and caecotrophy is fully developed. During this same period the production of ‘‘stomach oil’’ diminishes. Gastric pH reduces to the adult level of 1–2, which provides another effective barrier against microbial colonization of the stomach and small intestine. The protection of the growing rabbit against enteric infections during the period of weaning depends on the synchronization of this transfer from one protective mechanism to another. Thus, the majority of intestinal disease cases (eg, coliform infections, coccidiosis, mucoid enteropathy

syndrome, Rotavirus-related diarrhea) in rabbit colonies occur in this period immediately following weaning.

Post-weaning gastric physiology
In the adult rabbit, large quantities of water and acid are secreted into the gastric fundic lumen. The adult rabbit's gastric pH during digestion of food material is maintained between 1 and 2, which destroys most microbial organisms, maintaining an almost sterile stomach and small intestine. Passage of food material through the stomach has been estimated to take 3–6 hours. Hydrolysis of proteins begins in the stomach, with the pepsin–HCl complex. An important exception is digestion of the mucin covering of the caecotrophs. The caecotrophs are not macerated by the teeth, and remain intact, protected by their mucinous coat, within the stomach for at least 6–8 hours after ingestion. During this time, the caecal material within the caecotrophs is protected from the adverse gastric pH, and microbial fermentation continues, leading to lactic acid formation within the stomach. The pH in the stomach during the period when caecotrophs are present increases to 3 due to the buffering effects of lactate produced by microbes in the caecotroph. The protected environment within the caecotroph has led to the suggestion that feeding intact caecotrophs obtained from a healthy rabbit may be a useful probiotic adjunct in the treatment of various pathologic conditions of the rabbit hindgut (e.g. antibiotic-related dysenterobiosis, enteritis). There are two main problems with this concept. First, it can prove difficult or even impossible to ensure that the caecotrophs are swallowed without breaking the mucin coat. Second, the intact caecotrophs are too large to pass from the stomach to the small intestine until the mucinous coat has been broken down, at which point the bacteria are exposed to the normal gastric digestive processes, and so the bacteria within the cecotroph may not survive to colonize the intestines after all.

6.1.4. Small intestine

Gut motility can be divided into a number of different processes. Segmentation is the process involved in the mixing of intestinal contents by periodic static constriction of the intestinal wall, and is particularly important in the rabbit duodenum. Peristalsis is a different process, and involves a ring of contraction moving gradually along the intestine, usually in an aboral direction.

The regulation of peristaltic movement involves a number of gastrointestinal hormones and peptides, including cholecystokinin, somatostatin, vasoactive intestinal peptide and ''substance P''. Transit time of material through the rabbit small intestine is fast compared to other herbivore species. Peristaltic contractions occur slowly every 10–15 minutes, and do not alter with the stages of the caecotrophic cycle. Chyme retention times have been estimated as 10 to 20 minutes in the jejunum, and 30 to 60 minutes in the ileum. Small intestinal motility in the rabbit, as in the human, but in contrast to most other animal species, is regulated in part by motilin, a peptide secreted by enterochromaffin cells of the duodenum and jejunum. Motilin stimulates smooth muscle contractions. Its release is stimulated by the presence of fats and inhibited by the presence of carbohydrates within the intestinal content. Macrolide antibiotics incidentally also act as motilin receptor agonists, and so may promote smooth muscle contractions.

Motilin activity decreases in the distal small intestine, is absent in the caecum, but reappears in the colon and rectum. At the distal end of the ileum, dorsal to the large intestine in the left caudal abdominal quadrant, there is a round, muscular ampulla referred to as the sacculus rotundus. This structure seems to have an immunological function and is only found in Lagomorphs. It is one of the most common sites for foreign body obstruction of the rabbit intestine. An ''ileocaecal valve'' (actually sited between the ileum and the sacculus rotundus) retards reverse flow of fluid into the ileum, and directs chyme via the sacculus rotundus to the caecum.

6.1.5. Pancreatic and hepatic secretions

As would be expected in an animal with a constantly active digestive system and low protein and carbohydrate intakes the pancreas of the rabbit is small. It is diffuse, and often difficult to locate within the mesenteric fat located between the colon, stomach, and duodenum. The main pancreatic duct enters near the end of the duodenum, well away from the entry of the bile duct. Although ligation of the pancreatic duct causes dilation of the pancreatic ductules, pancreatic enzymes still appear in the ileal lumen, suggesting the existence of other, minor pancreatic ducts. Trypsin, chymotrypsin, and carboxypeptidases are produced in the pancreas and released into the intestinal lumen. These work along with intestinal aminopeptidases to complete protein digestion. Lipases of various forms are also produced. The pancreas is an important source of bicarbonate ions that neutralize the acidic chyme entering the small intestine from the stomach.

The hepatic ducts drain from the liver parenchyma to the gallbladder via a common bile duct, and thence to the intestine via a cystic duct, which drains just distal to the pylorus. The rabbit produces around 100–150 ml of bile per kilogram bodyweight daily, independent of secretin stimulation—seven times the rate of production in the dog. Bile acids, such as cholic and chenodeoxycholic acids, are synthesized by the liver, and released into the small intestine where a proportion of these is converted by microbial activity to deoxycholic acid. The bile acids are important as detergents that break down fatty or oily material into small micelles, allowing absorption of fats and fat-soluble vitamins in the distal small intestine. The other functional components of bile are the bile pigments.

Biliverdin is produced as a breakdown product of haemoglobin, and in most mammalian species is converted by the action of the biliverdin reductase enzyme to bilirubin, before being secreted in the bile. The activity of biliverdin reductase is low in the rabbit, 60 times lower than in the rat, and 63% of bile pigment in rabbits is found as unconverted biliverdin.

Small intestinal secretive and absorptive physiology

Small intestinal digestion and absorption in the rabbit are similar to that in other species. Bicarbonate ions are secreted in the duodenum to neutralize the acidity of the chyme passing from the stomach. Most of the digestion of carbohydrates and simple proteins takes place in the duodenum and jejunum and the products of this digestion (monosaccharides, amino acids) are absorbed across the jejunal brush border. This includes digestion and absorption of the caecotroph material such as amino acids, volatile fatty acids, vitamins, and digested microbial organisms. The digestion of caecotroph microbial protein is aided by the addition of lysozyme into the caecotrophs as they pass through the large intestine. Lysis of the microbes within the caecotrophs also releases microbial enzymes, notably amylase, which enhances the rabbit's own digestive processes. The ileum also plays an important role in regulating and recycling the electrolytes secreted by the stomach and proximal small intestine by reabsorbing bicarbonate ions.

6.1.6. Large intestine

The rabbit's caecum is proportionally the largest of any mammal. It is twice the length of the abdominal cavity and 40–60% of the total volume of the gastrointestinal tract. It is a blind sac that folds into four parts (gyri). The first gyrus passes from the umbilical region cranially and to the right across the abdominal floor. It then flexes caudally and the second gyrus passes back, parallel to the first fold, caudally and to the left across the abdominal floor. The third gyrus then passes cranially along the ventral left flank, and runs again parallel to the other folds across the abdominal floor, this time cranial to the first fold and separated from it by the ascending colon. A long fold (the ''spiral valve'') extends in spiral form from the caecocolic ampulla at the junction with the colon, along these first three folds, with 20–30 ''turns.'' These first three gyri have thin, translucent walls. The ''vermiform'' appendix forms the final fold. It is a 5-inch blind tube that ends on the left flank dorsal to the first part of the caecum and has thick walls containing lymphoid tissue. The appendix secretes bicarbonate ions into the caecal lumen, which are thought to act as a buffer for the volatile fatty acids produced by caecal fermentation. Rabbits fed diets with low fibre and high fermentable carbohydrate develop an enlarged appendix. This has been used as evidence that increased appendix secretory function is needed to counteract the products of increased carbohydrate fermentation. However, it could also be explained by the increased need for lymphoid tissue due to altered microbial populations in such rabbits. Water, secreted by the appendix and colon, is continually added to the caecal contents from where it is absorbed across the caecal wall. This maintains a soft paste to viscous liquid consistency of the caecal contents. The normal pH of the rabbit caecum varies with the stage of the caecotrophic cycle. However, the mid-afternoon pH value (the most acidic period) is generally higher in adult rabbits (5.9–6.8) than in weanlings (5.4–6.3). The caecum provides an anaerobic fermentation chamber for organisms such as *Bacteroides spp*., which are found at up to 10^9/g. In addition to the ingesta, mucopolysaccharides secreted from goblet cells in the mucosa serve as a significant carbohydrate source for caecal fermentation by *Bacteroides spp*. One report describes a large, metachromatic anaerobic bacterium as the most common organism found in the caecal lumen, at 10^8 to 10^{10}/ml. Coliform bacteria are rarely isolated from normal rabbit caecal contents. They are suspected to be present in low numbers, and rapidly multiply if any rise in the caecal pH occurs (e.g. due to other gastrointestinal disease, or postmortem). Therefore, bacteriological culture even of a pure growth of *Escherichia coli* is not necessarily diagnostic of primary E. coli related diarrhea. Other criteria such as epidemiologic evidence and histopathologic findings should also be considered. Various other organisms are normally found in the caecum. Bacterial species include *Bifidobacterium spp., Endophorus spp., Streptococcus spp*., and *Acuformis spp*. in the lumen, *Clostridium, Peptococcus, Peptostreptococcus*, and *Fusobacterium* species adherent to the mucous membrane, and many unidentified anaerobic species. Many nonpathogenic protozoa are found in the caecal contents, including ciliated protozoa morphologically similar to Isotricha of ruminants (10^7/ml), flagellate protozoa such as *Eutrichomastix spp., Enteromonas spp*., and *Retortamonas spp*., and an amoeboid organism, *Entamoeba cuniculi*. A rabbit specific yeast, *Saccharomyces guttulatulus* is present at around 10^6/g and is often seen in fecal smears. Lactobacilli are notably absent from the normal intestinal flora of the rabbit. The use of Lactobacilli as a ''probiotic'' medication for sick rabbits is common. While *Lactobacillus acidophilus* may well be able to survive the rabbit's gastric pH, its usefulness is widely debated. In the authors' experience some inwater Lactobacillus products seem to be beneficial to some animals, but this may be because of effects on fluid and electrolyte intake rather than microbial colonization. The combined microbial flora of the caecum breaks down ammonia, urea, proteins, and enzymes from the small intestine and cellulose (preferentially in that order). These microbes also have the ability to metabolize xylan and pectin. The products of this metabolism are the protein and enzyme structures of the microbes themselves (which are later digested as caecotrophs), and by-products of microbial fermentation referred to collectively as volatile fatty acids (formic, acetic, propionic, and butyric acids). These volatile fatty acids (VFAs) are actively absorbed through the caecal and colonic walls and utilized by the rabbit as energy sources, as is the case in ruminants. Rabbits differ from other animals in that the level of butyric acid normally exceeds that of propionic acid. Proportions of VFAs in the caecal contents are 60–70% acetic, 15–20% butyric, and 10–15% propionic acid. Both increasing the fibre level of a diet and fasting increase the proportion of acetic acid within the caecal content. It has been suggested that butyric acid may have an inhibitory effect on peristalsis, and hence, the reduction in relative butyric acid level may be one reason why increased dietary fibre promotes gastrointestinal motility. VFAs in the blood are found in similar proportions to those in the caecal contents, suggesting that they are mostly absorbed unchanged into the blood. However, the presence of lactic acid within the blood even when caecotroph ingestion is prevented suggests some degree of parietal metabolism. Prevention of caecotrophy has little effect on circulating levels of VFAs, but high VFA levels within the caecal lumen and blood have been investigated as trigger factors in the initiation of the caecotrophy cycle.

Colon and fusus coli: anatomy and regulatory physiology

The colon of the rabbit is divisible into a number of different positional and morphologic parts. The ascending colon is very long, and divided into five limbs extending forwards and back separated by flexures. The first limb has three taeniae forming three rows of sacculations referred to as “haustrae”. In the second and third limbs the taeniae combine to a single taenia and one row of haustra. The remainder of the ascending colon has no taeniae, and lies coiled in the dorsal part of the abdominal cavity. Faecal pellets can first be distinguished towards the end of the ascending colon. The transverse colon is short, and ends in a muscular thickening known as the “fusus coli”, a structure unique to lagomorphs. The separation of the colon into two anatomical and physiologic parts by the fusus coli has led to a renaming of these as “proximal” and “distal” colon, rather than using the more traditional ascending/transverse/descending nomenclature. The fusus coli is a differential pacemaker for the initiation of peristaltic waves in both proximal and distal colon, and regulates the separation (by contractions of the taeniae/haustrae) of fermentable material from indigestible fibre. Researchers have shown correlations between fusus coli activity and several potential regulatory mechanisms, including autonomic nervous influences and circulating levels of prostaglandins, aldosterone, and other substances. Aldosterone levels are highest during hard faeces production. However, it is not clear whether this is cause or effect of the fusus coli activity. Prostaglandins have been shown to inhibit the motility of the proximal colon and stimulate the activity in the distal colon, aiding the production of caecotrophs. The involvement of the autonomic nervous system and adrenal glands in the regulation of the fusus may be the reason (rather than immunosuppression) why rabbits are prone to stress related gastrointestinal disease. After the fusus coli, the descending colon and rectum return to simple tubular form with thicker walls.

Food intake and caecotrophy: temporal relativity

Caecotrophs are pellets produced at the anus from the partially fermented matter of the caecum rather than from unwanted fibre. Because they are not waste material, they are not, strictly speaking, faeces, although the term “soft faeces” is used synonymously with “cecotroph”. The process of cecotroph ingestion is erroneously referred to as coprophagy. The cecotrophs are ingested by the rabbit directly from the rectum as a result of a neurologic licking response, and are swallowed whole without being chewed. Caecotrophy is influenced by light, ingestive patterns, and varies between captive and wild rabbits. In wild rabbits most of the caecotrophy occurs during daytime when rabbits are within their burrows. This is in contrast to the situation in captive rabbits, where most of the caecotroph ingestion occurs at night although it can occur at any time of the day or night. Feed intake patterns inversely follow caecotroph production—when caecotrophy is taking place, food ingestion ceases.

Hunger is stimulated by a number of factors including a dry mouth and decreased blood levels of metabolites such as glucose, amino acids, and volatile fatty acids. Caecotrophy usually follows about 4 hours after ingestion of food. Caged rabbits on a normal daylight pattern and fed ad libitum show an increase in food intake from 3:00 to 5:00 PM, and food intake remains high until midnight. There is then a decreased food intake until 2:00 AM, followed by a further increase peaking at 6:00 AM and ending at 8:00 AM. Caecotrophy therefore occurs mainly in the periods between midnight and 02:00 AM, and again at 08:00 AM. When rabbits are fed a restricted feeding regime rather than ad libitum, caecotroph production is related to time of food ingestion and loses its influence from light signals. The degree of caecotroph ingestion is directly related to the fibre content of the ingested foods. Caecotroph ingestion is highest when rabbits are fed on a diet high in nondigestible fibre. Dietary fibre is distributed at a set ratio between hard faeces and caecotrophs. Caecotrophs have around 50% of the crude fibre level of the "hard feces". This is regardless of the level of fibre in the food material. However, if dietary protein is restricted, the protein level in the hard faeces drops whilst that in the caecotrophs is conserved.

The ''hard faeces'' phase

Initially the caecum is relatively empty, having just expelled its content in the previous "soft faeces phase". Small intestinal material derived from ingested food passes through the ileocaecal valve and sacculus rotundus, and is distributed evenly into the caecum and proximal colon. Little caecal fermentation occurs at this stage, and the caecum contracts, expelling most of its contents into the proximal colon. Water is secreted by the proximal colonic wall, which aids the processes of mixing and separation of the contents. Under the control of the fusus coli, three separate contraction types occur. There is a progressive monophasic peristaltic wave of 5 seconds duration, and a segmental low-frequency 14-second duration contraction. These both progress in an aboral direction. The third contraction type is that of the haustrae, which undergo high-frequency contractions of 3-second durations, which repeatedly churn the colonic contents. Particle and fluid flow dynamics during this "churning" process dictate that indigestible fibrous particles of greater than 0.5 mm length accumulate within the central lumen of the proximal colon. Smaller particles are moved to the periphery where they congregate in the pocket-like haustrae. The central fibrous material passes rapidly distally and is formed into "hard faeces" by the physical compressive actions of the fusus coli. Further, water, electrolyte, and volatile fatty acid absorption occurs as the pellets pass through the distal colon, and they are finally expelled as small, dry, hard faecal pellets (Photo). They do not have a mucus covering. Digestible components and fluid, which have accumulated in the haustrae, are passed by retrograde peristalsis back up the colon and into the caecum for fermentation.

Caecotroph production — the "soft faeces" phase

Following fermentation, the caecal contents form a soft dark green paste, which is rich in semi digested food material as well as microbial organisms. Various mechanisms that might trigger caecotroph production have been suggested, including increased VFA concentration, eating behaviour, and the presence of food materials in the stomach or small intestine, in addition to the controlling influences over fusus coli function that have already been discussed. The contractions that functioned to maintain the separation of fluid and different-sized particles during the hard faeces phase now decrease. Peristaltic monophasic contractions increase, occurring every 1.5 seconds. The caecum contracts and the caecal contents are passed rapidly through the colon. Colonic transit time during the "soft faeces" phase (Photo 40) is reportedly 1.5–2.5 times faster than during the "hard faeces" phase. The fusus coli contractions during caecotroph production are more gentle, and do not expel the fluid from the pellets. Goblet cells in the fusus secrete mucus. As the caecotroph pellets pass through the distal colon lysozyme is added, and the pellets are coated with mucus. Caecotrophs arrive at the anus and are ingested directly in bunches as a response to a number of factors, including rectal mechanoreceptor stimulation, olfactory stimuli, and blood concentrations of various metabolites and hormones.

Source: www.mekarn.org

Photo 40: Caecotroph (left) and hard droppings (right)

6.2. Nutritional requirements of the rabbit

For small and medium scale rabbit units it is reasonable to consider only one type of recommendation for all types of rabbit, corresponding in the nutritional tables to a mixed or single feed. The main nutritional recommendations are summarized in the Table 2. More detailed recommendations, especially the ratios between the different fibrous fractions are available. For a possible modulation of these recommendations according to the physiological situation, crude protein level could be increased up to 18% for lactating does, and calcium could be reduced down to 0.8% for growing rabbits. Another important point is that nutritional requirements expressed as composition of a complete diet are the same whatever the genotype of rabbits.

Table 2: Recommendation of nutrients for rabbit feeding

Type or period of production Without any other indication, unit = g/kg as fed (90% DM)		GROWTH		REPRODUCTION (1)		Single feed (2)
		18 to 42 days	42 to75-80 days	Intensive	½ intensive	
GROUPE 1 : Recommendations for the highest productivity						
Digestible Energy	(kcal / kg)	2400	2600	2700	2600	2400
	MJoules/ kg	9,5	10,5	11,0	10,5	9,5
Crude Protein		150-160	160-170	180-190	170-175	160
Digestible Protein		110-120	120-130	130-140	120-130	110-125
ratio Digest. Protein / Digestible Energy	(g / 1000 kcal)	45	48	53-54	51-53	48
	(g / 1 MJoule)	10,7	11,5	12,7-13,0	12,0-12,7	11,5-12,0
Lipids		20-25	25-40	40-50	30-40	20-30
Amino acids						
- lysine		7,5	8,0	8,5	8,2	8,0
- sulfur amino acids (methio.+cyst.)		5,5	6,0	6,2	6,0	6,0
- threonine		5,6	5,8	7,0	7,0	6,0
- tryptophan		1,2	1,4	1,5	1,5	1,4
- arginine		8,0	9,0	8,0	8,0	8,0
Minerals						
- calcium		7,0	8,0	12,0	12,0	11,0
- phosphorus		4,0	4,5	6,0	6,0	5,0
- sodium		2,2	2,2	2,5	2,5	2,2
- potassium		< 15	< 20	< 18	< 18	< 18
- chloride		2,8	2,8	3,5	3,5	3,0
- magnesium		3,0	3,0	4,0	3,0	3,0
- sulphur		2,5	2,5	2,5	2,5	2,5
- iron (ppm)		50	50	100	100	80
- copper (ppm)		6	6	10	10	10
- zinc (ppm)		25	25	50	50	40
- manganese (ppm)		8	8	12	12	10
Fat-soluble Vitamins						
- vitamin A (UI / kg)		6 000	6 000	10 000	10 000	10 000
- vitamin D (UI / kg)		1 000	1 000	1000 (<1500)	1000 (<1500)	1000 (<1500)
- vitamin E (mg / kg)		≥30	≥30	≥50	≥50	≥50
- vitamin K (mg / kg)		1	1	2	2	2
GROUPE 2 : Recommandation for the best health possible for rabbits						
Ligno-cellulose (ADF)		≥ 190	≥ 170	≥ 135	≥ 150	≥ 160
Lignins (ADL)		≥ 55	≥ 50	≥ 30	≥ 30	≥ 50
Cellulose (ADF – ADL)		≥ 130	≥ 110	≥ 90	≥ 90	≥ 110
ratio lignins / cellulose		≥ 0,40	≥ 0,40	≥ 0,35	≥ 0,40	≥ 0,40
NDF (Neutral Detergent Fiber)		≥ 320	≥ 310	≥ 300	≥ 315	≥ 310
Hemicelluloses (NDF – ADF)		≥ 120	≥ 100	≥ 85	≥ 90	≥ 100
ratio (hemicelluloses+pectins) / ADF		≤ 1,3	≤ 1,3	≤ 1,3	≤ 1,3	≤ 1,3
Starch		≤ 140	≤ 200	≤ 200	≤ 200	≤ 160
Water soluble Vitamins						
- vitamin C (ppm)		250	250	200	200	200
- vitamin B_1 (ppm)		2	2	2	2	2
- vitamin B_2 (ppm)		6	6	6	6	6
- nicotinamid (vitamin PP) (ppm)		50	50	40	40	40
- pantothenic acid (ppm		20	20	20	20	20
- vitamin B_6 (ppm)		2	2	2	2	2
- folic acid (ppm)		5	5	5	5	5
- vitamin B_{12} (ppm)		0,01	0,01	0,01	0,01	0,01
- choline (ppm)		200	200	100	100	100

(1) For does, ½ intensive production means a average yearly production of 40-50 weaned kits in the rabbitry, and an intensive production corresponds to a higher productivity (more than 50 kits /doe/year). (2) The single feed recommendation corresponds to a diet used for all rabbits in the rabbitry. It is a compromise between requirements of the different categories of rabbits.

Source: de Blas and Wiseman, 1998

6.3. Feedstuffs for rabbits

For rabbits as for any type of animal raised by farmers, feeding strategy would be based on feeding behaviour and nutritional requirements whatever the dimension of the production unit. Once these initial points known, for small and medium scale unit feeding strategy of rabbit breeders depends first of all of the type and source of feeds available for the unit. For units situated in an urban context (about 41% of the total population in Asia), with no or only a very small surface cultivable for rabbits, the main source of feeds can be only raw or manufactured materials (complete feeds) purchased from the local market. For units situated in the countryside, the situation would be more open with the same possibilities than in urban areas and in addition the possibility of utilization of raw materials produced on the farm for rabbits or collected around it.

The sources of raw material usable for rabbit feeding are very numerous but according to the country or the urban environment, only some raw materials are effectively available for practical rabbits feeding. To help in the choice of the most suitable ones, a list was established out of the encyclopaedic data basis "Feedipedia". This data basis is freely available on Internet at the URL www.feedipedia.org.

Rabbits are more or less able to correctly regulate their daily feed intake according to the diet's digestible energy concentration. If a feed ration respects the nutritional recommendations summarized even without consideration of the digestible energy, the corresponding diet is necessarily within the range of digestible energy ingestion regulation. Thus the next most important parameters to estimate the nutritive value of a feedstuff to be introduced in a balance diet are:

- the proteins level and these proteins amino-acids balance;
- the quantity and type of fibre (highly or poorly digestible according mainly to the lignin level);
- and the ability to provide calcium and phosphorus.

For the rabbit, a raw material could be an interesting source of protein, of amino acids, of fibre or of minerals if the content exceeds recommendations.
All cereal are poor in proteins and lysine, covering on average only 62 and 65% of requirement respectively, with the noticeable exception of quinoa grains rich in lysine. On the contrary their proteins are relatively rich in sulphur amino acids (116% of requirements on average). For other studied nutrients, cereals provide a small to very small proportion of requirements. Thus cereals are mainly sources of energy and secondarily of sulphur amino acids.
Some cereals by-products on the contrary could provide an appreciable proportion of proteins rich in sulphur amino acids but again with a low proportion of lysine. They could provide a high proportion of phosphorus requirements, with the exception of maize and sorghum bran and oats hulls, but for all of them as for the cereals grains, the content of calcium is very low. Cereal by-products represent an interesting source of fibre (123% of NDF requirement) but with a lignin content a little bit too low for rabbits (84% of requirements for ADL).
All studied legume seed are interesting sources of proteins (148% of rabbit's requirements on average) with the only exception of tamarind seeds. Most of them are also sources of lysine (125% of requirements on average) but they provide only few sulphur amino acids.
Their contribution to calcium, phosphorus and fibre balance are also poor.
Most of the legume seed by-products are poor sources of protein with the noticeable exception of the guar meal (germ+husk obtain after mechanical separation of the guar seed endosperm). The proteins are also poor in lysine (in opposition with the seeds proteins) and sulphur amino acid, only the elephant's ears pods are rich in lysine. The contribution of legume by-products to Ca and P is poor with again the exception of the elephant's ears pods, rich in calcium, and the guar meal rich in phosphorus.

A greater number of grasses could be used in rabbit feeding. Most of grasses can contribute only partially to the protein content of rabbit ration (59% of requirements on average). The lysine content of these proteins may vary widely and cover from 62 to 126% of lysine needs. Contrary to the grass seeds and grains, the sulphur amino acids content of forage grasses proteins, is below the rabbits requirements for almost all of these raw materials. If the contribution for calcium and phosphorus remains poor around 40% of requirements, the contribution on total fibre is really substantial: 188% of NDF requirements on average, but that of lignin is more variable and represent on average only 91% of requirements (from 44 to 113%).

On average the legume forages or *Fabaceae* forages according to the last denomination, provide a proportion of protein in dry matter corresponding to the rabbits requirements (98% on average), but variations from one forage to the other are very wide : covering from 51% of proteins requirement with low quality hay, up to 136-137% with fresh white clover. Some reasons of such variation are the classical variations with vegetative stage and type of plant but also with conditions of harvesting. The small leaves are very rich in proteins (up to 28-30%/DM) but they are also easily lost during the harvesting and drying process.

Because of their relatively high level of protein, legume forages present some potential interest for monogastric animals. For this reason a higher proportion of these forages were analyzed for the amino acids content. In the proteins, the lysine content is relatively close to rabbits requirement (94% on average) but with variations between 70% for example in the aerial part of soybean plant forage, up to 132% in the aerial part of common pea (*Pisum sativum*). It must be underlined that it is not possible to establish a simple relation between the lysine content of the seeds and that of the forage of the same plant. Some legume forages could be a good source of calcium but for some other the content is too poor for rabbit feeding. Nevertheless on average the legume forages content represents 127% of rabbit's requirements. For phosphorus the contribution is only 53% on average. Systematically the NDF content cover largely rabbits requirements (127% on average) and frequently, but not systematically that of lignin: 142% on average with variations from 69% up to 230%.

Roots, tuber or fruits are poor providers of proteins, and these proteins are in addition relatively poor in lysine and in sulphur amino acids. Only the relatively high proportion of lysine in the proteins in fodder beet, carrots and potato deserves some attention. These types of feeds are also deficient in calcium, phosphorus and fibre.

For the by-products of this heterogeneous group of feeds, the contribution to rabbit's requirements varies widely from one product to the other. It could nevertheless be underlined that it is in this by-product group, that are feed ingredients with the highest lignin level, even if the ADL method don't always separates correctly the true lignin and tannins.

With few exceptions, oil seed and the corresponding meals or cakes are potential important sources of proteins. Only sunflower seeds, maize germ oil meal, and peanut cake have lower protein content than the rabbits' requirement. According to botanical source these proteins are rich in lysine or sulphur amino acids, rarely in both together as it is the case for rapeseed meal, canola meal or sunflower meal. On the other hand, some meals or cakes frequently used such as groundnut meal or palm kernel meal are simultaneously deficient in lysine and sulphur amino acids. With few exceptions, the calcium content of this group of products is lower than requirements (44% on average) but rich in phosphorus (151% on average). The NDF content (40 to 209% of requirements) and that of lignin (9-395% of needs) vary so widely from one product to the other, that the calculation of an average is totally meaningless.

Most of the animal products are good sources of proteins. Fish meal and blood meal are interesting sources of lysine and the silkworm pupae meal also. Feather meal and silkworm pupae meal are good sources of sulphur amino acids, but attention must be paid to the correct

hydrolysis of feather meal, otherwise the proteins digestibility, and consequently that of all amino acids, are quite nil. The animal products are generally interesting sources of calcium and phosphorus and, despite some chemical results, completely devoid of fibre.
Among the classical sources of calcium and phosphorus only bone meals and dicalcium-phosphate are sources of phosphorus. Egg shells and limestone provide exclusively calcium.

6.4. Feeding behaviour

Different points must be underlined and taken account in the daily practice of rabbit feeding:

- Total digestive transit is relatively short (16-24 hours) when compared to other herbivorous animal (about 60 hours for a cow or 30 hours for a guinea pig).
- Contrary to the ruminants, an increase of the diet's fibrous content induces a acceleration of the speed of transit time in the rabbit. Correspondingly rabbit has a high capacity to adapt its feed intake to the fibre level of its ration: daily feed intake increases with the diet's fibrousness. This is mainly the consequence of the regulation of the energy daily intake: fibre digestibility is lower than the average digestibility value of the diet. Thus, an increase of the fibre content induces a decrease of the digestible energy content. In order to obtain enough energy, the rabbit offset the lowest energy concentration by an increase of the daily intake of the more diluted ration.
- The instantaneous capacity of ingestion is limited by the stomach small capacity: a content of about 15-18 g of dry matter for a stay of 1 to 2 hours and an average daily intake of 110-120 g (for a growing rabbit of 2kg).
- When it is fed *ad libitum* a pelleted complete diet, the rabbit makes about 35-40 meals per day (3-5g each), mainly during the dark part of the 24 hours. If the feed is distributed in limited quantity, the ingestion begins immediately after the distribution, but the rabbit makes the same number of meals per day just more close to each other.
- With pellets feeding, the rabbit spends about 10% of the 24 hours cycle to feed. If the feed is presented as meal instead of pellets this duration is multiplied by 1.5 to 2 and a great part of this time is devoted to scratch in the feeders to search more interesting fractions or particles. If the daily ration contents an important part of forages, this time could be multiplied by 3 or 4.
- Two or 3 rabbits are able to eat simultaneously in the same feeder without competition problems because once the feed is taken in the feeder (5-10 seconds) each rabbit removes his head from the feeder to chew during 0.5 to 1 minute and then after introduces again the head in the feeder for 5-10 seconds.
- When ambient temperature increases above 28-30°C the feed intake is reduced. This drawback could be partially, but only partially, offset by increasing the lipid concentration of the feed or by increasing the protein/energy ratio of the diet. Conversely, if the ambient temperature is below 10°C, the rabbit increases its food intake to compensate for the energy cost of thermoregulation. It can even endure a temperature of minus 15 to 20 °C below zero in the condition of having a water source (roots, unfrozen water, etc.).
- When a concentrate (low fibre diet compound diet) and a dry fibrous material are proposed as free choice to rabbits, they prefer the concentrate. The fibrous material is consumed in only small quantities and the growth rate may be reduced.
- The consequence is also an immediate increase of the sanitary risk for rabbits with digestive disorders by lack of fibre. If the fibrous material is presented fresh (green) the

balance between concentrate and forage is more difficult to predict, and the recommendation is to propose the more palatable in restricted quantity.

- The maximum intake capacity of a rabbit per day is about 5 to 9% of its live weight expressed as dry matter. For example dry matter intake of a rabbit doe varies from 3.5% of her live weight when she is empty and dry, up to 8-9% of the live weight at the peak of lactation. With the high speed growth selected lines, the dry matter intake may represent up to 10% of the live weight at peak of growth (when 35-40 days old).
- The need of water is about twice that of the dry matter intake, with an increase of the proportion when temperature is above 28-30°C. It means that if rabbits receive a daily ration with a minimum average content of 70-75% of humidity, water distribution is not "necessary" even if it is strongly recommended. In any other cases the distribution of clean water is absolutely necessary.

6.5. Practical feeding

Use of pellets and complete feeds

If complete pelleted feeds (Photo 41) are used for rabbits as exclusive source of nutrients, whatever the dimension of the rabbit unit, the best solution is to follow recommendations proposed by the feed manufacturer and to distribute *ad libitum* clean water in addition to the pellets. This is why this solution is not more broadly described herein. The only additional remark is that if the commercial so called complete feed has a too low level of fibre, it is advisable to distribute in addition some very palatable fibrous forages (alfalfa or grasses in general) to provide the fibre lacking in the pellets. The quantity may represent 10-20% of the daily dry matter intake, and the farmers must remember that almost always rabbits prefer the feeds in that order: green forages > pelleted complete feeds > dried forages > non-pelleted complete feeds.

Source: grahamfeedandfarmcenter.com

Photo 41: Rabbit pellet

Small units and direct use of raw materials

In small units of production, if raw materials are at the basis of rabbit's nutrition, the breeder, if possible with the help of the technician of an extension service, must search in his environment (crops, market, and uncultivated areas) which raw materials are available or possible to produce in the farm. Then he determines the ability of each to cover rabbit's nutritional requirements. To obtain a more or less balanced diet it is necessary to be able to propose to rabbits at minimum one raw material rich (more than 100% of requirement) for each of the main nutrients listed in the tables 2 to 9. According to climate and conditions of cultivation, with 1000 m² of crop cultivated exclusively for rabbits, one may expect to produce 15 to 60 slaughter rabbits per year. This idea of productivity may be useful to determine to real possibilities of rabbits feeding with home-made products, or with raw or manufactured material purchased on the market.

It is not advised to mix roughly non processed raw material because of the great ability of rabbits to select some parts of a mixture, to eat only the most palatable ones and then destroy the nutritional balance proposed by the breeder. In addition, when a rabbit seeks the most palatable parts, he scratches inside of the feeder and can waste up to 40-50% of the distributed mixture. One of the best ways is to distribute the dry concentrates such as cereals or cakes separately, in limited quantity in the morning. This makes possible a visual control of the real intake. The quantity distributed must be completely eaten within 6-7 hours. In many conditions, the concentrated raw materials may be economically replaced by complete rabbit feeds if possible pelleted. In this situation it is advisable that the pellets don't represent more than 40-50% of the daily dry matter ration, the other part being constituted by various forages.

It must be pointed out that in no case rabbit pellets + cereals can constitute a balanced diet, especially for reproduction. At the end of the afternoon, green forages can be distributed, in racks but never on the floor of the cage, in such quantity that, in the next morning, only very few or none of the distributed quantity remains in the rack. This remaining part should be discarded. Dry forages (hay) could be distributed *ad libitum* but in a different part of the rack if they are used simultaneously with greens.

In most regions, forages, the main source of the fibre for rabbits, are not necessarily available in the green form all the year round with optimum nutritive value. Consequently, the production and storage of dried forages is strongly encouraged for small breeders. The green forages can be harvest in small quantities, day after day, during the rainy season and/or at the beginning of the dry season, and sun dried in the immediate vicinity of the farmer's house. The advantage of drying in the vicinity of the house is the possibility for the farmer or his family to temporarily and quickly put the forage during drying process, out of the rain in a shed or an annex to the house for a few hours, waiting for the return of the sun.

Almost all forages, tree leaves or foliage can be sun dried. In the above chapters it was mentioned that during the drying process, one part of the nutrients could be lost, mainly the small leaves rich in proteins and carotene. But it is clearly preferable to have forage with a little bit lower quality than not having one at all. Moreover the farmer could harvest cultivated forages, weed forages or spontaneously grown forages or tree leaves, at the optimum of their nutritive value, while for the green forages the nutritive value declines gradually and irremediably as the plant matures.

Medium scale units and direct use of raw materials

All recommendations done for small units are suitable for medium one. Only the drying process of forages needs a better organization and specific means because quantities are greater. Medium scale production units can produce their own complete feed, alone or in association with some (3-4) nearby other medium rabbit units.

The only equipment strictly necessary is a forage grinder and a balance this small equipment is available for example from different farmer’s shop for a reasonable amount of money.

This type of forage grinder with a large "entry" is perfectly able to grind dried forages, cereals and any type of dry by-product. In extreme cases it is even able to grind half-dried products (used without grid), the obtained wet meal being easier to dry completely than the

raw product. The interest of grinding is to obtain a homogenous coarse meal (not a powder) whatever the processed raw material. The adequate quantity of the meal obtain from each raw material used in a dietary formula are weighted and then mixed together and with additives (minerals in powder, premix, pure amino acids if necessary, etc.) A correct mixture can be obtained by hand with a shovel on a cemented area, or with a mechanical mixing device. The later is not necessary equipment if the quantities to be mixed at one time are not too important. If the mixed raw meal obtain is not too dusty, the mixture can be distributed in this form to rabbits. Nevertheless it is strongly advised to pelletize this meal. Efficient pellet machines are available on the international market at low cost. The small pellet machine can be loaded by hand and the obtained hot pellets can be cooled by simple repartition in thin layer on a cemented area.
If the farmer must choose between a mixer and a pellet machine because of the price of the whole equipment, he has clearly to choose the pellet machine.
As mentioned for the small units, the home made pellets can be used alone or as a complement of green or dried forage. The farmer can easily produce different types of feed adapted for example to reproducing does, to just weaned or fattening rabbits, etc. Because the whole equipment is not very bulky it can be placed "fixed" on a trailer and transported in the vicinity to be used by 3 or 4 other breeders successively. It may be easier to carry the complete processing equipment, than to carry to a single working location the raw materials produced by the different farmers. If the option of making pelleted diets at home is not chosen a commercial diet can used without problem in the conditions described for small units.

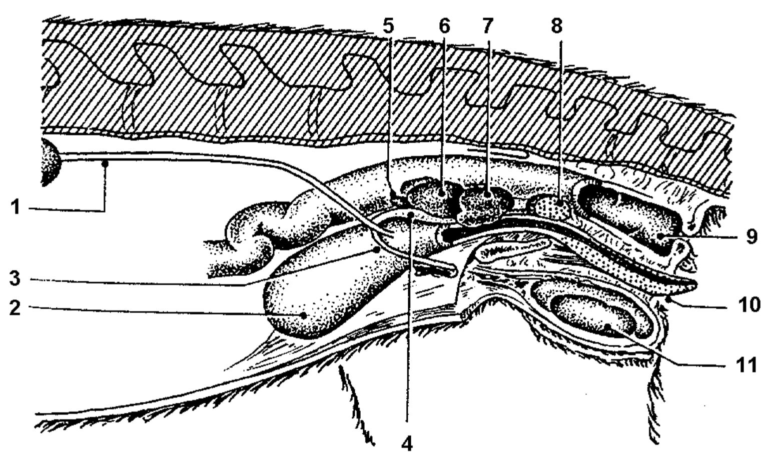
7. REPRODUCTION

Rabbits are known for reproducing, or breeding, frequently and for multiplying rapidly. There are many reasons for this. They do not have a heat period once a year as many animals do. Rather, rabbits can breed during any month of the year. Also, rabbits gestate for only 28 to 31 days, allowing them to have litters as much as five or six times a year. In addition, those litters are usually large, with up to ten baby rabbits per litter. Finally, rabbits can start breeding at a very young age; as young as five months old. Female rabbits release eggs during copulation and can conceive almost immediately after giving birth to a litter.

7.1. Management of the buck

7.1.1. Anatomy and physiology of the male rabbit

In the male, the oval-shaped testes within the scrotum remain in communication with the abdominal cavity, where they were at birth. The rabbit is actually able to withdraw its testes when frightened or fighting with other males. The testicles descend at about 2 months. The short, back slanting penis points forward when erect. Figure 9 shows the relative position of the various organs.



1. urethra
2. bladder
3. ductus deferens
4. ampulla ductus deferentis
5. vesicular seminalis
6. paraprostatic gland
7. prostate
8. Cowper's gland
9. rectum
10. penis
11. testis with epididymis

Source: Barone et al., 1973

Figure 9: Reproductive organs of the rabbit buck

Sexual maturity, defined as the moment when daily sperm production ceases to increase, is reached at 32 weeks by New Zealand White rabbits in temperate climates. However, a young buck in these same conditions can be used for reproduction from the age of 20 weeks. Indeed the first manifestations of sexual behaviour appear at days 60-70 when the rabbit makes its first attempts at riding. Coitus may occur for the first time at about 100 days, but the viability of the sperm cells is very weak or nil in the first ejaculates. So the first mating should be timed for age 135-140 days.

All these figures are to be considered approximate. The onset of puberty varies from breed to breed, but conditions in the rabbitry also play an essential role, particularly feeding, which is even more important than climate.

7.1.2. Characteristics of the rabbit semen

The ejaculated semen in rabbits comprises the spermatozoa suspended in the seminal plasma. Seminal plasma contains a number of substances secreted by epididymis and accessory glands (Table 3). This is a liquid containing high concentrations of fructose, citric acid, and also includes inositol, glycerol, ergothioniene, glutamic acid, certain enzymes, proteins, electrolytes and small lipid drops.

Table 3: Composition of the rabbit semen

Parameters	*First ejaculate*	*Second ejaculate*
Volume (without gel fraction) (ml)	0.1 - 1.1	0.2 - 0.4
Volume of the gel fraction (ml)	0.32 - 0.50	0.1 - 0.18
Ejaculates with gel fraction (%)	54	15
Spermatozoa/ml semen (x 10^6)	280 - 1,050	420 - 800
Sperm motility (%)	58 - 90	57 - 87
Motility rate (0 - 5)	2.3 - 3.3	2.0 - 4.8
Distal cytoplasmatic droplet (0 - 5)	0.6 - 1.0	0.4 - 0.8
Sperm agglutination (0 - 5)	1.2 - 2.0	0.8 - 1.6
pH	7.7 - 8.4	
Seminal plasma		
Fructose (mg/ 100 ml)	40 – 150	
Sorbitol (mg/100ml)	80	
Citric acid (mg/ 100 ml)	70 – 200	
Protein (mg/ 100 ml)	4 – 15	
Glycerylphosphorylcholine (mg/100ml)	215 – 370*	
Sodium (mmoles/l)	80 – 140	
Potassium (mmoles/l)	23 – 120	
Phosphorus (mmoles/l)	1 – 3	
Magnesium (mmoles/l)	2 – 4	
Calcium (mmoles/l)	2 – 8	

* Whole semen

Source: Alvarino, 2000

The volume of semen varies between 0.3 and 6.0 ml depending on the secretion of accessory glands (gel fraction). Sperm concentration range from 50 to 500×10^6/ml. False mountings, 1 or 2 minutes before copulation, increase the concentration of the ejaculate. In 2 successive servicing the first acts as a preparation for the second, which is less voluminous but more concentrated. During subsequent matings the volume of the ejaculate decreases, while concentration increases between the first and the second ejaculate and then diminishes. The total number of spermatozoa per ejaculate follows the same trend. Maximum spermatozoa production is obtained by using the buck regularly once a day. If the buck is used regularly twice a day, each ejaculate has only one half the concentration of spermatozoa. On the other hand, if bucks service several times a day, 1 day a week, the 3 or 4 ejaculates may be concentrated enough to effect fertilization. Further ejaculates contain very little spermatozoa and cannot effect fertilization often enough to be worthwhile.

The pH measured just after semen collection ranges between 6.8 and 8.4 and is a good index to estimate semen quality.

7.1.3. Factors affecting semen composition

Breed and age

Several parameters, such as the volume of the semen and gel fraction, sperm motility, sperm concentration, morphological alterations, or fructose concentration show high variations among the different breeds. Such differences should be relatively considered because of the high individual variability observed in each breed.

The mean volume of semen, mean sperm concentrations, as well as the fertility and litter size at birth are influenced by the age of the bucks. Globally, these parameters increase over time and higher values are observed in bucks of 5 month to 24 months versus older bucks. A significant effect of the age on sperm concentration, libido, sperm volume, motility and pH was also reported, confirming previous data.

Comparing the quantity of abnormal spermatozoa (16.1%, 16.5%, 27.3%) in the semen of the examined breeds (Pannon White, New Zealand White and Angora), it was observed that the ejaculates of Angora bucks contained more than 10% less normal spermia than the breeds with normal hair. Although, by reason of various types of abnormalities, great individual differences can be experienced and yet it can be found that the abnormalities of acrosoma (1.52%, 1.71%, 8.24%) and tails were generally prevalent. The incidence of abnormal acrosoma of the Angora bucks involved in the experiment was five times higher than the observed values of the other two breeds. This finding verifies that the semen is less fertile and it can directly cause the relatively reduced prolificacy of Angora breed. The incidence of abnormalities to such an extent can be explained both by the unfavourable consequence of heat stress associated with long wool and by significant genetic effect.

Seasonality of breeding and spermatogenesis

In some domestic species such as the boar, horse, ram, and rabbit spermatogenesis shows seasonal variations related chiefly to photoperiod and temperature. Wild bucks show a seasonal breeding pattern with the peak activity occurring in the spring. Several studies found bucks with testes exhibiting active spermatogenesis during every month of the year with a peak of fecundity occurring during April, May and June. Changes in the scrotal testis length provide a good indicator of the reproductive status of the male. This parameter may be influenced by changes in photoperiod. GnRH release is influenced by the photoperiod with a higher level of GnRH release in the evening than in the afternoon hours. Seasonal variations in GnRH release occurred even in bucks maintained in a fixed 12L:12D photoperiod. There were seasonal changes in the secretion of GnRH with the lowest values occurring just before the winter solstice. The frequency of GnRH pulses increased after the winter solstice, and GnRH release increased during and within one month after the summer solstice. Testis weight was highest in August and lowest during the winter. These strong seasonal breeding patterns are not observed in the domestic bucks, while the highest sperm volume and concentrations were found from March to June and the lowest at the beginning of the autumn. These parameters are also influenced by the local climate. Changes in the pH of semen and morphological alterations of the sperm increase during the summer. High temperatures (higher than 27 ºC) can affect fertility due to increasing semen pH values and morphological alterations, as well as a decrease in sperm motility and libido.

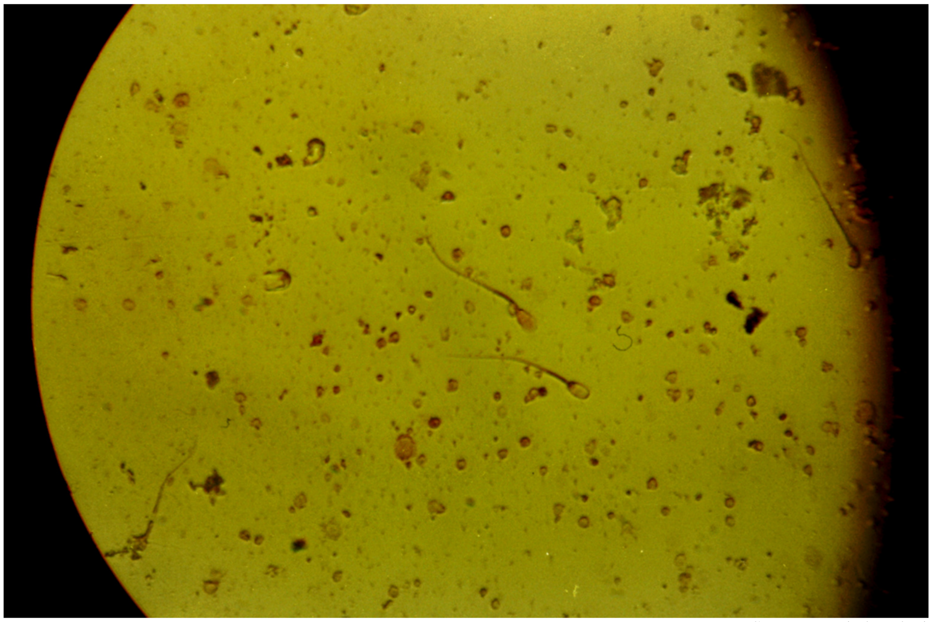
The incidence frequency of abnormalities of the meat rabbit breeds is definitely seasonable. The 10% ratio of deformations observed in winter reached 20% for summer. The Angora bucks performed poorer semen quality (25-30%) each season. The difference between Angora and normal haired breed decreased in winter. However, the deformation ratio even in that condition has increased in value than that of the stock of normal hair. It seems on the basis of observation that heat stress associated with long wool is responsible for the unfavourable development of abnormalities to a great extent. Interaction has not been detected between the genetic and the seasonal effect.

Angora bucks were kept in normal hair by frequent sharing during an experiment. Comparing the ejaculates and fertility of the normal hair breed (Pannon White) with the production of the Angora bucks, it can be found that the Angora bucks perform more than 10% less living spermatozoa and 10-18% more abnormal ones. This unfavourable condition was also reflected in the results of insemination. The fertility of Angora bucks was extremely low (32.7%) particularly in summer. The data of litter size followed the changes of the quality of semen each season. The quality of sperm and the fertility of Angora males were considerably behind those of the normal hair breed in spite of short fleece and apart from the seasons. The above mentioned fact comes to the conclusion that the fertility of bucks is determined decisively by the genetic background and to a lesser degree by the environment.

Feeding

The libido and sperm output/ejaculate are influenced by the feeding level, but semen quality seemed to be unaffected. Males fed ad libitum showed increased semen volume, spermatozoa/ejaculate and better libido. However, their sperm concentration (spermatozoa/ml) was comparable with the males fed with a restricted diet. Excepting the pH, semen quality was not affected by the diet. Only a slight effect on the initial pH was observed. Severe feed restriction can affect the sperm volume and number of spermatozoa/ejaculate. This management is not recommended for young males. Males fed ad libitum or with low or high protein levels showed no acrosome defects nor alterations of the live:dead spermatozoa ratio (Photo 42). Semen quality was not affected by a dietary supplementation of vitamins C and E. β-carotene (carrot) supplementation of bucks was effective on semen production. Feeding of carrot has resulted in significant improvement ($P<0.05$) in all of the examined quality traits (semen concentration has increased 65%, the ratio of living spermatozoa 14% while the ratio of intact spermatozoa 8%). Although good quality pellet for rabbits seems to cover the daily ß-carotene requirement of breeding animals, the semen quality of bucks can be improved by feeding extra quantity of carotene. The applied feed supplement is natural and cheap.

A negative effect was described on sperm parameters and blood concentrations of LH and FSH of lead and cadmium given in drinking water. Similar results were found after subcutaneous injections of lead acetate. Exposure of rabbit semen in vitro to lead, reduced the fertilizing ability of treated sperm, lowering the fertility rate from 82 to 68%.



Source: Bodnár Károly

Photo 42: Dead (upper) and live (below) spermatozoa (eosin-nigrosin)

Semen collection pattern

An improvement of semen production was reported when males were grouped together 3 hours before semen collection. This technique revealed to be a simple and effective method to enhance the volume of ejaculates and sperm motility. This management enhances sexual behaviour and probably stimulates the secretion of accessory glands increasing the volume of ejaculates. Previously, a relationship was observed between activation of sexual behaviour and a higher volume of ejaculates. The sperm motility may be enhanced by a modification in the seminal fluid composition. Similarly, higher number of live spermatozoa was found in male rabbits stimulated before semen collection. Since sperm production is highly variable between bucks, as well as, between successive ejaculates from the same male, the frequency of ejaculation revealed to have a great effect on the quality of semen, the reproductive performance of the male and the buck-doe rate in the farm. The sperm volume, sperm concentration and number of seminal doses decreased from the 2nd ejaculate when 4 ejaculates were taken in the same day, but were not affected when semen collection was separated (2+2) in two consecutive days. Intense mating rhythm causes spermatogenesis alterations with a high proportion of immature spermatozoa and low fertility results. Good sperm parameters and fertility rates were obtained after 3 times/week mating frequency and one rest day after each double mating.

During an experiment all the ten semen collections during 30 days from the group mated every third day were successful. They were continuously and keenly interested in the does. The males of the other group mated every day were exhausted on the 27th day and they did not show any sexual activities. There were no differences in any of the quality traits between the groups at the beginning of the experiment. At the advanced time the quantity of ejaculates, the semen concentration, the motility of spermia as well as the ratio of living spermatozoa decreased in a linear and significant way in the group mated each day. During the examination the ceasing of libido preceded the state when the quality of semen would have decreased below the limit of fertility. It is true for the application of natural mating as at the end of the experiment the semen, produced by the frequently ejaculated group, would not have been suitable for dilution and artificial insemination. It was found that bucks which have been naturally mated frequently produce fertile semen until the existence of libido.

Hormonal treatments

Male rabbits with low libido and poor sperm production are usually observed among rabbitries. Several authors reported improvement of these animals after treatments with GnRH or HCG, or prostaglandins. These hormones are also administered to stimulate steroid secretion and spermatogenesis in young bucks. More seminal doses/ejaculate was obtained in New Zealand White x California breed bucks aged 4-5 months after weekly administrations of GnRH during seven weeks, compared to HCG treatment. GnRH administration once a week increased total sperm output of heat-stressed low fertile male rabbits, as well as kindling rate and litter size. The effects of GnRH were greater in the summer than in winter. GnRH inductive test seems to have no effect on the size of testicles. According to the result of histological examination the state of testis and epididymis in the bucks of the untreated group appears the same as that of the healthy animals. While the group treated with GnRH showed that the seminiferous tubules placed relatively far from each other and the lumen of tubules was narrow (Photo 43). Loose connective tissue and possibly adipose tissue were found between the tubules. Leydig-cells appeared occasionally. The connective tissue increased in the epididymis. The tubules of epididymis were wide while the inner surface was plicated. The lumen contained little semen. Our observations suppose that the degenerative changes in the testis and the epididymis could have resulted from the negative feed-back mechanism caused by the relatively big doze of exogen GnRH.

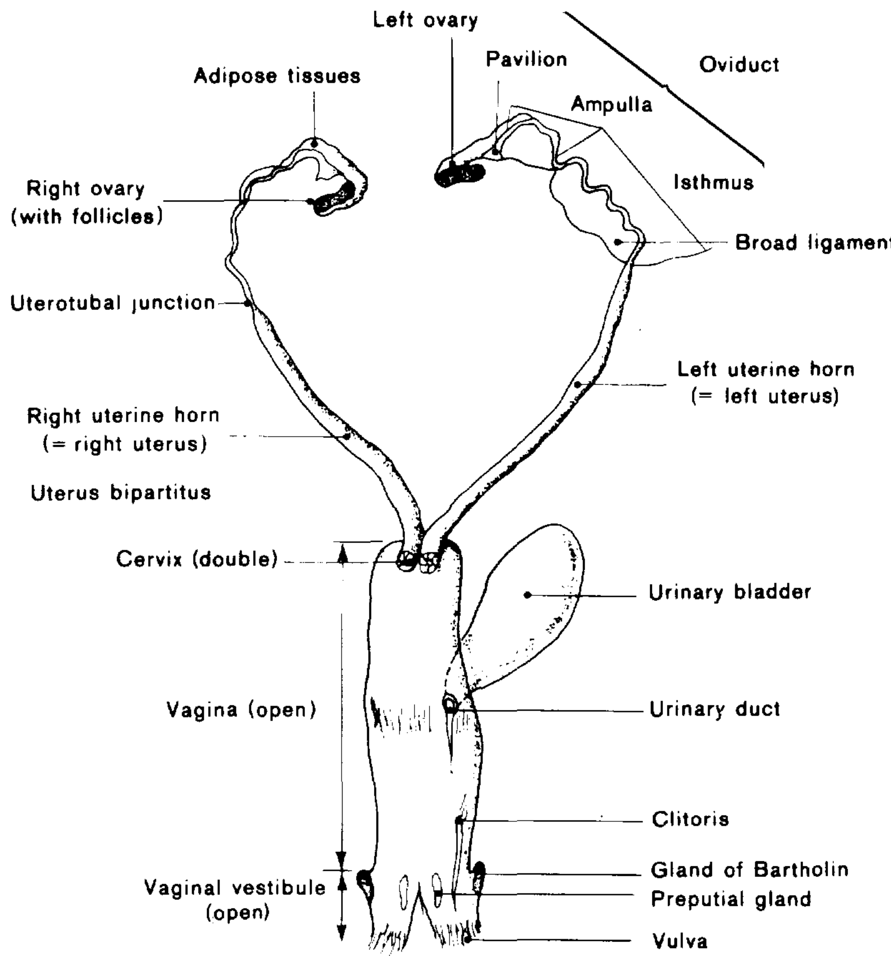
Source: Bodnár Károly

Photo 43: Histological appearance of the GnRH treated rabbit testis

7.2. Management of the doe

7.2.1. The anatomy and physiology of the female rabbit

In the female, ovaries (Photo 44) are oval-shaped and do not exceed 1-1.5 cm. Beneath the ovaries is the oviduct, made up of the duct, the ampulla and the isthmus (Figure 10). Though outwardly the uterine horns are joined at the back into a single organ, there are actually two independent uteri of about 7 cm, opening separately through two cervical ducts into the 6-10 cm vagina. The urethra opens midway along the vagina at the vaginal vestibule. The glands of Bartholin and the preputial glands can be identified. The whole is supported by the broad ligament attached at 4 main points under the vertebral column.



Source: www.fao.org

Figure 10: Genital apparatus of female rabbit

The first follicles appear on the 13th day after birth, and the first antrum follicles at about 65-70 days. Does are able to mate first at 10-12 weeks, but as a rule this will not produce ovulation. The onset of puberty varies greatly with:

- the breed: sexual precocity is more developed in small or medium breeds (4-6 months) than in large breeds (5-8 months). In Europe does are now mated at 120-130 days and fertility performance is good;

- body development: precocity goes hand in hand with rapid growth. Does fed ad libitum reach puberty 3 weeks earlier than other does of the same strain receiving only 75 percent of the same daily feed. The body development of the latter is also retarded by 3 weeks.

Source: Bodnár Károly

Photo 44: Rabbit ovaries

Does generally reach puberty when they have grown to 70-75 percent of their mature weight. However, it is usually preferable to wait until they reach 80 percent of their mature weight before breeding them. These relative weights should not be considered absolute thresholds for all rabbits, but rather limits applicable to the population as a whole. Sexual behaviour (acceptance of mating) appears long before the ability to ovulate and bear a litter. Such behaviour should not be regarded by the breeder as a sign of puberty, but as pre-puberty play.

In most domestic mammals ovulation takes place at regular intervals when the female is in heat or oestrus. The interval between two periods of oestrus represents the length of the oestrus cycle (4 days for rats, 17 for ewes, 21 for sows and cows).

The female rabbit, however, does not have an oestrus cycle with regular periods of heat during which ovulation will occur spontaneously. Does are considered to be in oestrus more or less permanently. Ovulation occurs only after mating. A female rabbit is therefore considered to be in heat when she accepts service and in dioestrus when she refuses.

There are many observations which denote the alternating periods of oestrus during which the doe accepts mating, and dioestrus in which she refuses. But the present state of knowledge does not make it possible to predict either the respective lengths of oestrus and dioestrus or the environmental or hormonal factors determining them.

It has been noted, however, that 90 percent of the time when a doe has a red vulva she will accept mating and ovulate, whereas when the vulva is not red (Photo 45) the doe will accept service and become fertilized only 10 percent of the time. A red vulva is therefore a strong indication, though not a proof, of oestrus. A doe in heat assumes a characteristic pose, called lordosis, with the back arched downwards and hindquarters raised. A doe in dioestrus tends to crouch in a corner of the cage or exhibit aggression towards the buck.

The sexual behaviour of a female rabbit is thus very special. She has no cycle and can stay in heat for several days running. On the ovary, follicles not having evolved to the ovulation stage through lack of stimulation undergo regression and are replaced by new follicles, which remain for a few days in the pre-ovulating state and may then in turn regress.

Photo 45: Rabbit vulva

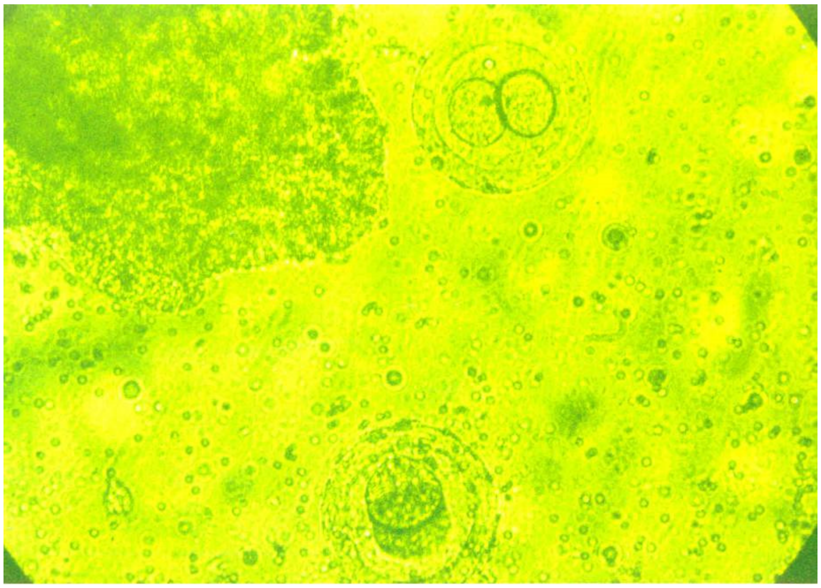
Gestation

In most mammals the progesterone secreted during gestation inhibits oestrus and the pregnant female refuses to mate, but a pregnant doe may accept mating throughout the gestation period. Indeed, in the second half of pregnancy this is the most common behaviour. A breeder cannot therefore use the sexual behaviour of does as an indication of pregnancy. Mating occurring during gestation has no dire consequences for the embryos. Unlike the phenomenon observed in the female hare (*Lepus europaeus*), superfoetation (2 simultaneous pregnancies at 2 different stages of development) never occurs in rabbits.

Ovulation is normally induced by the stimuli associated with coitus and occurs 10-12 hours after mating. Given this sort of pattern, ovulation can be induced artificially by various techniques. Mechanical stimulation of the vagina can cause ovulation, but the outcome is quite random. Injections of LHRH or LH can produce results, though repeated injections of the LH hormone lead to immunization and loss of effect beyond the 5th or 6th injection. Injections of LHRH repeated at 35 days for 2 years, however, have involved no loss of effect: 65 to 80 percent of the does became pregnant from this injection followed by artificial insemination.

At the moment the ovary follicles are ruptured the oviduct pavilion or infundibulum covers the ovary. When liberated the ovocytes are sucked in by the pavilion. The ovocytes are in fact fertilizable from the moment they are liberated, but they are not actually fertilized until about an hour and a half after release. The sperm is deposited by the male in the upper part of the vagina. The spermatozoa make their way upwards rapidly. They can reach the fertilization area (in the distal ampulla, near the isthmus) 30 minutes after coitus. During their journey the spermatozoa undergo a maturing process which enables them to fertilize the ovocytes. Of the 150-200 million spermatozoa ejaculated, only 2 million (1 percent) will reach the uterus. The rest are defeated by obstacles at the cervix and uterotubal junction.

The egg reaches the uterus 72 hours after ovulation. On its way through the oviduct the egg divides (Photo 46). The uterine wall differentiates, but the uterine dentellus appears only 5-8 days after coitus. It is the synchronization of these phenomena that makes possible the implantation of the egg. Implantation proper takes place 7 days after mating, at the blastocyst stage. Distribution of the blastocysts is roughly equidistant in each horn, but the blastocysts never move from one uterine horn to the other. From the 3rd to the 15th day after mating the progesterone rate continues to increase, then remains stationary and finally drops rapidly before parturition.



Source: Bodnár Károly

Photo 46: Dividing rabbit eggs

The maternal placenta develops along with the foetus, reaching its maximum weight towards the 16th day of pregnancy. At this time the checking of pregnancy is possible by the palpation of the abdomen (Photo 47-48). The foetal placenta is visible about the 10th day, and becomes larger until birth.

Embryo losses, measured by comparing the numbers of corpus luteum and living embryos, are usually very extensive. Generally speaking only 60-70 percent of the eggs become live rabbits. Most embryo mortalities occur in the 15 days before birth. Mortality is partly due to the viability of the embryos and partly to their situation in the uterine horns. External factors also play a part: the season and the physiological condition of the doe (especially her age).

Pseudopregnancy

Liberated ova which are not fertilized may occasion a pseudopregnancy lasting 15-17 days. At first the corpus luteum and uterus develop as in an ordinary pregnancy, but they do not reach the size or the level of progesterone production of the corpus luteum in pregnancy. Towards the 12th day they regress and disappear under the action of a luteolytic factor secreted by the uterus, undoubtedly prostaglandin. The end of pseudopregnancy is marked by the maternal behaviour of the doe and nest making. While such pseudopregnancy is much used in research laboratories on the physiology of reproduction, it is very uncommon in rabbits. Indeed, when a doe is serviced under unfavourable conditions she does not ovulate, and it is exceptional for ovulation to occur without fertilization (as in mating with a sterile but sexually active buck).

Source: Bodnár Károly

Photo 47: Uterus at the 15th day of pregnancy

Source: Bodnár Károly

Photo 48: Pregnancy detection by palpation

Kindling

The mechanism of parturition is not very well known. It seems that the secretion of corticosteroids by the suprarenals of the young plays a part, as in other animal species, in giving the signal for parturition. At the end of gestation the doe makes a nest for the litter with her own fur and materials she has available such as straw and shavings (Photo 49-50). This behaviour is linked with an increase in the oestrogen/progesterone ratio and with the secretion of prolactin. The doe does not always make a nest, or she may kindle outside the nesting box.

Photo 49: Doe prepares nest

Source: Kisjuhász Gabriella

Photo 50: Nest box with nest

Kindling lasts from 15 to 30 minutes, according to the size of the litter. Litter size varies as much as from 1 to 20 young. Most litters range between 3 and 12. In rabbit production units the average is 7-9, but there are great variations. After parturition the uterus retracts very quickly, losing more than half its weight in less than 48 hours.

Rabbit milk

Milk synthesis depends on prolactin, a lactogenic hormone. During pregnancy prolactin is inhibited by the oestrogens and by progesterone. At parturition there is a rapid drop in the progesterone level. As oxytocin is freed the action of the prolactin is stimulated and permits the milk to mount in a predeveloped gland.

Milk is let down as follows: the doe comes into the nest box to nurse her litter. The stimulus of nursing provokes the secretion of oxytocin, intramammary pressure mounts, the milk is let down and the young suckle. The amount of secreted oxytocin is proportional to the number of young feeding. But the doe sets the number of feeds: just once in 24 hours. Suckling alone will not provoke the secretion of oxytocin; the mother must want to nurse.

Doe's milk is much more concentrated than cow's milk except for the lactose component (Table 11). After the 3rd week of lactation the milk becomes markedly richer in proteins and

especially fats (up to 20-22 percent). The already low lactose content tapers off to almost zero after the 30th day of lactation.
The mature rabbit milk is richer than cow's milk in all the water-soluble vitamins and vitamin A. The samples all had high total solids contents, consisting of 10.2-17.7% fat, 11.9-13.2% protein and 1.12-1.76% lactose. The potassium and sodium concentrations ranged from 145 to 212 and from 82 to 160 mg/100g respectively.
Daily milk production increases from 30-50 g in the first 2 days to 200-250 g towards the end of the 3rd week of lactation. It then drops rapidly. The decrease is even swifter if the doe has been fertilized immediately after kindling. The lactation curve varies from doe to doe, especially with regard to duration.

Table 11: Average composition of cow's and rabbit's milk

Components	Rabbit's milk (%)	Cow's milk (%)
Dry matter	26.1 - 26.4	13
Proteins	13.2 - 13.7	3.5
Fats	9.2 - 9.7	4
Minerals	2 4 - 2.5	0.7
Lactose	0.86 - 0.87	5

Source: Lebas, 1997

Measuring the young rabbits' weight at 21 days gives a fairly good estimate of total lactation, as milk production between days 0 and 21 is closely correlated with total milk production (r+=0.92). The doe's milk output increases with litter size but the baby rabbits get less milk each than they would in a smaller litter.

7.3. Reproduction and environment

7.3.1. Lighting

Males exposed to artificial lighting for only 8 out of the 24 hours produce significantly more sperm than those exposed to light for 16 hours.
Does, however, are far more opposed to mating with only 8 hours of light than they are with 16. For both males and females 12 hours of light a day produce average results. The practice in rational European rabbit production units is to light breeding areas artificially for 15-16 hours a day. The males and females are together in the same room. The advantage of the does' behaviour and fertilization more than compensates for the drawback of the males' reaction to the light.

7.3.2. Temperature

The impact of temperature on spermatogenesis has been studied by various authors, but usually for short periods ranging from just a few hours to a few weeks at most. In a prolonged 5-week trial, the authors noted actual falls in the volume and concentration of ejaculates at a high temperature (33°C). A high temperature also affects sperm motility even after such short periods of exposure as 8 hours at 36°C, or medium periods such as 14 days at 30°C.

Furthermore, and this seems to be the worst effect, temperatures in excess of 30°C reduce the bucks' sexual urge.
However, these findings should not obscure the fact that rabbits do reproduce effectively in hot tropical or equatorial climates. Breeders should take the precaution of protecting their rabbits against extreme heat; they should avoid direct sunshine and protect the cages with an insulating roof, not just a corrugated metal sheet (which in fact transmits too much heat).
It should be noted that humidity does not seem to have been recorded in the various laboratory tests on the effects of temperature on spermatogenesis.
High temperatures also seem to affect female rabbits negatively. The lower prolificacy attributed to does reared in hot climates (30-31°) would appear to be due not so much to the temperature itself as to a reduction in body weight caused by a lower feed intake in the heat. It would seem, however, that embryo mortality increases when the temperature exceeds 30-33°C, though here again decreased feed intake needs to be considered as a possible cause.

7.3.3. Season

In Europe the season is usually analysed in terms of the combined effects of light and temperature. In tropical climates the temperature effect seems to be dominant, but an effect due to variations in the length of daylight cannot be excluded. The reproduction cycles of the European wild rabbit are strongly influenced by the season. The does breed from the end of winter until early summer. The reproduction period can be longer or shorter, at either and, according to both temperature and availability of feed.
Exposing domestic does to light for 16 out of 24 hours in Europe considerably attenuates this seasonal variation; indeed it nearly suppresses it. Even so, reproduction problems sometimes appear at the end of summer with no direct relation to the temperature. In tropical climates a drop in the rate of reproduction is noted during the same period, the wet season, when temperatures are high and so is humidity.

7.3.4. Rates of reproduction

The physiological features of the male and especially the female are such that the breeder has great latitude in choosing a reproduction method. But for successful rabbit production the choice of method must be preceded by careful study and planning. The goal is to increase doe productivity and reduce inputs.
Productivity, defined as the number of young per doe per unit of time, depends on: the interval between successive kindlings; litter size at birth; and the survival rate of the young. These criteria can be improved by slow, methodical selection and careful management of the rabbitry environment. In practice the crucial factor in increasing productivity is shortening the kindling-to-mating interval. This means non-productive periods must be pared as far as possible. Before such a strategy is adopted the breeder should consider:

- whether or not it will be exhausting for the does, perhaps leading to premature culling (this depends mainly on feeding conditions);
- whether or not it might cause a spontaneous reduction in doe fertility and prolificacy;
- whether it will lead to more work for the breeder. The breeder's desire to improve working conditions and reduce labour costs must also be considered.

Age at first mating

Before discussing the rate of reproduction, the first factor to consider is the age at first mating. If the unproductive period before the first litter can be shortened rabbit productivity will naturally be increased. Studies conducted in France on does receiving a balanced concentrated feed showed that female rabbits first serviced at 5 1/2 months had a lower annual productivity than females serviced 3 weeks earlier. The first group had virtually reached their adult weight and was too fat. The best plan is to have does serviced as soon as they reach 80, or at the most, 85 percent of the mature weight for their breed. Females can be serviced even earlier if their feed is extremely well balanced.

The three basic reproduction rates

The second method of stepping up production, after earlier servicing, is to accelerate the rate of reproduction. This amounts to shortening the theoretical interval between 2 successive litters. In fact, the true rate of reproduction is always slower than the theoretical rate because not all does immediately accept the buck and not all are fertilized when retired. There are 3 basic rates of reproduction: extensive, semi-intensive and intensive.

Extensive reproduction rate

The breeder fully utilizes the does' maternal instincts by allowing them to nurse their young for 5-6 weeks, rebreeding them soon after weaning. Does are therefore serviced once every 2 1/2 months.

Later weaning is in no way advantageous except for fryer production -very young animals which can be sold at 8 weeks and have not undergone weaning shock. In the United States and the United Kingdom fryers with a live weight of 1.7-1.8 kg are produced this way, using breeds such as the New Zealand White. The mother can be serviced before weaning, about 5-6 weeks after kindling, which allows 2 1/2 months between litters.

When feed is not quite adequate in quality or quantity, it is preferable to wean rabbits at about 40 days. At the same time the breeder should slightly lengthen the resting period between weaning and rebreeding so the doe can build up her reserves again. In any case, weaning later than 6 weeks offers no particular nutritional advantage. The milk produced by the doe after this period provides at most 3 to 5 percent of the young rabbits' daily feed intake.

Semi-intensive rate

The breeder has does serviced 10-20 days after kindling and the young are weaned at 4-5 weeks. For 10-20 days the doe is newly pregnant while still nursing. The most important phase of embryo development takes place during the slump in milk production, which may even have ceased, so there is no real competition between the demands of gestation and lactation. As these does never have a resting period they need sufficient and well balanced concentrate feed.

Intensive rate

The breeder has the does re-serviced just after kindling, taking advantage of the fact that they are then in heat. Weaning should take place at 4 weeks at the latest' usually 26-28 days. There are 3 main techniques:

- servicing the same day or the day after kindling: the true post-partum rate;
- servicing scheduled for a specific day, generally 3 or 4 days after kindling. This corresponds to a constant interval of 35 days (5 weeks) between litters;

- ad libitum mating. A buck left together with post-partum does will serve them several times during the 48 hours following kindling. This is the natural rhythm of wild rabbits.

To arrange ad libitum mating, breeders have worked out 2 types of rabbit housing. The first is the corridor-collar type: the does live in individual cages. They have a broad collar around their necks to prevent them from leaving the cage through the calibrated opening leading into a communicating corridor. The buck, however, has free access (at least temporarily) to the does' cages and can mate whenever the doe is ready.

The second is the group system: a buck and perhaps 10 does live together in the same cage. They can mate at the optimum times. However, special arrangements must be made to curb the natural tendency of females to kill the offspring of other does when they themselves are lactating or ready to kindle.

Choosing the reproduction rate

Considering the greater nutritional needs of the pregnant doe, especially one which is also lactating, semi-intensive and intensive reproduction systems are only suitable where does get the right quantity and quality of feed. If these conditions are not met, the does will usually accept the male but will abort.

Abortion extends the interval between litters to make it as long as the extensive breeding interval. Under intensive reproduction the doe has no opportunity to build up reserves.

Numerous comparisons of intensive and extensive reproduction have been made, principally in France. Ten years ago the litters of does mated post-partum numbered one less than those of does mated 10 or more days after kindling. This is virtually no longer true, mainly because of improved feeding and the selection of strains and lines suitable for intensive reproduction. Where it is feasible it is the most productive method, though also the most demanding.

In fact breeders in France, Italy and Spain adopt a variable rate of reproduction depending on the condition of the does. For instance, a good healthy doe which produces a litter of fewer than 7 or 8 is immediately remated. If she has given birth to 10 or so young the breeder waits about 12 days before having her serviced. In autumn, when it is harder to get the rabbits to mate, breeders systematically take the does for servicing after parturition. This is to take advantage of the strong post-partum oestrus during which 95-99 percent accept servicing.

In intensive reproduction in European rabbitries 1 doe can produce 50-60 weaned young annually. At the same technological level 45-55 rabbits can be produced in a semi-intensive reproduction system. In a wet tropical climate, with balanced feeding, it is possible for a doe to produce 40-50 weaned young a year by a combination of intensive and semi-intensive rates.

Using the extensive rate the best breeders obtain 30-35 weaned young per doe per year. In a tropical climate, depending on the region and especially on feeding, 15-30 weaned young can be produced under extensive reproduction.

8. ARTIFICIAL INSEMINATION

The control of rabbit reproduction has experienced a great change in the last decades, mainly as a consequence of the development of new techniques such as artificial insemination (AI) on a commercial level.
Undoubtedly male rabbits are the basis of the reproductive success, but they have not received the attention they should have, mainly if we consider that one single male is affecting the fertility and prolificacy of about one hundred females when A.I. is performed as a routine in rabbit farms. In commercial rabbit farms AI is widely employed and this diffusion has contributed to the increase in knowledge of spermatozoa metabolism and management of rabbit bucks.

Semen is a mixture of spermatozoa, produced by testicles, and seminal plasma secreted at different sites by accessories glands and by the epididymis, which are combined at the time of ejaculation. Seminal plasma also contains other particles of different size which affect the spermatozoa behaviour during the transit along the female reproductive tract.
Many factors affect seminal traits and thus it is crucial to define suitable protocols to improve spermatozoa characteristics. Hence, it is possible to produce more doses of semen with higher “expected” fertility and with less variability.

Semen evaluation must provide information on the fertilizing ability of spermatozoa. The most relevant parameters correlated with the fertility rate are the number of spermatozoa inseminated and their motility, although the use of a single attribute is not sufficiently accurate to predict the fertilizing ability of the semen. Additional semen traits or composite indexes better predict the fertilizing capacity of spermatozoa. A composite index was developed using a multivariate regression approach by entering several parameters of rabbit semen (motility, sperm abnormalities and altered acrosomes), which better predicts the fertilizing ability and the prolificacy of semen samples.
The low correlation between individual semen traits and fertility can also be explained by other reasons such as the use of sperm/AI in excess that masks the effect of several semen quality traits on fertility. However, variation in the seminal characteristics is known to be affected by many factors (genetic strain, feeding, health status, rearing condition, season, age and collection frequency), thus contributing to the large variability in semen traits. Furthermore, the complexity of semen evaluation is such that substantial variability among laboratories can be introduced in the evaluation of sperm parameters (sperm counts, motility and morphology).

8.1. FACTORS INFLUENCING SEMEN PRODUCTION

8.1.1. Individual and genetic

The variability of semen characteristics in male rabbits is generally high; however, the sperm traits of some genetic strains exposed to strict protocols of rearing (light, temperature and feed) and collection frequencies has shown lower variability within and between bucks.
Differences between genetic types of bucks have also been found for semen characteristics and fertility. Differences in semen characteristics were observed for males from different genetic lines and from crossbred and purebred males. Crossbred sires tended to express a moderate advantage for various semen traits, but when semen from these bucks was used for AI, a negative heterotic effect was observed. Therefore, the use of crossbred males may not provide a major advantage with respect to the use of purebred males from sire lines. These differences could be explained by differences in maternal genetic effects and the existence of heterosis for this trait.

8.1.2. Frequency of collection

Collection frequency has an important effect on semen characteristics: two ejaculates collected once a week (with an interval of at least 15 min.) allows for the best semen production, both in terms of quality and quantity. Conversely, too long collection frequency (every 14 days) exerts a depressive effect on sperm output probably for the scarce sexual stimulus followed by androgen reduction.
Collection frequency affects not only sperm production but also the concentration of seminal granules: daily collection, in comparison to a collection every week, reduced the spermatozoa and granule concentration even if granules showed a more stable and higher production.

8.1.3. Light

Light length affects the hypothalamus-pituitary axis and consequently hormonal release and spermatozoa production. A daily constant 16L:8D light program increases sperm production (qualitative and quantitative aspects) compared with a shorter light length (8L:16D). By contrast, light intensity did not significantly affect semen characteristics.

8.1.4. Age

Sexual maturity occurs approximately at 5 months (depending on the strain) and semen quality generally decreases in older rabbit bucks. Recently, some authors showed that the sperm chromatin structure of the semen of rabbits between 5 and 28 months of age significantly changed. Changes in chromatin structure suggested a relatively high stability of sperm chromatin in the rabbit. The lowest percentage of sperm with damaged chromatin (1.7-2.4%) was observed between 6 and 16 months of age. Decreased sperm chromatin stability was found in ejaculates taken from male rabbits less than 5 months and more than 20 months of age. Spermatozoa of aged animals show less stable membranes and they seem more vulnerable to dietary deficiency of polyunsaturated fatty acids (PUFA).

8.1.5. Health status

It is widely known that inflammation of the male reproductive apparatus worsens various testicle functions and seminal characteristics by affecting biosynthesis of pro- inflammatory eicosanoids (prostaglandins and leukotriens) and cytokines.
A high concentration of leukocytes during spermatogenesis or after ejaculation caused by inflammation/infection can deeply reduce the integrity of acrosome by increasing free radical production. Bucks' health has to be regularly controlled mainly in aged animals.

8.1.6. Feeding protocols

Regarding the quantity of feed that should be administered to rabbit bucks, it was showed that a restricted dietary protocol reduces *libido* and some seminal traits. However, the most important factor is not the amount of diet furnished but its chemical characteristics. Specific recommendations for rabbit bucks are not available, and only some specific requirements have been established.

Crude protein
Diets with more than 15% of crude protein are recommended to assure suitable sperm production.

Fat
More critical than the total amount of fat is a balanced fatty acid composition. In mammalian spermatozoa, a very high amount of lipids are PUFA of n-3 and n-6 series, which are associated with the membrane fluidity and its competence. Animal species are not able to synthesize essential PUFA (C18:2n-6 or C18:3n-3) and the diet has to provide adequate amounts of these fatty acids in the form of precursors (C18) or elongated (C>20) fatty acids. Our previous research has shown that dietary addition of PUFA n-3 modified several traits of rabbit spermatozoa. Relevant modifications regarding the motility and the kinetic traits of sperm cells (curvilinear velocity and lateral head displacement) is probably due to higher membrane elasticity in spermatozoa of n-3 supplemented group. The best results occurred when 20% flaxseed were added to the feed. On the contrary, high levels of cholesterol in the diet alter the metabolism of Sertoli-cells and the normal process of spermatogenesis.

Antioxidant protection
The high unsaturation levels of spermatozoa membrane render these cells very susceptible to peroxidation, which degrades membrane structure, sperm metabolism and DNA integrity. The more common way to increase the antioxidant stability of semen is to fortify diets with antioxidant molecules. Alpha-tocopherol is retained as one of the most powerful antioxidants.

8.2. SEMEN COLLECTION AND HANDLING

Some authors reported that a previous stimulation of the buck increases sperm concentration. For this aim, a doe can be put on the top of the cage for few minutes. Semen usually is collected by artificial vagina using a doe as a dummy.
The type of artificial vagina influences the adaptation of buck to the collection. An artificial vagina with a wider collection hole increases the number of bucks adapted to the collection. At each collection time, a sterile artificial vagina should be used. Indeed, considerable

bacterial contaminants come from the environment, and it is important to hygienically collect the semen sample.

As a general rule, during semen handling, any shock of sample (temperature, chemical, oxygen, etc.) may be reduced to avoid reduced fertility. Within 5 minutes from collection, semen should be diluted with a buffer medium at the same temperature to avoid heat or cold shocks. Generally, all the semen handling has a negative effect on semen traits.

8.3. STORAGE CONDITIONS

8.3.1. Temperature

Regarding the storage temperature, generally 15-18 °C represents a good condition to store rabbit semen. Nevertheless, optimal temperature could depend on the extender used.

8.3.2. Extenders

One important factor to have good survival rate of sperm is the medium used in semen dilution and the dilution rate. The comparison between different media has shown that any physiologic buffered saline solution is adequate for very short storage period. However, for longer storage there are differences in the ability to support sperm survival. Tris-buffer is enough to allow storage from 24-48h.

The high dilution rate (more than 1/100) has a detrimental effect on motility and the excessive dilution of seminal plasma, which in rabbit plays a relevant role, which reduces kinetic characteristics of spermatozoa.

8.3.3. Incubation

In accordance to specific demands of semen for further laboratory analysis or for AI, an adequate procedure has to be chosen to maintain vitality and physiological capability of fertilisation over a defined time interval. Thus, semen has to be diluted or spermatozoa have to be separated and put into a final medium. For semen dilution as well as for the spermatozoa containing medium, optimal conditions must be assured by selecting buffers that are adapted to the reproduction organs; CO_2 (5%) incubators preferentially will support long term spermatozoa vitality by simultaneously reducing excessive contact with oxygen.

8.4. SPERM PRESERVATION

Rabbit semen conservation is to date, one of the main problems for a wide utilisation of artificial insemination. Rabbit semen is more sensible to hypertonic solutions compared to other species and to cryoprotective agents containing glycerol. To date, several steps towards an effective cryoprotective substance have been given, so freezing could soon be a method to preserve valuable semen from selected bucks. Several techniques have been developed to keep diluted semen during short periods of time, usually up to 48 hour at 5 to 25ºC. Most extenders are based on Tris-citric acid combined with egg yolk, which acts as a protective agent. Dimethylsulphoxide, ethylene glycol or acetamide showed low toxicity showing good sperm motility at 20ºC. Glycerol revealed no toxic effects on diluted semen under 5% concentrations.

8.4.1. Short term storage

Effects of short term storage on spermatozoa morphology and motility

It is possible to preserve rabbit spermatozoa during 24 hours at a wide range of cooling temperatures (6 to 25ºC). More researchers showed better motility and acrosome integrity at 15ºC. Best AI results were obtained at 18 and 19ºC, being 18ºC the preservation temperature recommended. Motility at 24 hours is greatly reduced in relation to the observation made immediately after semen dilution. It seems clear that relatively high cooling temperatures (25ºC) show higher motility than low ones (6 an 11ºC), but it has no practical consequences as no correlation has been found between motility after 24 hours and fertility. Only pooled ejaculates showing motility score under 1 (in a scale 0 to 5), provoked a lower conception rate, although results were not disastrous and litter size was normal. That means that apparently dead spermatozoa are only in a sleeping state and are reactivated once inside the female genital tract. No differences were observed in the seminal parameters between fresh and refrigerated semen at 16-18ºC for 26-30 hours.

Effects of storage on fertility and litter size

The extender MA24 (Spanish patent no. 2106686) based on glucose, fructose, EDTA and sodium citrate, has been tested at the commercial level. Globally, the performance of the AI with 24 hour stored diluted semen using the MA 24 extender has been satisfactory, without any decrease in fertility or prolificacy. The fertility reached an average rate of 80% and litter size was 8.5 in lactating does.

Fertility was significantly affected by cooling temperature, reaching the highest values in a range of 17 to 19ºC, and decreasing at lower (15, 11 and 6), or higher (21 and 5ºC) cooling temperatures. This could be explained by the effect of temperature on motility, acrosomal damages and depletion of endogenous energetic reserves. Although metabolic activity slows down, temperatures under 17ºC are not beneficial to rabbit spermatozoa preservation because acrosomal damage increases. Temperatures over 19ºC would have a negative effect because of a lower acrosome integrity probably associated to a partial alteration of the ability to employ exogenous energetic resources.

Litter size was affected by cooling temperature. The highest value was obtained at 18ºC. Mortality at birth was increased at 6 and 11ºC compared to higher semen preservation temperatures. A similar increase in birth mortality was reported in PMSG stimulated does, which suggest that some mechanisms could exist relating gamete quality and birth mortality. Differences in fertility was not found and prolificacy between fresh and refrigerated semen at 16-18 ºC for 26-30 hours. Periods of conservation longer than 72 hours led to a decrease of fertility (around 40%) unacceptable from an economic point of view. Similar fertility and litter size have been obtained after preserving semen diluted in the commercial diluent GALAP, for 72 hours at 18 ºC.

The readiness of an extender able to maintain rabbit semen during periods of time longer than 72 hours would be of great utility, allowing the integration of farms with breeding females and fattening rabbits on one hand, and semen production centres on the another. With this objective at commercial level, the search for new products has been intensified, with launchings of new extenders. At the moment, the extenders for rabbit semen are working well between 1 and 3 days, although diverse centres are working to increase the time of conservation. Thus, a new organisation system, based on transportation of rabbit semen from specialised centres to the all female rabbit farms, could be set up.

The effect of gelatine addition to the semen extender on the viability and acrosome integrity of rabbit spermatozoa was studied. Pooled semen samples were processed in a boar semen

extender with or without gelatine addition. Semen samples were stored at 5◦C for 72 hours. Viability and acrosome integrity was evaluated by light microscope. Results showed that gelatine addition had a significant positive effect on the quality of the stored semen.
The percentage of the viable, acrosome-intact spermatozoa was higher in the gelatine-added extender, than in the control extender after the short-term storage. Although, buffers are added to the extenders to minimize pH-fluctuations due to the metabolic products of the spermatozoa, sedimentation of the sperm cells occurs during preservation. Therefore, pH may be lower at the region of sedimented cells; moreover, the concentration of some toxic metabolic products may be higher at this region. As gelatine prevents sedimentation, sperm cells are more uniformly distributed and buffers can prevent pH-changes more efficiently. Gelatine has a further advantage: extended semen samples are solid, which makes handling and sending samples by mail easier and safer.

8.4.2. Dilution rate

The attempt to determine the lower limit of sperm concentration when AI is performed with 24 hour stored semen hasn't led to a clear conclusion. On a commercial scale, a dose of 20 million negatively affects fertility and a dose of 14 million also negatively affects prolificacy. When fresh semen is employed, it seems clear that the reduction from 60 million to a half of this does not affect either fertility or prolificacy but the reduction to a third, which means 20 million spermatozoa/dose lowers the conception rate by 12%. Thus, the lowest advisable limit should be over 20-million spermatozoa/dose.
l5x106 motile spermatozoa/ml (7.5x106 per dose) seem to be enough to reach a high fertility level, the use of doses containing a higher number of motile spermatozoa having little influence on the percentage of pregnancy. Values under 5x106 motile spermatozoa/doses, are likely to reduce the reproductive performance. The number of motile spermatozoa/dose needed to obtain a threshold value of 95% of the maximum fertility, depends on the sexual receptivity of females, being 11 million for receptive and 13 million for non receptive does. On the contrary, the physiological state doesn't affect litter size results, and only 4 million are necessary to reach the threshold value. A dose of 12 million spermatozoa refrigerated at 16-18ºC for 26-30 hr showed a similar fertility rate to 6 million preserved 0-4 hours.
The reduction from 12 to 4 million spermatozoa/dose did not affect fertility (90%) nor the number of implanted embryos (10.7), although a further reduction to 2 or 1 million provoked a lowering of these parameters.
Semen dilution factor 1: 10 induced on the average lower litter size, without affecting birth rate in comparison with dilution 1:5. Although no general recommendations could be put forward because of variability of results between the weeks. The mean litter size at birth is less sensitive to low semen concentrations as only a negative effect was detected at a 14 and 8 million spermatozoa/dose. Although structural damage of spermatozoa linked to cooling was not evaluated, authors assume that the number of intact spermatozoa is well above 0.3 million, reported previously as enough to get satisfactory results in AI.
The minimum sperm numbers required for normal fertility were 0.05 million, and 0.1 million for normal litter size. Probably the lowest advisable dose is not the same for different breeds and selected strains of rabbit bucks, so that specific study should be performed in each case. The determination of the optimal spermatic concentration could help to reach a more efficient utilisation of the bucks, and to necessitate a lower number of them in the rabbitry, thus being of clear economical and practical utility.

8.4.3. Addition of sperm stimulating substances

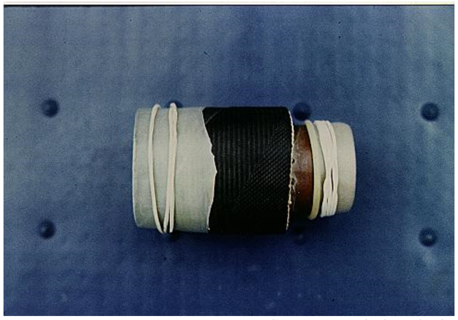
The motility and metabolic activity of sperm stored for large periods has been increased in several species by adding cAMP, calcium, prostaglandin, oxytocin, adrenaline, or caffeine. Several studies have indicated that cyclic AMP and calcium either separately or synergistically regulate the motility of mammalian sperm. Addition of C-AMP or phosphodiesterase inhibitors (e.g. caffeine, theophylline, papaverine) appears to stimulate sperm motility, added calcium can have positive or negative effects depending on the concentration and species.

Intratesticular injections of oxytocin or adrenaline given to low fertility males increased libido, ejaculate volume, sperm motility, sperm concentration and litter size.

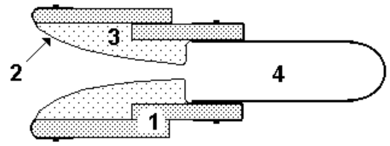
Increased sperm motility was observed after adding 1 ml of caffeine (10 mM/l) to a pool of semen stored for 24 hour at 18 ºC, although this increment was not associated to improved fertility or prolificacy rates in farm conditions, when performing AI. Semen stored for longer periods (72–96 hr) was unable to react to added caffeine. The number of live kits /litter, and the litter size at birth, was reduced when using higher caffeine concentrations (100 mM/l). Caffeine salicylate improved conception rate and increased the rate of new-born male rabbits by 15%.

8.4.4. Rabbit AI procedure

1. Semen is collected from a buck using an artificial vagina (AV) (Photo 51, Figure 12).
2. Semen collection is evaluated for number of live sperm (Photo 52) and rated for motility (movement) and morphology (structure).
3. The semen collection is then extended using a solution (Table 4) that provides nutrients for sperm metabolism and cryoprotectants to prevent damage during the freezing and thawing processes.
4. The doe is positioned on her back to be inseminated. The insemination pipette is inserted into the vagina (Photo 53) so the tip is just outside the cervical opening and the semen is deposited.
5. Ovulation in rabbits is normally induced as a result of mating and takes place after mating with 10-13 hours. Therefore, an artificially inseminated doe must be stimulated to ovulate with either a vasectomized buck, mechanical stimulation or an injection with a GnRH analogue hormone. A drug is given to induce ovulation and fertilization can occur once the sperm moves into the oviduct and has undergone capacitation. Commercial forms of GnRH (i.e., Lutal®, Receptal®) are commonly administered during rabbit AI in Europe, however they have not been approved for use in the United States by the FDA. Similar GnRH compounds are approve in the US for use in dairy cattle and can be used to induce ovulation in rabbits, but must be used under veterinary supervision.



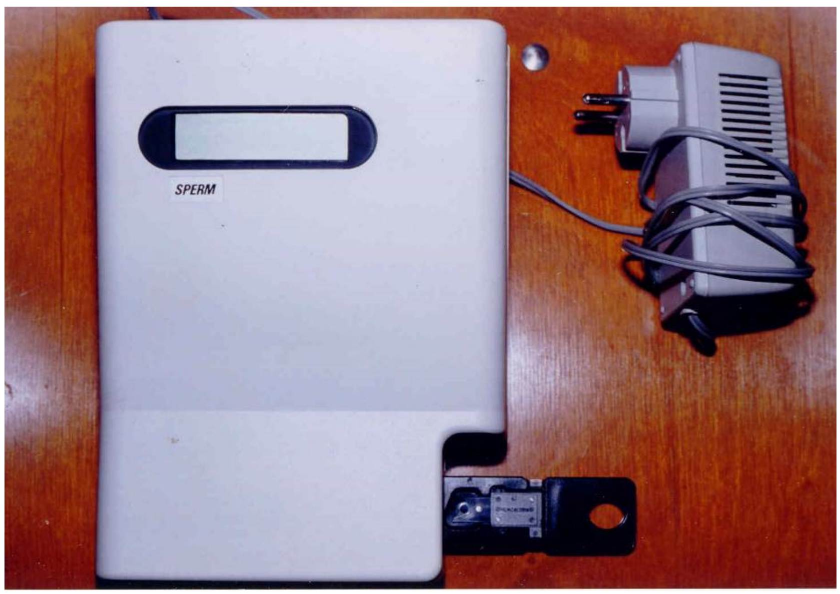
Source: Bodnár Károly



1. hard plastic tube
2. rubber liner
3. water
4. test tube

Photo 51: Artificial vagina

Figure 12: Structure of artificial vagina



Source: Bodnár Károly

Photo 52: Sperm counter

Table 4: Recipe of a simple semen extender

Ingredients	Quantity
Trisodium-citrate	2.03 g
D-glucose	1.50 g
Aqua bidestillata	100 ml
Egg yolk	10 %
Antibiotics	100,000 IU

Photo 53: Insemination of doe

9. REARING OF YOUNG RABBITS

The nest box
On the 28th day of the pregnancy, you put a box in their cage. It's to be made of either wood, plastic or steel. You can buy the steel kind from cage vendors. The wood kind, you can build yourself. The size of it matters on the size of your rabbit. The young are born within 28–31 days of mating and a normal rabbit litter is around 6-8 kittens but can range from two to twelve.
Don't put the box in before the 28th day, only because the doe will then use it as a bathroom. Stuff the box with straw or hay. Straw is preferred to use, as it's more of a bedding than food, so the does won't eat as much of it as they would with hay. Some people put shaving at the bottom of the box before putting the straw in. When you put the box in, the doe usually immediately starts throwing the straw around to put it in how she wants. Most experience does will immediately start pulling their fur to line the nest. However some does will wait until right before they give birth before pulling fur. Pulling fur helps expose the nipples for the babies to nurse. The does put it in the nest box to help keep the babies warm.

The young are usually born between the 28th and the 32nd day. Gently check the new babies and remove dead ones after the doe has kindled. A doe will cover the young with fur from her body.

Born on the wire
See if they're fully gone. If they're dead they won't do anything, however if they're still alive they will start slowly kicking, and moving their mouth, making little squeaks. If they do start moving, bring them into the house to warm them up. You can take a heating pad, lay a towel over it, then put the babies on it. After the heating pad gets warmed up, keep it on the lowest setting, as to not burn the babies. Keep a constant eye on them, so they will not crawl off the heating pad or get burned. Once they feel warm enough and are kicking a lot, you can remove them from the pad and put them back in their nest box. You do not want to leave them on the pad too long as it can kill them. If the doe did not pick any fur to line the nest, you can pick fur from her stomach. It should come off easily. Put that in the box for the babies.

The doe enters the box to feed the young for about 1 minute early in the morning and again late in the evening. Well-fed babies are sleek, clean, fat and well-filled most of the time. Have no fear that they are starving; most rabbits are excellent mothers. Young rabbits are about 10 to 12 days old when their eyes open and fur appears.

Fostering
When breeding, it's best to breed all your does on the same day, if you have more doe, you'll have other litters to foster the babies to. Does do not care if you foster babies into their litter. When fostering litters, if you're mixing more than one litter make sure you know what kits are from what litters. Mixing different breeds or varieties together makes it easier to tell them apart. However, if they're different breeds, make sure they are similar to the same size when fully grown, as a larger breed will push the smaller breed off the nipples when nursing. If they are all the same breed and variety, you can mark the back of their ears with nail polish, a different colour for each litter. You'll have to repaint the ears every few days though, as it wears off after a while.

Opening eyes
Rabbits open their eyes at 10 days old. If by day 12 they're still not open, you'll want to take a damp wash cloth and gently wipe their eyes to clean any gunk that is causing the eyes to remain close. You will want to do this a few times a day, every day, until they're open. Be very gentle, as it can scar the eye.

Jumping out of the box
Between 2-3 weeks of age, the kits will start jumping out of the nest box. They will start experimenting with solid foods at this time. You want to make sure that the feeder is always filled with food (they can and will climb out of the cage through the feeder, if it's not full) and the water bottle is always filled for them. You'll want to make sure the water bottle is down low enough for the kits to reach.
You'll want to keep an eye on the babies as they first start jumping out of the nest box, so their legs do not get caught in the wire. You can put a board in the cage in front of the box for them to sit on. Mattering on the weather outside, you can take the nest box out once you see them staying out of the box more so than inside of it. This is usually at about 3 weeks of age.
Sometimes they like to pop out of the box when they're too young, and can't get back in. When this happens, I flip the box on its side, so they can come and go as they like.

Weaning
When rabbits are about 3 weeks old, they leave the box and eat with their mother.
Weaning age is between 4-6 weeks of age. Do not wean before 28 days of age.

The rabbits should be kept until they weigh about 1.8-2 kg each before sent to be butchered. This normally takes about 2 months. However, one should also be aware that by the time the rabbit is butchered and dressed it will have lost about 33% of its original weight. The bigger the breed, the more loss there will be, sometimes as much as 45%. Therefore a 3 kg rabbit before being butchered will weigh about 2 kg after being butchered.

Meat pen and fryers
1. Members may exhibit one entry in the Meat Pen or one entry in the Single Fryer class (not both classes).
2. Entries in these classes are limited to 6 commercial rabbit breeds only. There will be NO Fancy rabbit breeds entered in this division.
3. The rabbits may NOT be older than 10 weeks.
4. Weight of each individual rabbit in either class must not be less than 1.5kg and not more than 2.5kg. Rabbits will be weighed in on entry day.

Crating and transporting live rabbits
Most rabbits will probably be sent to market live. Properly crated rabbits in good condition can be transported safely, but do not expose them to extreme heat or cold. Good ventilation is important. Avoid overcrowding. Although having individual shipping compartments is better, transporting rabbits for relatively short distances can probably use shipping crates made from packing boxes. As the scope of the project grows, obtain permanent shipping crates (Photo 54).

Source: Bodnár Károly

Photo 54: Crates for rabbit transportation

10. BEHAVIOUR AND WELFARE

Information on common rabbit behaviour, body language and noises, daily routine, companionship, hierarchy, personality, destructive behaviour, aggression, bonding and bereavement, handling, training and exercise.
This section contains information on rabbit behaviour, how they relate to each other and to us through their actions, body language and noises. Here you can find out what your rabbit is saying to you and why, understand why companionship is so important to rabbits and learn what causes behavioural problems.

The key to a happy rabbit is companionship, lots of space to run around and a bolt hole to retreat to. In this way, they are very close to their wild cousins still.
In the right environment, rabbits reveal their true nature - intelligent, affectionate and often cheeky! Rabbits are wonderful companions and are increasingly being kept as free range, indoor pets (house rabbits). Every rabbit is different and discovering your rabbit's own unique personality is one of the great joys of rabbit ownership.

The key to rabbit behaviour is understanding their nature as prey animals and adapting your behaviour towards them to allow for this. Most "bad" behaviour in rabbits stems from mistrust of humans or a lack of security in their environment and can therefore be overcome with time and patience. A rabbit may learn its behavioural pattern at a young age yet still be taught something different at an older age.

Rabbits that have not been neutered or spayed are far more likely to have behavioural problems, caused by sexual frustration and/or territoriality. Many "problem" rabbits have been cured simply by de-sexing them.

Aggression is generally caused by the rabbit either trying to defend its territory or itself but it may also be caused by a lack of trust in humans i.e. the rabbit assumes you are going to do something bad to it so reacts first by warning you off with a growl or bite.

Lack of trust takes a lot of patience. Spend time with your rabbit at ground level, lying or sitting on the floor and letting it approach you in its own time. Tempt it with bits of food, talk to it in a low, soft voice and avoid sudden movements. Let your rabbit become comfortable simply being close to you before trying to touch or stroke it.

For example, a rabbit may growl or lunge at you with its front feet when you are trying to clean out its hutch or litter tray, or if you enter its sleeping area. This is more common in female rabbits. Avoid entering your rabbit's territory when it is there - put your rabbit in its exercise run or a different room when you are cleaning out its hutch or litter tray.

Standing frozen with weight equally on all four legs in a braced stance, ears straight up and eyes wide open: the rabbit has heard something and is waiting to see if it is dangerous.

Thumping back leg hard on ground and dashing away to hide: the rabbit has identified danger in the vicinity and is scared.

Sitting up on hind legs with ears up and nose pointed up: wild rabbits do this just to get a better view and have a look around for possible danger. Domestic rabbits are more likely to be requesting food that you are holding or trying to get your attention.

Laying head flat on ground: the rabbit is showing submission to you or another rabbit and may be requesting petting or grooming.

Shaking ears followed by scratching inside them with a hind foot: the rabbit may have hair in its ears after a grooming session and be trying to get rid of it. If frequent, could indicate ear mites.

Shaking ears followed by a little hop or jump: the rabbit is inviting you to play or is excited about something, for example if you are about to feed it.

Nudging your hand, leg or foot forcefully: tricky one - if you are stroking your rabbit, it may be asking you to stop. But, if you have just stopped stroking it, it may be asking you to continue. If you are just minding your own business and your rabbit nudges you lightly, it is probably trying to get your attention or is requesting food.

Digging or biting at your feet: the rabbit may be trying to get your attention or be asking you to move your feet out of its way.

Turning its back on you or moving away, flicking hind feet out behind it: the rabbit is annoyed with you for doing something it disapproves of, such as cleaning out its litter tray or clipping its nails.

Interaction between rabbits

Bonded rabbits spend the majority of their days and nights together. They tend to visit the litter tray at the same time, eat together and groom together. A lot of time is spent simply snuggled up together sleeping. They can become competitive with each other over food and attention from us. For example, if one of them suspects that the other is being given food it will rush over to ensure it is not being left out. The rabbits may play together; racing up and down and jumping in the air, dig at the same hole in the garden, or rip up some old newspapers together.

Bonded rabbits often groom each other as a sign of affection and this is a useful indicator of the hierarchy. Generally speaking, the "top" rabbit will get the most grooming from its rabbit partner(s) and/or its human owners. Rabbits request grooming by putting their head on the ground or nudging in under the other rabbit's chin.

There are subtle (or not so subtle!) hierarchies in any rabbit relationship. In the wild, this hierarchy is important to keep the peace in a large warren. House rabbits tend to draw their human owners into this hierarchy also and females in particular can be surprisingly bossy, nipping your feet if they are in her way or jumping on your lap to request food or attention.

As the homemakers, female rabbits are more territorial by nature than male rabbits. It is much easier to introduce a female rabbit into a male rabbit's living space as he is unlikely to be territorial about it. However, once settled in she is quite likely to establish herself at the top of the pecking order. A male rabbit introduced into a female's living space will almost certainly be submissive to her or at least equal.

A healthy rabbit will groom itself thoroughly several times a day. Bonded rabbits will often groom each other as a sign of affection and your rabbit may even "groom" you by licking your hands or face.

A rabbit will rub the underside of its chin against something to mark it with its scent and claim their territory. A rabbit may even chin a human.

A rabbit will thump a hind foot on the ground when it feels there is danger around, to warn other rabbits. Unneutered males also use it as a sign of wanting to mate. De-sexed rabbits may use it as a sign of annoyance.

When your rabbit runs around your (circling) feet or around another rabbit, he is displaying his intention to mate or is trying to get your attention.

A little exhalation of breath, another sign of wanting to mate. Males and females may continue to honk even after neutering.

A female rabbit will sometimes make a growling noise when you are interfering with her space, for example cleaning out her litter tray. She may also lunge at you with her front feet - this is a territorial thing but she is unlikely to bite you.

When a male rabbit mounts another rabbit or even your foot, he is either trying to mate or is displaying dominance. A female rabbit may mount a male rabbit to display dominance.

A rabbit will nudge you lightly with their nose to get your attention or nudge you more forcefully to get you to go away or stop doing something to them.

A light grinding or 'munching' of teeth indicates your rabbit is happy, for example when you are stroking them. A heavier grinding can indicate pain or discomfort and will generally be accompanied by other symptoms.

Rolling over and lying on side or back with eyes closed: the rabbit is very relaxed and happy.

Flicking ears: the rabbit is inviting you to play. If a rabbit shakes its ears frequently and scratches inside them, it can mean they have a problem in their ears so check inside them for redness or scabs.

Acrobatics or 'binkying': rabbits play and get rid of excess energy by running fast, leaping around and twisting their body mid-air. It is an expression of happiness.

Fur pulling can be a sign of boredom but is usually associated with unspayed females going through a phantom pregnancy - they pull hair from their chest and tummy and may try to build a nest somewhere lined with the fur.

If a rabbit points its ears forward it is curious about something. If it puts them straight up it is alarmed and trying to listen better. If it folds them flat on its back it is frightened and trying to make itself inconspicuous.

Normally only the tip of a rabbit's tail can be seen. When a rabbit is curious and leaning forward with pricked ears, its tail will extrude further. When a rabbit is excited its tail will rise higher up its back. When a rabbit is about to attack or wants to mate it may flick its tail from side to side.

When a rabbit stands up on its back feet it is trying to get a better view of its surroundings. It may be trying to get your attention or reach for food that you are holding.

Putting head flat on ground is a sign of submission or a request for grooming/stroking from another rabbit or yourself.

Panting is a sign that the rabbit is too hot, overweight or ill.

Let's hope you never hear screaming. A rabbit will only scream or squeal if it is in extreme pain or fear e.g. when it has been caught by a predator.

The behaviour of caecotrophy

Rabbits produce two types of droppings - the hard pellets that you see, and soft, caecal pellets that they take directly from their bottom and eat. This is the rabbit's way of maximising the value of its food as they take more nutrients from the droppings as they pass through their body again.

The caecotrophy plays an important role in rabbit nutrition, providing proteins and vitamins B from bacterial source. Physiological mechanisms implicated in the caecotrophy. The starting of caecotrophy behaviour in young rabbit is not fully known but probably starts around 25 days of age, when a significant dry feed intake occurs that leads to a caecal and a colon filling.

The hard pellets are expelled, but the soft pellets are recovered by the rabbit directly upon being expelled from the anus. To do this the rabbit twists itself round, sucks in the soft faeces as they emerge from the anus, and then swallows without chewing them. The rabbit can retrieve the soft pellets easily, even from a mesh floor. By the end of the morning there are large numbers of these pellets inside the stomach, where they may comprise three quarters of the total contents.

11. HOUSING AND EQUIPMENT

Housing is a critical issue for rabbit health. In general, the type of housing is dependent upon the climate, location and size of the rabbitry.
Breeding and growing rabbits are kept to a large extent in intensive husbandry systems, mainly in cages with wire nets or slatted floor (Photo 55-56). The housing of rabbits is related to behavioural, hygienic, economic and welfare aspects. With regard to the specific European Convention for the protection of animals kept for farming purposes, a Standing Committee composed of representatives of the parties of the Convention has prepared a draft (in the 17^{th} revision from 2009) recommendation concerning the welfare of farmed domestic rabbits.

Source: Bodnár Károly

Photo 55: Intensive rabbit farm

Source: Bodnár Károly

Photo 56: Rabbits in cages

11.1. Temperature and ventilation

The optimum temperature in a rabbit shed is around 10–25°C. Effective ventilation is required to control extremes of temperature and also to remove ammonia. Poor ventilation will result in irritation to the respiratory tract and susceptibility to infection from bacteria. Heat stress will cause major rabbit mortalities and reproductive failure.
Natural ventilation systems can use wind and animal heat to move air. Natural ventilation is low cost, the disadvantages being lack of control over air movement, inability to lower the inside temperature of the rabbitry below that outside (in summer or on hot climate), and over-ventilation. Natural ventilation can be provided with a high gable roof, a ridge vent, and open sides with flaps that can be opened or closed depending on the atmospheric requirements. In high wind areas, a stub wall or wind baffle outside the open sided sheds is needed to reduce wind velocity. Mechanical ventilation systems are used in environmentally controlled buildings, using fans to provide required airflow. The advantage of this system is the ability to control rate of airflow for effective removal of moisture, heat and ammonia; disadvantages being the high initial and operating cost and the need for back-up systems in case of power failure. Evaporative cooling systems (Photo 57) may be used in a hot, dry climate. A water sprinkling system on the roof of the rabbit shed will help to reduce high temperatures.

Source: Bodnár Károly

Photo 57: Cooling panel in the wall of the building

11.2. Space requirement

The following information is drawn from the code of practice published for intensive husbandry of rabbits in Australia. Sufficient room is required for caged rabbits to move around, to feed and drink without difficulty. The minimum legal standards for different classes of rabbits are given below:

- Doe and litter (5 weeks) 0.56 m^2 (total area)
- Doe and litter (8 weeks) 0.74 m^2 (total area)
- Rabbits (5-12 weeks) 0.07 m^2 (per rabbit)

- Rabbits (12 weeks or more) 0.18 m^2 (per rabbit)
- Adult does and bucks for breeding 0.56 m^2
- Cage height (>12 weeks) 45 cm.

If the floor of the cage is of wire mesh material it should be of woven or flat construction (Photo 58). The square mesh of the floor should not exceed 19x19 mm for adults and 13x13 mm for kittens. The optimum for rectangular mesh is 50x13 mm. The thickness of the wire mesh should not be less than 2.5 mm diameter. Cage arrangement can vary depending on the size of the enterprise. Multiple deck configurations require a faeces diverter or multideck conveyor belt (Photo 59).

Source: Bodnár Károly

Photo 58: Wire mash cage with feeder and drinker system

Space restriction has been found to cause welfare problems in several livestock species and it has been argued whether domestic rabbits are well suited to live in small enclosures such as wire cages. In this sense, knowing the motivation of the rabbits for different behaviours is crucial to lead to conclusions about their space requirements.

Several authors defend that, based on the highly social behaviour in the wild, both reproducing and growing rabbits should be reared in groups. Therefore, this is a conditioning factor when individual housing is used for rabbit rearing. To reduce the negative effects of isolation, the use of wired cages in which animals can keep visual and olfactive contact with other rabbits is an interesting tool.

Source: Bodnár Károly

Photo 59: Conveyor system under the cages

Some studies of domestic rabbits in farmed and laboratory conditions have found that providing additional resources, space, and companionship allow a more varied behavioural repertoire. Nevertheless, the absence of a behavioural pattern does not necessarily indicate a poor state of welfare. In these terms, it becomes necessary to determine the behavioural needs of rabbits in terms of welfare, so that the spatial requirements can be known. This might lead to define appropriate housing conditions, although the needs of the animal can change according to age, learning, diurnal rhythm, season and genetic relations. Thus, the main questions to solve are the behavioural needs, even more, for each type of animal: growing rabbits, males and females.

Nowadays, there is a lack of information in these aspects, so decisions have to be taken carefully. However, there are a few research groups working in this topic during the last years, and some of their findings are summarized subsequently:

- An inventory of rabbit behaviours showed that they spent a large proportion of time inactive and perform exploratory behaviours when allowed. In addition, standing was more frequent than coprophagy or kicking wall, being all these activities less than 17% of the time.
- When space allowance is increased and cage enrichment such as tunnels exists, does leave the pups more often.
- A motivation test was developed and found 5168 cm^2 for inactive lines and 7300 cm^2 for active lines were the minimum cage size for growing rabbits.
- Rabbits kept in cages spent more time resting and the social and investigatory behaviours were more frequent in pens. In addition, aggressions occurred more frequently in larger groups.
- Growing rabbits had a low preference for open top cages, whereas they liked to rest in low cages (20 cm), although locomotory behaviours were impaired. They finally propose 30-35 cm as enough.

- Adult rabbits did not have tendency to adopt postures in which more than 40 cm were required. Nevertheless, 0.5% of the total time was employed in postures with required more than this height.
- Rearing mean duration was higher than urinating or defecation, for example.

In general, regarding the height of the cages (as well as width), few papers have been found and the EFSA report (2005) recognises that in the absence of scientific evidence concerning these needs of rabbits, they consider that it may be important for growing rabbits to be able to sit and stand with ears erect, as well as rear up occasionally. They also suggest providing a minimum of 65-80 cm of length to lie down and 38 cm to turn round and to groom comfortably.

11.3. Equipment and environmental enrichment

Good feeding and watering equipment will supply feed and water in hygienic condition and will avoid causing discomfort or stress to the rabbits. "J" type feeders are most widely used. A feed hopper in a cage should have a sufficiently big opening and should be large enough to feed all the rabbits in the cage at the same time. An automatic watering system can be installed. The drinking nipples of the watering system should be at optimum height from the floor of the cage, around 10 cm from the floor of the cage and they should not project more than 2.5 cm into the cage. It is always advisable to have a backup system to ensure that rabbits have access to water in case of a failure of an automated system.

Floor of the shed
The following anecdotal information has been gathered from rabbit farmers in Australia and the Thumper Newsletter. Earthern floor is preferred by some breeders as it absorbs urine and thereby reduces ammonia accumulation in the shed. Earthen floors combined with compost worms under the cages require less cleaning than concrete floors thereby saving a lot of labour. Mucking out is only required about 3 times a year. Concrete flooring needs regular cleaning and a high quality epoxy coating is desirable to completely seal the pores of the concrete. Development guidelines for rabbit sheds are available from your local council. In most instances you will be required to lodge a development application with your local council to construct a rabbitry. This is to ensure proper disposal of waste and to guard against environmental impact that may be detrimental to ground water, waterways and your neighbours!

Animal welfare is a major concern in livestock production and the impact of housing conditions on animal well-being is under study in several species such as chickens, laying hens, or pigs. In this sense, some European Directives have been developed in order to protect animal welfare. In these Directives aspects related to housing conditions have been regulated among other aspects such as transport or slaughter.

Ethology, housing and welfare
One of the main hot spots of this discussion is related to cages design. In this sense, especial concerns have been raised that barren cages lead to poor welfare and, especially, decisions about cage dimensions are being dramatic. This last issue might be related to the big differences in the type of production among countries. Strong efforts are being made nowadays in order to reach a compromise to define cages characteristics which could lead to a real benefit on rabbits' welfare.

The main aim of this work is to develop a critical review about rabbit space needs in relation to cages design. To this aim, scientific information about rabbit needs in terms of space requirements and their behaviour will be explored. Current recommendations for cages design will be also analysed and discussed in order to achieve optimal dimensions based on both welfare and technical criteria. The case of rabbit does will be followed throughout this work as an example.
Proposals agree with most of the findings presented above, thus, they could be considered in general as welfare-friendly for does. Nevertheless, some discrepancies can be noticed mainly regarding the height recommendations (e.g. 30cm) which may restrict behaviours such as sitting with erect ears. On the other hand, the use of platforms is not completely justified in terms of welfare and hygiene as it will be discussed subsequently.

Platform
Enriching the cage with raised platforms aims at satisfying the doe's need for isolation from the litter, rather than stimulating exercise although results are contradictory. In addition, EFSA report (2005) stated that there may be hygiene problems which have to be solved, such as faeces accumulation on the platform or urine and droppings falling onto the young rabbits.
Motivation to reach access to platforms, adult rabbits seemed to use it as a bolt hole in case of danger or even as a vigilant element, more than going on it. Moreover, Barge et al. (2008) pointed out that the interaction between genotypes and environment might have influence on the use of platforms. In addition, they found several productive aspects improved, whereas conception ability, for example, was reduced.
According to all this information, elevated platforms should be considered as environmental enrichment elements. In this context, its inclusion in cages might be understood as a possibility, as well as tunnels or gnawing sticks, among others.

In general, it seems clear that rabbits spend most of their time resting and they lie down totally extended when possible. However, other aspects such as the height needs are not so scientifically justified, as real needs of the animals have not been deeply assessed. In fact, height of the cage is important just because in the wild, a vigilant rabbit sits on its hind legs with ears pricked (lookout position). In addition, it has been observed that, sometimes, needs are measured in terms of time dedicated to a certain activity, whereas we think that is the motivation to perform a certain activity the aspect which has to be taken into account.
This general lack of information must be considered when new housing conditions are being proposed and only those aspects which are definitely an improvement in rabbits welfare have to be taken into account. Moreover, it is important to bear in mind that modifying minimum cage dimensions may lead to change most cages in rabbit farms. This is extremely delicate when proposing a European regulation that should be applied in countries with strong differences in production systems. Thus, considering technical, economic and welfare aspects, the authors make a proposal based on the scientific information available nowadays for cages for rabbit does as follows:

- Area per doe without nest box 3,500 cm^2,
- Minimum height 45 cm,
- Minimum length 75 cm,
- Minimum width 38 cm.

These dimensions ensure rabbits' welfare as far as scientific research has provided information, they allow performing natural behaviours like lookout position, turning, etc. As it can be observed, they do not include platforms, which we consider it has to be added as an optional enrichment element.

The protection of animals used for scientific purposes
The Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes establishes measures for the protection of animals used for scientific or educational purposes. To that end, it lays down rules on the following:

- the replacement and reduction of the use of animals in procedures and the refinement of the breeding, accommodation, care and use of animals in procedures;
- the origin, breeding, marking, care and accommodation and killing of animals;
- the operations of breeders, suppliers and users;
- the evaluation and authorisation of projects involving the use of animals in procedures.

All facilities shall be constructed so as to provide an environment which takes into account the physiological and ethological needs of the species kept in them. Facilities shall also be designed and managed to prevent access by unauthorised persons and the ingress or escape of animals. Insulation, heating and ventilation of the holding room shall ensure that the air circulation, dust levels and gas concentrations are kept within limits that are not harmful to the animals housed. Temperature and relative humidity in the holding rooms shall be adapted to the species and age groups housed. Where natural light does not provide an appropriate light/dark cycle, controlled lighting shall be provided to satisfy the biological requirements of the animals and to provide a satisfactory working environment.
Illumination shall satisfy the needs for the performance of husbandry procedures and inspection of the animals. Regular photoperiods and intensity of light adapted to the species shall be provided. Animals shall be checked at least daily by a competent person. These checks shall ensure that all sick or injured animals are identified and appropriate action is taken.
All animals shall be provided with space of sufficient complexity to allow expression of a wide range of normal behaviour. They shall be given a degree of control and choice over their environment to reduce stress-induced behaviour. Establishments shall have appropriate enrichment techniques in place, to extend the range of activities available to the animals and increase their coping activities including physical exercise, foraging, manipulative and cognitive activities, as appropriate to the species. Environmental enrichment in animal enclosures shall be adapted to the species and individual needs of the animals concerned. The design of animal enclosure floors shall be adapted to the species and age of the animals and be designed to facilitate the removal of excreta.
Following this directive, the keeping of the rabbits shall at least follow the standards laid down in Directive 98/58/EC. A raised area shall be provided within the enclosure. This raised area must allow the animal to lie and sit and easily move underneath, and shall not cover more than 40% of the floor space. When for scientific or veterinary reasons a raised area cannot be used, the enclosure shall be 33% larger for a single rabbit and 60% larger for two rabbits. Where a raised area is provided for rabbits of less than 10 weeks of age, the size of the raised area shall be at least of 55 cm by 25 cm and the height above the floor shall be such that the animals can make use of it. The directive also defines the requirements of rabbits with different age concerning minimum floor area or enclosure size.
In public, enforced by animal welfare groups, the welfare and housing of rabbits are increasingly being discussed from a more emotional point of view.

The use of enriched cages is recommended. The 2nd floor can be used by the doe as withdrawal and the room under the 2nd floor can be used by the kits as a hiding-place. The use of a perforated plastic pad (foot-rests) wedged on the wire is to be recommended when

metal wire is used in the cage. It is not necessary for growing rabbits. Rabbits can choose between different materials for lying depending on room temperature and air velocity. The plastic pad must not obstruct the falling through of faecal drops and must be included in the cleaning and disinfection procedures.
Enriched cages should be used allowing the rabbits to have access to material for engagement and – if possible – to an elevated platform. The elevated platform (the "third dimension") for breeding rabbits seems to be more important than an enlarged cage size. It allows the does to jump away from the kits. Enrichment belongs to the animal-friendly housing of rabbits. The material for engagement (e.g. gnawing sticks made of wood) should hang within the cage. It was demonstrated in different investigations that welfare-friendly pens with a plastic platform, a hiding box and gnawing material had no negative effect on health and performance.
The rabbits shall have permanent access to water of good quality. There has to be in minimum one nipple waterer per cage or box in single housing. More than one nipple waterer should be used in groups of more than ten rabbits. The width of the feeding place has to be 6 to 8 cm, depending on the size of the rabbits, up to a live weight of 4 kg. For bucks the width of the feeding place should be 10cm. If the rabbits are fed *ad libitum* the width of the feeding place can be reduced to half. The nest box should be installed 3 days before kindling. A light schedule in windowless rabbitries has to be used with 8 to 16 hours light and 8 to 16 hours darkness in 24 hours with a light intensity of 20 lux. 20 ppm
ammonia and 3,000 ppm carbon dioxide (0.30 Vol.-%) shall be the maximum limits tolerated within the rabbitry.

Notwithstanding the general requirements for housing conditions for farm animals much stronger requirements are intended concerning the area of walls through which daylight may illuminate the stable: natural light should invade into the interior of the rabbitry for at least 5% of floor area whereas for other farm animals this value must be only 3%. The single housing of breeding rabbits is not mentioned explicitly. But, it is known that sexually mature rabbits must be kept separately to avoid injuries caused by aggressive behaviour of high ranking group-mates. Group housing of does with kits is not ready to be used widely in practice.
Non-perforated floors very quickly lead to an accumulation of faeces resulting in an increasing health risk because of the contamination with *E. coli* and *coccidia*. The demand for an elevated seat will be supported by the German branch of WRSA. Especially does with kits but also growing rabbits use this additional space as a withdrawal or a hiding place.
The Federal Ministry wishes to offer an additional spatially separated and darkened area. But, this makes the required twice daily animal control very difficult and is not necessary. It is not realistic to demand that these areas must be controlled twice daily. Even the use of an elevated seat makes it difficult to control animal health daily. Also, the Ministry wishes to have tubes or similar hiding places. But, this increases the risk to identify sick animals too late which have retreated into these areas. Poorer animal health control may not be in the interest of animal welfare regulation.
The continuous supply of hay or straw on a perforated floor leads to a more or less polluted perforated floor and to an inadequate separation of animals from their faeces. As a result, the risk of diseases caused by *E. coli* or *coccidia* increases.

12. MAIN DISEASES OF THE RABBIT

It would be inappropriate here to insert a tractate on rabbit diseases. A disease cannot be described without reference to medical data with which the user of this material is in all likelihood not familiar. In addition, the pathogenic agents of many rabbit diseases are known and in some cases well described, but their presence does not necessarily imply the existence of a disease. Disease is almost always the result of poor husbandry and environment coupled with the attack of a pathogenic agent - microbe, virus or parasite. This chapter contains a general discussion of the descriptions of the main diseases.

12.1. Viral diseases

12.1.1. Myxomatosis

Myxomatosis is a viral infection of rabbits, caused by a member of the Poxvirus family. Blood-sucking insects, including mosquitoes (Photo 60-61), fleas, lice, ticks, and mites, are the main method of spread. Direct transmission is possible, usually by the aerosol route. Those rabbits infected via this route usually develop nasal and eye discharges as part of the disease process. Transmission is also possible via infected hutches or enclosures. An owner may spread the virus from one rabbit to another. Similarly, animals that are congregated at rabbit shows or fairs may become infected if one of the rabbits has the disease and is shedding the virus.

Source: Bodnár Károly

Photo 60-61: Mosquito bite on the nose

The clinical signs of myxomatosis vary with the strain of virus involved and the species of rabbit infected. In rabbits, there are several forms of the disease:

- The peracute form progresses most rapidly and may cause death within 7 days of infection, and within 48 hours of showing signs of disease. The only signs may be lethargy, swelling of the eyelids, loss of appetite, and fever.
- In the acute form, fluid accumulates under the skin, causing swellings around the head and face, including the lips, nose, and around the eyes. The swelling around the eyes gives the rabbit a sleepy appearance. Swellings of the ears may cause them to droop. The area around the anus and genitalia also appears swollen. The lesions progress rapidly, and within 24-48 hours may become severe, causing blindness. The rabbit continues to

have a fever and be depressed. Most rabbits die of hemorrhage and seizures within 10 days. In a susceptible population, over 90% of rabbits may die in this stage of disease.

- The chronic form of the disease is less common, and occurs in animals that survive the acute form of the disease. Rabbits with this form develop thick ocular (eye) discharge and swelling around the base of the ears. Nodules called "myxomas" may develop with 1-2.5 cm diameter especially on the head (Photo 62). Affected rabbits may also show respiratory signs including difficulty breathing. Most animals die of the disease within two weeks. Rabbits that survive may shed the virus up to 30 days. Most rabbits who recover from myxomatosis are immune to re-infection for the rest of their lives.

Source: www.foxyrabbits.eu

Photo 62: Myxomas on the head

There is no effective treatment for myxomatosis. Vaccine has been developed (an attenuated modified-live virus) against myxomatosis for prevention.

12.1.2. Rabbit haemorrhagic disease (RHD)

Rabbit haemorrhagic disease (RHD), also known as rabbit calicivirus disease (RCD) or viral haemorrhagic disease (VHD), is a highly infectious and often fatal disease that affects wild and domestic rabbits of the species *Oryctolagus cuniculus*, but other rabbit species and other wildlife are not susceptible.. The infectious agent responsible for the disease is rabbit haemorrhagic disease virus (RHDV), or rabbit calicivirus (RCV), genus *Lagovirus* of the family Caliciviridae. The virus infects only rabbits, and has been used in some countries to control rabbit populations. Spread is by contact, possibly by infected feces, fomites, possibly by spread of carrion by birds, and by recently contaminated insects such as bush flies. After infection rabbits show few clinical signs other than depression and immobility and die after an illness of about 18 hours. Characteristic gross necropsy lesions are enlargement of the liver and spleen and small, focal, pulmonary hemorrhages. There is massive liver necrosis which is believed to be the trigger for disseminated intravascular coagulation. Rabbits less than 6 weeks of age are curiously not susceptible to fatal disease. An effective vaccine is available.
RHD is endemic throughout most of Europe.

12.2. Bacterial diseases

12.2.1. Pasteurellosis

Pasteurellosis is an infection with a species of the bacteria genus *Pasteurella*. *Pasteurella multocida* is carried in mouth and respiratory tract of several animals, notably cats. Pasteurellosis in humans is associated with a close animal contact, and may be transmitted by injuries caused by rabbit, cat or dog. Pasteurellosis is the disease most often cited, because rodents and lagomorphs are particularly susceptible to this germ.
Pasteurellosis may take many forms in the rabbit: abscesses, mastitis, diarrhoea, metritis, wryneck or septicaemia (Photo 62-63). The rabbitry can easily become thoroughly infected, to the point where pasteurellosis can become endemic. Some *Pasteurella* strains are more pathogenic than others. Pathogenicity can be acquired during the endemic stage, provoking an epizootic outbreak in the rabbitry or even in the entire region.

Source: microbewiki.kenion.edu

A ↑ B →

Photo 62-63:
A – Pathology
B – Discharge from the nose

Environmental conditions (transportation, housing deficiency, and new animals on the farm) also play a role. A point that agricultural officials have all too often ignored is that this basic notion is as true at the production-unit level as it is at the village, region or country level. In traditional French rabbitries, for example, Pasteurellosis was once a lethal respiratory disease that could decimate the rabbit population of a whole village within a few weeks. Today, the drop in the numbers of these traditional units has led to a marked reduction in the epizootic and lethal properties of this disease.
Chronic pasteurellosis, particularly during fattening, is also a direct or indirect cause of diarrhoea and mortality in rabbits.

These are usually secondary infections or associations such as *Streptococci* and *Bordetella*. All production units are contaminated with *Pasteurella* and, while there may not be respiratory pasteurellosis, the constant threat is there, and varies with the pathogenic strength of the strain.

12.2.2. Tularaemia (rabbit fever)

This very contagious disease (zoonosis) is common in hares, but rabbits seldom contract it. Its significance is the danger it represents for humans (Photo 64). A bacterial disease caused by *Francisella tularensis,* it gives rise to high fever, leaving the animals in a semicomatose state. Lesions are enlargement and congestion of the spleen. The liver is often dotted with numerous tiny greyish-white spots (miliary necrosis) about the size of a grain of millet.

Source: www.healthhype.com

Photo 64: Tularaemia skin ulcer

12.2.3. Listeriosis

This disease is less rare than tularaemia, and still appears sporadically in farm rabbitries. A septicaemic disease caused by *Listeria monocytogenes,* it is very difficult to diagnose clinically. Listeriosis should be suspected when the following symptoms appear on the farm:

- nervous upsets: photophobia, spasms, wryneck;
- abortions in does or ewes;
- miliary necrosis of the liver and spleen (without enlargement).

12.3. Fungal disease

12.3.1. Ringworm

Also called dermatomycosis or trichophytosis, ringworm is a skin and hair disorder. Not very common in farm rabbitries, it is widespread in intensive rabbit production. It starts with circular bald patches, usually on the nose. The hair looks clipped and the skin is irritated and

inflamed. More small patches appear on the head, ears and forepaws and then over the whole body (Photo 65). On the oldest lesions the hair can be seen growing again in the centre.
It is a very contagious infestation that can sometimes be transmitted to humans, although it is more commonly transmitted to other domestic animals such as dogs and cats. Ringworm is caused by microscopic fungi that can belong to different genera *(Trichophyton, Microsporum, Achorion)* and are not specific to rabbits.
There is no economic loss as long as infestation is light. Treatment is long and costly. An antimycotic is administered in the feed. During treatment all equipment should be frequently cleaned and disinfected. Many producers, successfully it seems, sprinkle powdered sulphur (sulphur flowers) on the ground, cages and nesting boxes. In small rabbitries local treatment can be applied with antimycotics in powder or liquid (e.g. tincture of iodine), but preventive hygiene should accompany the treatment. Badly afflicted animals should be culled and domestic animals treated.

Source: Bodnár Károly

Photo 65: Bald patches on the ears

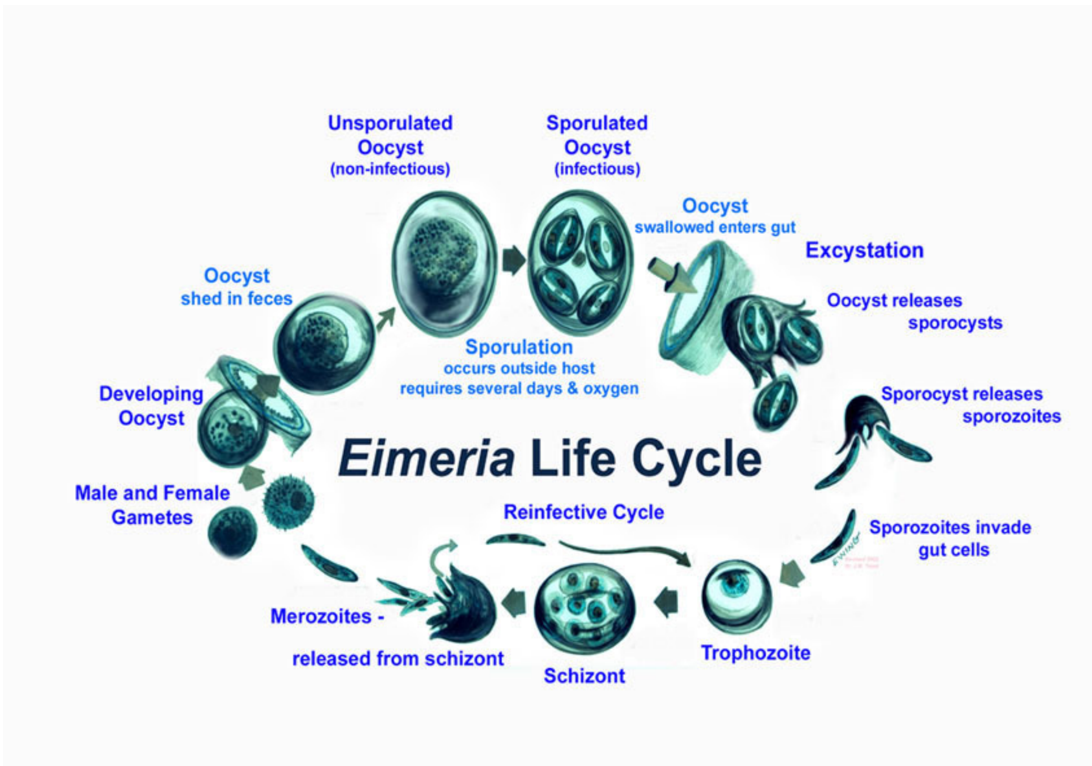
12.4. Parasites

12.4.1. Coccidiosis

Coccidia are protozoa, the most primitive phylum of the animal kingdom, which reproduce both sexually and asexually. A large number of families are represented. The *Eimeriidae* family is typified by the independent development of male and female gametes.
Almost all coccidia belong to the genus *Eimeria* - they include four sporocysts containing two sporozoites. Typically they form oocysts, a parasite mechanism for dispersal and defence in an external environment.
The coccidia cycle (Figure 13). *Eimeria* are monoxenous and have very high host specificity. The rabbit therefore cannot be infested by the coccidia of other animal species. *Eimeria* develop in the epithelial cells of the digestive apparatus (intestine, liver). Eggs (oocysts) are found in the intestine and faeces. After maturing (sporulation), the oocysts contain eight "embryos" (sporozoites).
The *Eimeria* cycle includes two distinct phases:

- an internal phase (schizogony + gamogony) in which the parasite multiplies and the oocysts are eliminated in the faeces;
- an external phase (sporogony) during which the oocyst becomes able to infest if it finds favourable conditions of humidity, heat and oxygenation.

The internal part of the cycle begins with ingestion of the sporulated oocyst and the excretion of the sporozoites. The parasite then multiplies. This may entail one, two or more schizogonies (asexual reproduction) according to the species *(E. media,* two schizogonies; *E. irresidua,* three or four schizogonies). It can take place in different parts of the digestive system *(E. stiedai* in the liver; *E. magna* in the small intestine; *E. flavescens* in the caecum). The final schizogony leads to the formation of gametes.



Source: www.vuvb.utc.sk

Figure 13: The coccidia cycle

The next step, gamogony (sexual reproduction), ends in the formation of oocysts that are excreted with the faeces; the total duration of the internal phase of the cycle also varies with the species (e.g. E. *stiedai,* 14 days; *E. perforans,* four days).

Coudert in France and many others have studied this part of the cycle, as the oocyst is the agent to be destroyed. In practice, oocyst resistance is hard to overcome, particularly in disinfecting rabbitries. Chemical disinfection is pointless as oocysts can only be destroyed by heating and drying.

At least 11 coccidia species are rabbit parasites. One infests the liver (*Eimeria stiedai*), the others the intestine (*E. perforans, E. irresidua, E. magna, E. media, E. piriformis, E. intestinalis, E. flavescens*).

Pathogenic effect has been judged here solely on the basis of retarded growth and mortality. But it must not be forgotten that coccidiosis, like all diseases, can have certain after-effects

on the kidneys or liver in particular, which in turn have repercussions on fattening status at slaughter or on the animal's future if it is to be kept as a breeding animal.
Often one disease is also complicated by other diseases.
Coccidia are specific pathogenic agents. When inoculated into rabbits pathogenic coccidia cause the same lesions and the same symptoms (diarrhoea, loss of weight, death) in all the animals tested.
The main symptoms are: diarrhoea, weight loss, low intake of feed and water, contagion and death. Depending on the coccidia species, diarrhoea appears between the fourth and the sixth day after infestation. The peak is from the eighth to the tenth day. It then declines in three or four days. Diarrhoea is the first visible symptom, together with cutaneous dehydration, clinically demonstrated by the persistence of skin folds.
Coccidiosis is very difficult to diagnose. It can be done by fecal flotation, by identifying the oocysts in the feces, or under the microscope by counting the coccidia per gram of feces.
Good hygiene is the proper way to prevent the first. Preventive medicine should be added to combat coccidiosis. Anticoccidial drugs administered as a preventive measure in balanced pelleted feeds are without doubt the most popular control method. Antibiotics do not cure coccidiosis.

12.4.2. Tapeworm (Cysticercosis, Taeniasis)

Intestinal parasitism is very common in wild rabbits. It is frequent and not of great economic importance in farm-bred domestic rabbits if overall sanitary and health conditions are satisfactory. In poorly kept hutches, or where infestation is massive, these parasites enhance all other ailments, both intestinal and other, making them acute, enzootic and lethal. This common parasite (*Taenia pisiformis*) produces fine, white streaks on the liver and translucent cysts, alone or in bunches, on the peritoneum and viscera (Photo 66-67). The cysts are produced by the larvae of dog and cat tapeworms. Rabbits are contaminated by eating feed that has been in contact with excrement. The terminal hosts (dog, cat, fox) become carriers by eating rabbit viscera (Figure 14). Symptoms are few - sometimes diarrhoea - except with heavy infestations (not uncommon) when growth rate slows. There is no curative treatment. The other domestic animals have to be treated. Tapeworm larvae of other species of animals (pig, rat, etc.) can also infest rabbits.

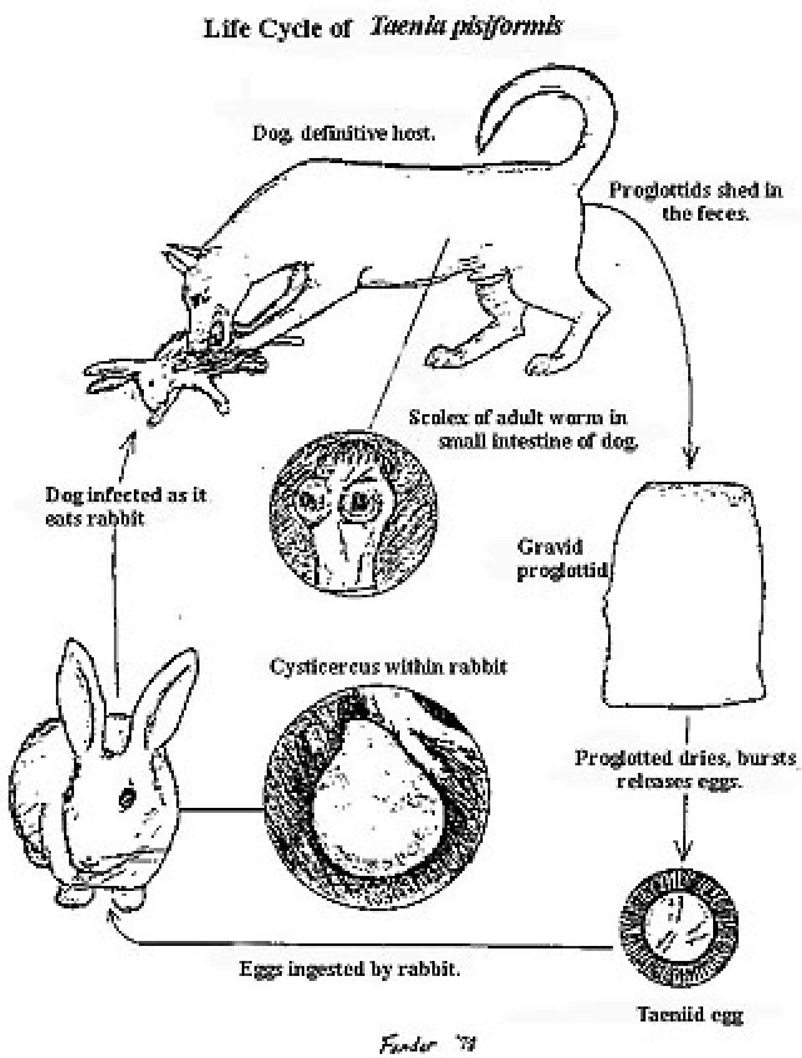
Source: Bodnár Károly

Photo 66-67: Cysticercus on the peritoneum of the rabbit

Rational rabbit production has done away with all these intestinal worms. Control is easy; it is only necessary to break the parasite's life cycle. Essentially this means taking the following measures regarding forage:

- it should not be gathered in areas where there are large numbers of dogs, cats or wild rabbits;
- it should be distributed on feed racks where animals are unable to soil it with their faeces or urine.

Regular treatment can also include broad-spectrum antihelmintics or copper sulphate-based preparations in drinking-water (1%) for one or two days.



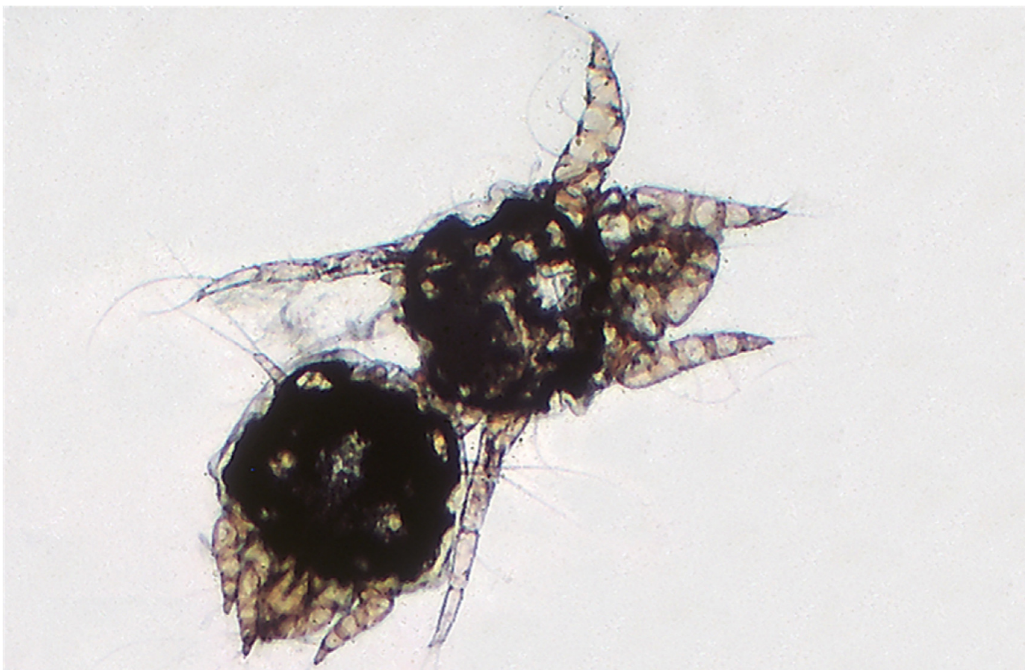
Source: www.geocities.ws

Figure 14: Life cycle of *Taenia pisiformis*

12.4.3. Psoroptic mange

Ear mite is very common. It is a parasitic disease caused by a mite *(Psoroptes cuniculi)* (Photo 68) and frequently complicated by bacterial infection. The symptoms are external otitis and yellow or brown scabs in the ear canal. First signs of a possible ear mite infestation include unusual amount of dark coloured earwax (arrow) and small adherent skin scales deep in the ear canal and the earlobes, and a foul smell in the ear. The course of the disease can be very long. The scabs become waxy and invade the whole ear. The inside of the ear

becomes scaly. The middle ear may then be affected, causing wryneck (the rabbit's head is held constantly to one side).
Treatment can be effective if the disease is caught in the very early stages, that is, as soon as small yellow-brown deposits are noticed in the ear. Insecticides are applied locally in the ear or with injection. Ivermectine is unquestionably the drug of choice; two 200 mg injections per kilogram of live weight every eight hours provide a spectacular cure. The product is very persistent and if the stock is carefully treated at the same time and the rabbitry cleaned out, it will be effective for several months. This is a very strong medicine and should be reserved for breeders, for animals treated with it cannot be eaten for several months. Glycerine or vegetable oil are also effective when applied frequently locally.



Source: www.studyblue.com

Photo 68: Ear mites (*Psoroptes cuniculi*)

Prevention involves culling rabbits whose external ears are severely affected, and treating all other rabbits for several days running and then every fortnight. Throughout the treatment the straw litter (if any) must be changed frequently as the parasites can stay alive in the litter for a long time.

The scales/crust (Photo 69-70) should never be removed! Removing them is horribly painful to the rabbit, leading to screaming.

Source: Bodnár Károly

Photo 69-70: Scales in ear (early stage left)

12.5. Other diseases

12.5.1. Trichobezoar

Trichobezoars ("hairballs") (Photo 71), originally thought to be simply due to fur ingestion, are now generally considered to be the result of decreased gastric movement, often because of physical inactivity of the rabbit or secondary to reduced motility of the intestine.

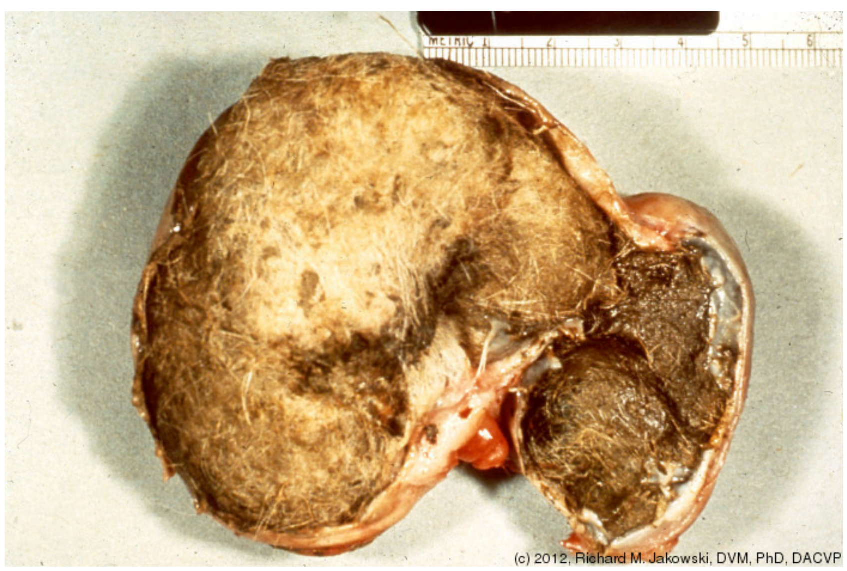


Photo 71: Rabbit gastric trichobezoar

For rabbit owners, the word hairball can strike fear in their hearts. Hairballs have long been considered one of the most serious ailments, with the potential to cause death. But what exactly is a hairball and why does it seem to primarily affect pet rabbits and not their wild cousins?

A hairball, technically called a trichobezoar, is an accumulation of hair within the digestive tract. It is thought that this hair is ingested when the bunny grooms. The accumulated hair bunches up into a ball that cannot pass through the intestinal tract, usually leading to an obstruction. This is also referred to as wool block, gastric stasis or hair block. The stomach is the most common part of the intestinal tract affected. Cats are also commonly affected with hairballs, but the difference between cats and rabbits is that cats typically and harmlessly vomit their hairballs. Rabbits do not have the physical ability to vomit.

Historically, rabbits with poor appetite, smaller faecal pellets, weakness and weight loss are often diagnosed with a hairball obstruction. Sometimes, X-rays are taken to evaluate the intestinal tract. Without treatment, many of these bunnies do not survive.

Treatment of hairball obstructions can be either medical or surgical. Medical treatment includes the administration of injectable fluids, most often subcutaneous, and medication to try to increase contractions of the intestinal tract. If not effective, surgical removal of the hairball may be necessary.

Prevention of hairballs has been an important part of keeping your rabbit healthy. Prevention usually consists of daily grooming, cat hairball medication, pineapple juice or papaya enzyme. It is theorized that these fruits have an enzyme that helps breakdown hair. Unfortunately, this has not been scientifically proven.

For years, veterinarians have noticed that after removal of the hairball from the affected rabbit, the hairball readily fell apart in a small amount of water. They began to wonder why hairballs weren't falling apart in the liquid of the stomach and why it was causing a problem. They also wondered why hairballs did not cause serious and common illness in wild rabbits. After years of research, the syndrome of hairballs is being reevaluated. The most current thoughts are that the real culprit is not hairballs; it is abnormal gastrointestinal function.

Gastrointestinal problems

Most rabbits afflicted with hair balls are on a high carbohydrate, low fibre diet. These rabbits are most often kept caged and have been under stress, causing changes in the motility and function of the stomach and intestines.

What these new thoughts mean to the pet rabbit is primarily aimed at preventing problems. Treating a rabbit with a suspected hairball or intestinal motility problem remains the same. Initially, injectable subcutaneous fluids and motility stimulating drugs are used and the rabbit is force fed. Most rabbits respond to this treatment in about four to five days. If there is no response to treatment, surgery is needed in an attempt to save the pet.

Prevention

Preventing hairballs is crucial to maintaining the health of your rabbit. It is thought that hairballs are a secondary problem. The real problem is a motility problem. By keeping your bunny healthy, hairballs are often prevented.

High fibre diets have been found to reduce the incidence of hairballs drastically. This means that your rabbit should have plenty of fresh timothy or oat grass hay available at all times and plenty of fresh greens available.

Offer limited pellets. This diet provides sufficient moisture and fibre to keep your rabbits internal organs functioning in top form. Continuing to groom your rabbit and even providing pineapple or papaya can still be helpful. Even if these have not been proven to prevent hairballs, at least they don't do any harm.

13. RABBIT MEAT

Selection for growth rate is commonly practiced in rabbit sire lines. Selection increases all weights along the growth curve. Because carcass weight is fixed by the market, selection for an improved growth rate results in less mature animals, as expressed as weight divided by adult BW. The importance of examining the results of selection in relation to maturity degree was accentuated that most of the phenotypic responses observed in growth-selected animals have been achieved as a consequence of change in adult size; however, a part of the phenotypic variance is truly genetic. Divergently selected lines may provide a model of both genetic and biological relevance for analyzing complex quantitative responses. Because rabbit meat is found both as a whole or cut-up carcass (Photo 72) and processed ready products, classical attributes of quality for both carcass and meat need to be considered. Bone resistance recently has been considered as another quality factor for the commercialization of retail cuts and mechanically deboned meats. The frequency of leg bone breaking during carcass handling has been estimated to be approximately 10% of the slaughtered animals.
Meat pH was not affected by selection, and minor modifications were noted for raw meat texture.

Source: Bodnár Károly

Photo 72: Whole carcass (left) and cut-up (right)

13.1. Characteristics of the rabbit meat

Rabbit carcass and meat quality is influenced by breed, age of animals, their diet, ante and post mortem factors, etc. Rabbit meat doesn’t have a very strong flavour, being comparable but not identical to chicken (Table 5). In New Zealand White rabbit meat moisture of 77.3 g/100 g, protein 21.5 g/100 g and ash 1.6 g/100 g, fat 2.5-3.4 g/100 g was found. Females had more moisture than males in both breeds, but less protein and fat. In addition, higher intramuscular fat content influenced by the genotype, age, and sex of rabbits. The fat

content varies widely in the carcass, from 0.6 to 14.4 g/100 g (intramuscular and intermuscular) with an average value of 6.8 g/100 g with the loin being the leanest part of the carcass (1.2 g/100 g).
Rabbit meat is characterized by its low contents in sodium and iron, while the phosphorus level is high. The sodium content varies from 37 to 49 mg/100 g in rabbit meat and there is a lower level of phosphorus (222 to 230 mg/100g). The high potassium and low sodium concentration may make rabbit meat particularly recommended for hypertension diets. Rabbit meat is rich in phosphorus, and 100 g provide approximately 30% of the recommended daily intake for human.
Major sources of cholesterol in the human diet are meat from domestic livestock. Cholesterol content of raw and cooked meat and poultry products ranges from 40 to 90 mg/100 g. The amount of cholesterol in rabbit meat was about 59 mg/100 g of muscle, similar to the value we found in the present study (56.4 mg/100 g), but lower than those reported for meat from other species (61 mg in pork, 70 mg in beef and 81 mg in chicken/100 g). The cholesterol content of raw bovine meats ranges from 43 to 84 mg/100g. Cholesterol content of beef is affected by multiple factors such animal breed, gender, animal maturity, degree of marbling, subcutaneous fat thickness, dietary energy level, feeding and type of cut. Cholesterol content of pork, from 30 to 81 mg/100 g for raw pork, is generally lower than that of beef, although some studies indicated no significant difference between the two types of meat. Cholesterol in pork is influenced by maturity, type of cut, fat thickness, animal diet, degree of marbling, and genetic variation. Due to the presence of skin, cholesterol content of poultry is difficult to compare with beef, pork or rabbit. In general, raw poultry meat has approximately 27 to 90 mg cholesterol/100 g.

Table 5: Comparative nutritional composition of different meats.

	Rabbit	**Chicken**	**Beef**	**Pork**
Moisture (g/100 g)	68.5 ± 1.05	68.1 ± 1.19	53.2 ± 1.21	43.7 ± 2.13
Protein (g/100 g)	21.2 ± 0.79	20.1 ± 0.27	26.3 ± 0.16	27.3 ± 0.22
Fat (g/100 g)	9.2 ± 0.38	10.8 ± 0.08	19.6 ± 0.09	28.2 ± 0.13
Ash (g/100 g)	1.1 ± 0.08	1.0 ± 0.05	0.9 ± 0.07	0.8 ± 0.11
Calcium (mg/100 g)	21.4 ± 0.09	12.1 ± 0.04	10.9 ± 0.38	9.3 ± 0.47
Phosphorus (mg/100 g)	347 ± 0.26	252 ± 0.06	179 ± 3.62	176.4 ± 3.36
Sodium (mg/100 g)	40.5 ± 0.89	71.4 ± 0.92	63 ± 0.90	67.3 ± 0.91
Cholesterol (mg/100 g)	56.4 ± 0.92	68.3 ± 2.14	114.5 ± 11.68	108.4 ± 10.31

Number of samples/species = 6. Values represent duplicate assays of eight subsamples (mean ± SD) for each meat sample.

Source: Nistor et al., 2013.

The quality of the nutrients from the food which we intake represent a main factor of health state. Man procures from food the necessary elements for a good function of organism form the angle of physiology and life sustain. Meat quality concept is in a continuous change also nowadays, the consumer is interested by its’ influence on health state, hedonism properties, sensorial properties, easy and quick way of cooking and at last but not least by the achievement price.
Rabbit meat correspond to the actual demands of consumers, being rich in proteins with a high biological role, due to the high content in essential amino acids; also contain a reduced quantity of lipids (especially cholesterol), and its quality is superior compared with other species, by high content in monounsaturated and polyunsaturated fatty acids (especially ω3 and ω6, essential fatty acids, which have positive influences regarding the health state of human organism). Content in mineral substances is high (especially potassium, phosphorous, magnesium and sodium), as well as the one in vitamins (especially B complex and liposoluble vitamins A and E).

Another advantage of rabbit meat (in according with the studies effectuated in world), is represented by the very low content in urate, being recommended even to the persons with gout. It is necessary a profound study of those rabbit meat features, especially its high diet and nutritive-biological value, mainly in the actual period, when the so called civilization maladies, respectively cardio-vascular diseases and the metabolic ones (diabetes, gout, obesity) have an increased incidence.
Therefore, from the above data one can conclude that rabbit is a most acceptable source of protein.

Rabbit meat represents a homogeneous food product based on lack of a detectable influence of natural factors on cholesterol content; this could be promoted by the industry to increase rabbit meat consumption. In contrast to other common livestock species, in the rabbit the sex (i.e., bucks vs does), likewise, did not influence growth, carcass or lean yield traits. Traits generally were more favourable in kits from smaller litters. Growth, carcass and lean yield traits were not related to total cholesterol content of lean tissue per rabbit. The total cholesterol level of rabbit meat ranks in the lower range of published values for popular red meats and poultry.

13.2. Factors affecting meat quality

The effect of selection for growth rate on carcass and meat quality was assessed by comparing selected and control populations of rabbits measured at the same stage of maturity and slaughtered at 9 and 13 week of age. When animals were compared at similar degrees of maturity, selection for growth rate did not produce a negative effect on carcass and meat quality. There was no increase in fat content of the carcass, and there was an improvement of the meat:bone ratio with selection, with a difference between Controll (C) and Selection (S) groups of −0.42. However, the carcasses of S animals have 1.45% lower water-holding capacity. Carcass quality changed markedly with animal age.
Heavy rabbit carcasses had lower organ percent and a higher loin percent. Dissectible and i.m. fat content were higher in older rabbits, with older animals having 0.97 and 0.79% more dissectible and i.m. fat content, respectively. Meat quality traits improved with age of slaughter, although there was an increase in glycolytic metabolism. Results from this study indicate that selection for growth rate has little effect in carcass and meat quality when rabbits are measured at the same stage of maturity.
Table 6 shows the means of different descriptors of meat quality traits. The S line had a slightly higher LM pH than the C line. In contrast, S line had an inferior WHC (water holding capacity) and a higher percentage of released water than the C line. In a similar experiment in rabbits, comparing different generations of the same line.
Regarding the colour measurements, no differences between groups were found for L* and b* coordinates, whereas the C group showed higher values of a* coordinate. The chemical composition of the hind leg was scarcely affected by selection for growth rate. The S group showed lower protein content and higher water content than the C group, but these differences were not of practical importance.

Table 6: Differences between selection (S) and control (C) groups and age of slaughter (13 wk – 9 wk) for meat quality traits in rabbits selected by growth rate

Trait[a]	Mean	CV, %	C – S	SE (C – S)	Sig[b]	Age	SE	Sig[b]
pH LL	5.77	2.1	–0.051	0.026	*	0.040	0.026	ns
PRW, %	32.1	5.0	–1.2	0.34	***	–0.82	0.34	*
WHC, %	29.8	10.8	1.5	0.68	*	1.8	0.67	**
LL L*	48.8	6.7	0.065	0.60	ns	–2.0	0.60	**
LL a*	4.70	24.2	0.48	0.21	*	–0.87	0.21	***
LL b*	1.79	56.2	0.31	0.19	ns	–1.3	0.19	***
HL protein, %	20.9	1.7	0.18	0.066	**	0.44	0.07	***
HL fat, %	3.59	25.9	0.29	0.17	†	0.79	0.17	***
LH moisture, %	74.1	1.4	–0.48	0.19	*	–0.94	0.19	***

[a]pH LL = muscular pH of the longissimus lumborum (LL); PRW = percentage of released water of muscle LL; WHC = water-holding capacity of muscle LL; LL L* = lightness of the muscle longissimus; a* = redness of the muscle longissimus; b* = yellowness of the muscle longissimus; HL protein, fat, moisture = percentages of crude protein, crude fat, and moisture of meat of a hind leg.
[b]Significance levels: ns = not significant = $P > 0.05$; †$P < 0.10$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Source: Hernández et al., 2004

No differences were found in pH of LL muscle between 9 and 13 wk of age (Table 2). The WHC improved with increasing age (higher WHC and lower percentage of released water at 13 than 9 week of age). In addition, differences in color measurements were found with the increase of age. Animals at 9 week of age had higher values of L*, a*, and b* than animals at 13 week of age. These lower values in older animals could be a consequence of a decrease in oxidative metabolism in LM during growth. As the age increased, the oxidative metabolism and the myoglobin level decreased. Moreover, the higher percentage of released water in younger animals may be related to the higher value of L* coordinate because lighter meat is associated with more exudative meat.
The chemical composition of hind leg meat was also affected by age. There was an increase in protein and fat content and a decrease in water content with the increase of age. Several authors have reported an increase in lipid content and a loss of water content with increasing rabbit age.

However, carcass weight is fixed by the market, and animals selected for increased growth rate will shorten the growth period and will reach slaughter weight at a younger age. We found a clear effect of slaughter age in carcass and meat quality traits. The effect of selection changing maturity at slaughter age will be positive for some traits and negative for some other traits. Younger animals had a poorer dressing out percent, but carcasses also had a lower fat content.
Loin percent was lower in younger animals, but hind legs part percent was higher. Meat-to-bone ratio was poorer in younger animals. Meat quality was also affected, with younger animals having lower lipid content in the meat and some differences in colour.

13.3. Meat processing and traceability

Rabbit meat is a highly digestible, tasty, low-calorie food, often recommended by nutritionists over other meats, yet it is still considered a niche product, especially because of its time consuming preparation which requires culinary skills and because of cultural differences among European consumers. For this reason, the processing industry in Europe is gradually improving the availability of rabbit meat in a large variety of processed ready-meals which make it easier to prepare thus meeting the demands of consumers. The proportion of cut-up and further processed products should increase in the next years. As with poultry, this shift towards further processed products in Europe will soon underscore the necessity for higher standards in rabbit meat in order to improve sensory characteristics and functional properties. Complex products such as sausages, breaded products and fully cooked heat-and-serve items require an understanding of the contribution of rabbit meat to these products as well as their influence on sensory properties of the food.

Moreover, large rabbit industry integration is becoming more important and the development of rabbit meat production is forcing processing plants to improve slaughter capacities by using high-speed and more automated slaughter lines. From the point of view of food safety, as observed in poultry, these changes can lead to higher microbial risks due to possible cross-contamination during pre-slaughter (crating, transportation, and holding conditions) and processing (skinning and evisceration) operations. The microbial risks are also increased by the higher degree of manipulation needed by produce added-value products as for example the use of meat after grinding and the mix with ingredients of different origin. Furthermore, European rabbit production has been influenced by the introduction of more restrictive regulations and higher consumer attention to food safety aspects. All this has come about as a consequence of the many meat safety crises of previous years which have convinced the European Union to enact several regulations aimed at guaranteeing meat safety and systems to prevent or at least manage similar future crises. The major objective was to enforce the provision of clear and reliable information to consumers at sale points, based on a system of tracking meat back to animal of origin, the slaughterhouse and the cutting unit. Nowadays, if consumers benefit from EU-wide compulsory beef label system, so far, no compulsory label system is running in rabbit production systems. Moreover major companies have improved voluntary traceability systems and indicators on labels aimed at restoring consumer confidence in meat products. However from January 1st 2005 (Regulation 178/2002/EC), it is compulsory for all feed and food operators to adopt a traceability system. They are able *"to identify any person from whom they have been supplied with a food, a feed, a foodproducing animal, or any substance intended to be, or expected to be, incorporated into a food or feed. To this end, such operators shall have in place systems and procedures which allow for this information to be made available to the competent authorities on demand".*

13.3.1. Processing

Rabbit production and processing involve a series of interrelated steps designed to convert rabbits into ready-to-cook whole carcasses, cut-up carcass parts, or various forms of deboned meat products (Figure 15).

Table 7 summarizes the main operations and issues concerning commercial rabbit processing. The quality of rabbit muscle as food depends upon chemical, physical, and structural changes that occur in the conversion of muscle to meat. During production and management of rabbits, (preslaughter) factors not only exert important effects on muscle growth, composition, and development, but also determine the state of the animal at slaughter. Thus, events which occur both before and after slaughtering of rabbits influence carcass and meat quality. Short term factors affecting carcass and meat quality are those that occur during the last 24 hours that the animal is alive, such as harvesting (feed and water withdrawal, crating), transportation, plant holding, unloading, hanging, stunning, and killing. It is also likely that the effects that variation in handling during this period and at slaughter can have on quality are greater than those attributable to variation in husbandry practises during rearing.

Fasting
↓
Crating
↓
Transportation
↓
Holding at the processing plant
↓
Stunning
↓
Hanging
↓
Killing
↓
Bleeding
↓
Skinning
↓
Evisceration
↓
Chilling
↓
Processing
↓
Packaging
↓
Marketing

Source: Cavani and Petracci, 2004

Figure 15: Preslaughter, slaughter and processing steps of rabbit.

Table 7: Main operations and issues in commercial rabbit slaughtering and processing.

Harvesting (fasting, crating, transportation and holding at the processing plant) - Feed withdrawal 8-12 h prior to slaughtering - reduce faecal contamination during evisceration - Catching, crating, transport, holding, *ante mortem* inspection - Issues: animal welfare, live shrink, damage, dead-on-arrival
Immobilization (hanging, stunning and killing) - Unloading and hanging on processing line - Stunning, killing and bleeding - Issues: Carcass damage, animal welfare, quality, automation
Skinning and evisceration - Skinning - Removal of forefeet - Opening cut, removal of viscera and uro-genital tract - *Post mortem* inspection by veterinary surveillance - Whole carcass washer - Offal, blood, and skin are collected for disposal - Issues: Carcass damage, sanitation, automation, condemnation
Chilling - Rabbit carcasses must be chilled to reduce microbial growth - Issues: Sanitation, weight loss
Processing, packaging, marketing - Grading - the sorting into lots according to similar quality attributes - Further processing - cut-up parts, deboned meat, formed products, cooking, freezing, etc. - Market distribution - Issues: Market changes, packaging, retail pressure, value added products

Source: Cavani and Petracci, 2004

Harvesting (fasting, crating, transportation and holding at the processing plant)

Before rabbits are caught, crated, and transported to the processing plant, feed is removed to allow time for the evacuation of intestinal contents. This reduces the incidence of faecal contamination of the carcass which may occur during processing as well as reducing stress during transportation. Fasting refers to the total length of time rabbits are without feed before processing including the time the rabbits are in the farm without feed, as well as the time rabbits are in transport and in the holding area at the processing plant. Thus, attaining optimal feed withdrawal requires cooperation and communication between live production and processing personnel. Length of fasting is important because it affects carcass yield (live weight losses), carcass contamination and product safety (pathogenic and spoilage bacteria) and quality (ultimate muscle pH).

Ideally, the length of feed withdrawal before processing should be the shortest amount of time required for the digestive tracts to become empty. Due to caecotrophy, rabbits are usually considered to be very resistant to hunger. Recommended length of time off-feed for rabbits before processing is between 8 to 12 hours because the majority of the rabbits in the flock will have had enough time period to evacuate properly, and effects of the time period without feed weight will be minimal on their carcass. Rabbits lose 3-6% of body weight during the first 12 hours of fasting, increasing to about 8-12% at 36-48 hours. Generally, weight loss is slightly lower if fasted rabbits are allowed access to water before crating. In the first 4-6 hours, weight loss in rabbits is mainly due to emptying of the gut, so carcass yield is not negatively influenced.

After 6 hours, there is also loss in moisture and nutrients from body tissues, which can affect carcass yield. It is not clear whether transport has any effect on the live weight of rabbits other than through the concomitant fasting. A longer duration of transportation negatively affected weight loss. Furthermore live shrinkage of rabbits was found to be lower if transport is conducted at lower environmental temperatures. Close environmental control in the crates on the vehicle is difficult, mainly because on most vehicles ventilation is passive and is impeded by the close stacking of adjacent crates.

Rabbits on the inside of a load may suffer hyperthermia, whereas those on the outside may experience hypothermia. Of course the way in which transport affects the pattern of changes to gut fill depends on whether the rabbits are allowed free access to feed and water before crating. At least 12 hours prior transportation, transport causes no additional weight loss from the gut. If rabbits are allowed free access to feed and water before transportation, loss of gut fill is lower than if rabbits are fasted before transportation. Crating and transportation can also cause a slow rate of transit of feed into the digestive tract and the rupture of caecotrophy practice which leads to higher spillage and rabbit contamination. Solid floors in transport crates are recommended to prevent the transfer of urine and faeces from higher crates in a stack to those below.

There is much evidence that harvesting, transport and handling of rabbits are stressful as indicated by physiological and biochemical changes occurring during these phases. This stress causes catecholamine release, muscular contractions and rise in body temperature.

Rabbits which are dead-on-arrival (DOA) at the plant represent a complete loss of economic value. There are no experimental data on mortality during transportation, but it is mostly very low as indicated by non-scientific observations of plant personnel. Prior to transport to the slaughter plant, rabbits are removed from the fattening cages and loaded into crates by hand. This method of handling has been associated with animal welfare problems, but also results in injuries which are typically bruises consisting in the rupture of cells and capillaries beneath the skin. The areas of the rabbits most frequently bruised are legs, thoracic muscles and the internal part of the loin region. These bruises are mostly not detectable in the live rabbit and become visible only during slaughter after skin removal.

The influence of feed withdrawal and transportation on rabbit meat quality is poorly understood, however it has been observed that transport increases the depletion of glycogen over fasting irrespective of whether the animals are fed before the journey. Glycogen reserves can be depleted by prolonged feed withdrawal and stress of transport. It has been suggested that glycogen concentration in the liver falls rapidly between 6 and 12 hours of fasting. The consumption of glycogen reserves determine an increase in muscle ultimate pH leading to a lower degree of protein denaturation with higher water holding capacity and darker colour. Although these effects are not all detrimental to quality, they could undoubtedly contribute to a variability in quality. There is no evidence of transport causing pale, soft, exudative (PSE) rabbit meat.
Holding prior to slaughter at the processing plant can contribute to mild the effect of transportation on rabbit meat quality properties. Holding the rabbits after transportation for 18 hours led to ultimate lower muscle pH values due to the restoration of glycogen stores during holding time. Because processing plant efficiency depends on product uniformity, this effect can contribute to increasing product uniformity among rabbits belonging both to the same flock and to different flocks improving product quality. Before slaughtering, *ante mortem* inspection of rabbits is required to be conducted based on national legislation to ensure that animals are not affected by diseases as well as animal welfare has been maintained at slaughter.

Immobilization (stunning, hanging and killing)
Rabbit slaughtering starts with the individual unloading of rabbits from transport crates after which they are stunned. The goal of stunning is to render the rabbit unconscious prior to killing for human slaughter issues complying the legislation requirements. In addition, it has been widely reported stunning techniques are critical for processing efficiency and product quality. For many years mechanical stunning was replaced by electrical stunning in rabbit slaughtering. Nowadays the use of gas stunning in rabbit slaughtering is not reasonable for economic impact. Electrical stunning is usually applied using devices which produce anaesthesia by passing an electric current through the brain of the animal. From an animal welfare point of view electrical stunning can be achieved using currents with minimal amperage of 140 mA which can be obtained with the application of 100 V. These conditions could yield an adequate time of unconsciousness for the neck to be cut and sufficient blood to be lost so as to kill the rabbit before it regains consciousness. The stunning of rabbits affects meat quality by influencing *post mortem* muscle acidification. Electrical stunning conducted at low voltage (45 vs. 80V), independent of amperage applied, slowed the rate of *post mortem* pH fall as compared with stunning by cervical dislocation. On the contrary it was found that electrical stunning accelerates early muscle acidification when compared with stunning by cervical dislocation. These differences in muscle pH during early rigor development, however, do not affect ultimate muscle pH, tenderness values, or meat quality.

Usually, after stunning, the rabbits are hung by the hind feet at the processing line and killing is conducted by cutting the jugular veins and carotid arteries on one or both sides of the neck. Once the neck has been cut, the rabbits are allowed to bleed for 2-3 minutes. During this period the rabbit loses most of its blood, which eventually causes brain failure and death. Insufficient blood loss due to bad neck cutting can cause residual blood engorging vessels and absence of muscular contraction favouring the emptying of blood vessels. This can produce carcasses with visible engorged veins and dark meat.

Skinning and Evisceration

Although the removal of skin is becoming more automated, it is still largely carried out manually worldwide. This phase is critical for bacterial cross-contamination of carcasses originating from the contact of skin and the tools or the machines used for skinning. After the skin, forefeet are removed and the carcass, while still hanging, is opened to remove the viscera.

As for skin, this operation is mainly conducted by hand even if it is becoming partially automated. Evisceration is the removal of viscera and it has conducted as follows:

- the body cavity is opened via an incision from the lower part of the abdomen near the anus to the mid-point of the lowest rib;
- the viscera including the gastrointestinal tract and associated organs (stomach, caecum and intestinal contents) and the uro-genital tract with empty urinary bladder are taken out.

On the contrary liver, kidneys, and the organs located in the thorax and neck (lungs, oesophagus, trachea, thymus and heart) remain inside the carcass. Reducing faecal material at slaughter is an important practice which reduces contamination during processing which can occur either because of leakage of the contents of the intestinal tract onto the carcass, or through spillage resulting from ruptures of the gastrointestinal tract and viscera during evisceration. Incidence of faecal contamination, assumed to be primary pathway for pathogen contamination of carcasses, can be used as an indicator of process control during slaughter. Prevention and removal of faecal contamination is considered a critical part of the HACCP plan in slaughter plants. At the time of evisceration, veterinary service carried out *post mortem* inspection of the carcass of every rabbit to evaluate if carcass parts or organs fit for human consumption or have to be condemned.

Chilling

After evisceration rabbit carcasses are submitted to chilling (Photo 73). The primary objective of chilling rabbit carcasses is the reduction of microbial growth to a level that maximizes both food safety and time available for marketing (shelf-life).

Source: Bodnár Károly

Photo 73: Carcasses on conveyor chain

The most common method of chilling is by air. Air chilling involves passing the carcasses hung on the processing line through large rooms of circulating cold air. To enhance cooling, the product can be sprayed with water, which absorbs heat as it evaporates. Humidity can also be controlled to maximize the air ability to absorb heat from the carcasses and also the air ability to evaporate the surface water for evaporative cooling. Air-chilled rabbit carcasses usually exhibit slight weight loss during chilling. Rapid chilling of rabbit carcasses mainly serves to reduce microbial growth, but also serves to increase the firmness of the muscle and stiffness of the skeleton to facilitate portioning and deboning. However exposure to low temperatures when ATP is still present in the muscle cell, such as prior to the development of *rigor mortis*, has been demonstrated to toughen the meat thorough a process termed "cold shortening".

Electrical stimulation pulses electricity through a carcass immediately after death has been proposed as a method of preventing cold shortening. Firstly electrical stimulation accelerates ATP depletion and secondly it hastens the decline of *post mortem* pH while muscle temperatures are still high, possibly enhancing the action of endogenous proteases and finally it induces physical disruption of muscle fibres. Electrical stimulation accelerates early rigor development, the magnitude of such effects and its subsequent applicability for commercial utilisation is still in question.

Processing, packaging, marketing

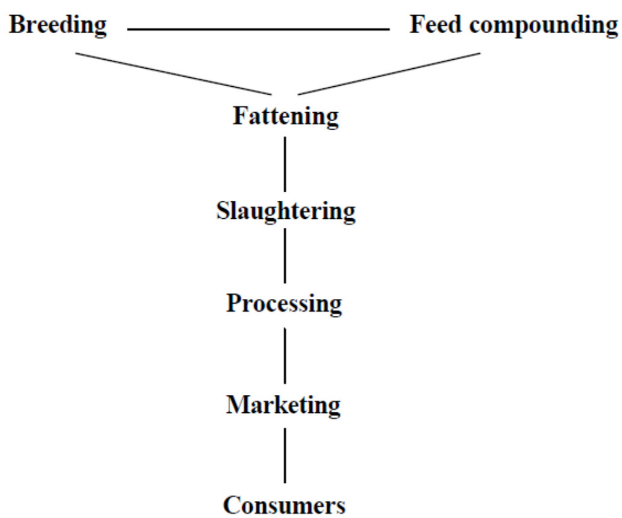
Once the rabbits have been converted into carcasses and chilled to the required temperature, they can be packaged and marketed whole or be converted into some other forms as portioned or boneless meat. Usually the rabbit industry develops voluntary grading systems for classifying and sorting carcasses into lots according to similar quality attributes (i.e. weight, carcass conformation, fleshing, etc.). With the evolution of modern lifestyles and the industrialisation of rabbit production and slaughtering, a shift towards convenience rabbit products such as carcass parts or restructured and further processed products has come about. Many different portions can be obtained from a carcass. It can be simply cut in two halves for grilling, or it can be cut into many portions.

The main commercial cuts are loin cut, the hind part, the loin (the *L. lumborum* muscles with or without ribs and bones), fore legs and hind legs. Some further processed meat products are starting to gain attention in the market. Deboned rabbit meat can be included in roll products or grounded and used for prepare hamburger-type products or sausages. Some major processing plants are trying to develop further processed ready-to-cook and ready-to-eat products. The residual meat remaining attached to bones can be harvested by mechanical deboning equipment, and the meat obtained is called mechanically-deboned-meat (MDM) which can be used for frankfurter-type products. Until now the development of further processing in rabbit has already been accompanied by few investigations on the property of this meat during processing and storage. The amount of free fatty acids sharply increases during the refrigerated storage especially that of long chain polyunsaturated fatty acids. Because rabbit meat is naturally rich in unsaturated fatty acids, it is likely that it can undergo lipid oxidation in processed (grinding, mixing, tumbling, etc.) and cooked products. Its innate instability can be counteracted in part by feeding increased amounts of tocopherols, particularly α-tocopherols (vitamin E) and using appropriate modified atmosphere packaging. Further investigations are needed to examine this topic under commercial conditions and evaluate the effects of the atmosphere on microbial population evolution and lipolysis specificity. In fact the spoilage pattern of rabbit meat and the growth dynamics of the various microbial groups, also in relation to the package atmosphere, remains little known.

13.3.2. Traceability

In the past 10-15 years, computer technology has made traceability of food possible in new and innovative ways. Nowadays there are sophisticated meat traceability software systems that can enable producers to track a meat product all the way from animal birth to the supermarket display case and every step along the way.

Few rabbit production companies are highly integrated in that each company or organisation virtually controls all the aspects of rabbit production chain, i.e. (in reverse order) marketing, processing, feed compounding, commercial rearing and breeder management (Figure 16). The identity of the rabbit carcasses and meat products from a farm can be maintained by collecting the documentation and labelling. The introduction of traceability procedures results more difficult for company or organisation partially or not vertically integrated because it requires a suitable level of organization within the companies involved in rabbit chain. A single farm, slaughtering plant or cutting unit would, in fact, have great difficulty in adopting traceability system independently, or even simply in participating in such a system without a technical and organisational support.
This chapter presents a case of rabbit pathway traceability of a company, or organisation, which is vertically integrated and controls all aspects of rabbit production. However, this approach can be also adopted by each component of rabbit production chain.
The procedures and the documents needed in each production step for ensuring traceability of rabbit meat products. It is recommended to serve documentation at least for two years.



Source: Cavani and Petracci, 2004

Figure 16: Food chain of rabbit products.

Breeding

Nowadays rabbits reared for commercial purpose belong mainly to breeds or hybrids developed by breeding companies. The economics of animal production prevent the possibilities of cross breeding and back-breeding from grand -parents to commercial levels and indirectly serve to protect the integrity of the traceability. Full records are available at each genetic level. While this extraordinary depth of traceability has developed for productivity reasons, it can also be used to provide quality and safety guarantees to the consumers.

From the perspective of traceability, all rabbits born the same day, in the same house from the same genetic group of rabbit breeders can be considered a single production unit. This means that the synchronisation of births is very important in the rearing management of rabbit does. Traceability procedures are different depending on whether breeding and fattening are conducted in the same (closed-cycle) or separate (open-cycle) farms. Weaned rabbits are usually placed in fattening cages in rabbitries that may contain up to a few thousand rabbits. Considering a closed-cycle farm, the weaned rabbits are directly transferred from the breeding to the fattening house. The adoption of "all-in all-out" practise could facilitate traceability procedures. In open-cycle farms, weaned rabbits are usually transported by trucks from the breeding to the fattening farm. It is suggested to send each production unit to one single fattening farm. An accompanying document has to contain the identification of the farm of origin and the map of the disposition in the trucks of the weaned rabbits.

Fattening and feed compounding

From a traceability point of view, the main points to check during the fattening period feeding, medication and vaccination treatments and the chemicals to which rabbits may have been exposed. The identification of feed is given during manufacturing in the feed mill by registering the type and the source of each raw material. After January 1st 2005, companies must also be able to trace feed and feed materials used in feed compounding. An accompanying document for feed should also contain information concerning the storage silos at the feed mill and at the farm, respectively. Care should be taken to avoid possible cross-contamination between unmedicated and medicated feed during compounding, transportation and storage phases.

All animal tests and medications during the animal lifecycle must be administered under veterinary surveillance and recorded. Concurrent storage of paper and electronic data may be used as an alternative method for the collection and storage of data. Technical personnel should check the compliance of the rules concerning feeding, environment and sanitary treatment at least every 2 weeks as well as the documentation recording.

Slaughtering

For good management of slaughter and traceability procedures, the collection of the production units (rabbit flocks) from the farms should be planned well in advance. At the farm, the fattening rabbits must be crated in order to maintain the identification of the production units. The accompanying document must contain the disposition of crates on the truck if different production units are present. Upon arrival in the holding area of the processing plant, the blocks of crates must be unloaded from the trucks, placed separately and identified by production unit. Each production unit must be separately slaughtered and it is useful to space two consecutive production units by leaving a gap of some minutes as well as by hanging a mark on the processing line with the traceability code. Critical points for traceability during processing depend on the type of technology and particular attention must be paid when carcasses are temporarily removed from processing line. After chilling each carcass or at least each box in which carcasses are placed must be labelled with the traceability code. Apart from the utilisation of the carcasses (further chilling, refrigeration storage, packaging, portioning or deboning) well-identified blocks containing carcasses belonging to the same production unit should be formed.

Further processing

The blocks of carcasses can be moved inside the same processing plant or transported to an external plant. The latter case requires accompanying documents. The carcasses sold as whole must be packaged and the labelling (Photo 74) must contain information variable depending on the different countries, but also the traceability code and some voluntary information concerning farm of origin, place of slaughtering, some characteristics of feeding (no GMO, vegetable diet, etc.). The traceability code may be formed from production line numbers, shift number, time of production, etc., in any combination. This may additionally be encoded within a bar code.

Source: Bodnár Károly

Photo 74: Label on rabbit carcass in Italy

Major difficulties arise when carcasses are portioned into parts prior to retail packaging. As for processing, the quantities of meat needed for portioning, deboning and further processing should be planned in advance. Any kind of production must be separately conducted for each unit and the products should be packaged in continuum after portioning or deboning. If this is not possible, it has been suggested to maintain group differentiation by physical separation and manual records. The packaging and labelling
of cut-up and deboned products must be conducted following the same indications given above for the whole carcasses. Traceability must be guaranteed for ready-to-cook products containing additives and further raw materials such as other kinds of meat or vegetables. In these environments, the implementation of process control practises utilising mechanical separation and written documentation (of type described by the International Organization for Standardization in ISO 9000) offers opportunities to maintain such identify system control.

Marketing and measures of recall

In order to comply to legislation, measures of recall of products must be carried out. Notification has to be sent to all members of the network to verify whether the products on the market have reached their market yet so they can take the necessary measures.

Definition of responsibilities

By virtue of their complexity, these integrated business have developed specialised management to oversee elements of the enterprise. It would be desirable for experts in agriculture, nutrition, veterinary medicine and food science to be employed. Each part of the enterprise (e.g. the feed mill, the breeding flocks, the reproduction and the rearing farms and the processing establishment) must have an assigned manager who is responsible for optimising the output of his section.

Future developments

The development of biological identification technologies and DNA testing allows for straightforward traceability of individual animals such as cattle and pork. However systems of individual identification are unlikely for commercial rabbits. Ear-bands have traditionally been used to identify individual rabbits at elite breeding level, principally for research purposes. As each flock/production unit of rabbits has similar status and the existing systems are well developed, individual rabbit identification does not appear to offer any advantages. Individual identification would contribute no useful additional information to what already exists. Some trials have been undertaken in poultry on using various automatic methods for identifying individual carcasses by batch code at the grading line.

Inkjet and laser systems have been tested. The laser systems appear to be the more successful, but both system suffer from consumer resistance to the appearance of the marked part of the carcass. In either case, this identification is rapidly lost as the carcass is further processed. Computer systems for maintaining traceability of batches of product to the farm of origin are likely to be adopted by the integrations not already doing so. The sophistication and automation of the systems already functioning in some places will no doubt continue to be refined. The limiting factor of these systems is the situation in which the volume of a particular product produced from a batch of meat falls below the minimum required for industrial handling. In the case of certain specialised products, raw materials may be sourced from many different flocks. These products may in themselves from an ingredient, which is added to other batches of product.

13.4. Some rabbit recipes

Maltese Rabbit Stew

1 rabbit
Oil or butter for frying
100g onions
3 bay leaves
170g tomatoes
2 tablespoons oil
Fresh garlic
4 cups water
100g fresh peas
100g fresh carrots, chopped
100g potatoes, chopped
2 cups red wine
Salt and pepper

Cut the rabbit into pieces and fry lightly in a small amount of oil or butter.
In a separate saucepan fry the chopped onions and garlic until golden brown. Add the peeled, chopped tomatoes and bay-leaves.
Add water to the rabbit and leave it to simmer for about 15 minutes. Then add wine, peas, carrots, potatoes, salt & pepper and tomato mixture from saucepan. Cook on low heat for 1 hour.
(Photo 75-76)

Source: Bodnár Károly

Photo 75: Stew on Maltese menu card


Source: Bodnár Károly

Photo 76: Maltese rabbit stew

Fried rabbit

2 rabbits (1.5kg each)
2 egg yolks, slightly beaten
3 cups milk
1 1/4 cups flour
1 tsp salt
1/2 cup butter
1 tbsp parsley, minced
Salt and Pepper to taste
currant jelly, for garnish

6 - 8 servings
Cooking time - 55 min.

Wash dressed rabbit with water and cut into serving pieces.
Combine eggs and one cup of the milk; add one cup flour gradually, then salt and beat until smooth.
Dip rabbit pieces into batter and fry in hot butter until golden brown, about 15 minutes.
Reduce heat and continue cooking until tender, 30 to 40 minutes, turning frequently.
Make gravy out of left over drippings, pour over rabbit pieces and serve.

Konijn Met Bier (Belgian style rabbit)

1 cut up rabbit
1 small amount fat, to fry rabbit in
1 large onion, finely chopped
2 carrots, cubed in small blocks
1 apple, cubed in small blocks
3 sliced smoked bacon, finely diced
water
1 bottle dark beer or 1 bottle cherry/kriek beer or 1 glass madeira wine
salt
thyme
sugar
bay leaf
1 slice bread, large
mustard

Brown the rabbit pieces in the fat.
Sprinkle a little sugar over all and add all ingredients except the bread and mustard.
Cover with lid and let simmer until rabbit is tender.
Spread mustard on slice of bread.
Take rabbit pieces from sauce and lay bread slice in sauce and stir until sauce is thickened.
Serve with fries and applesauce.
(Photo 77)

Photo 77: Konijn met bier

Rabbit in Mustard Sauce (Burgundy, France)

4 slices bacon, cut in 1-inch pieces
1/2 cup Dijon mustard
3 tablespoons peanut oil
1 large onion, chopped
1 1/2 teaspoons chopped fresh thyme
1 teaspoon chopped fresh rosemary
1 bay leaf
1 cup dry white wine
1/4 cup half-and-half
salt and pepper

Cut the rabbit up into six pieces and rub it all over with dijon mustard. Let marinade in the fridge, covered, for three or four hours.
Fry the bacon over medium heat until lightly browned, then drain on paper towels. Pour off all but about a tablespoon of oil from the skillet, then add peanut oil and the rabbit pieces with the mustard. Sauté for 10 minutes or until brown, turning once.

If needed
1 tablespoon butter mixed with 1 tbsp flour

4 servings

Add the bacon, onion, herbs and white wine. Bring to a boil, then reduce heat and cover. Simmer for 45 to 50 minutes or until tender.
Add the half and half. Stir and cook for another five minutes. Remove the bay leaf and discard. Arrange the rabbit on a serving plate, leaving the sauce in the pot. If your sauce needs thickening, mix the flour with the softened butter and wisk inches Boil for one or two minutes or until thick. Serve the rabbit with the sauce spooned over.
(Photo 78)

Photo 78: Rabbit in mustard sauce

Grilled Rabbit With Rosemary and Garlic

1 (1.5kg) fryer rabbit
1/4 cup olive oil
4 garlic cloves
2 sprigs rosemary

4 servings

Cut the rabbit in 8 pieces; the legs, 2 pieces from the loin, and 2 from the ribs.
Place them in a bowl or Ziploc bag, and add oil.
Mince the garlic and chop the rosemary; add the rabbit, mix to coat well.
Season with salt and pepper.
Allow to marinate for at least 2 hrs, or overnight.
Prepare to grill.
Grill for 8-10 min per side.

(Photo 79-80)

Photo 79

Photo 80

Hungarian Rabbit with Cream Sauce & Mushrooms

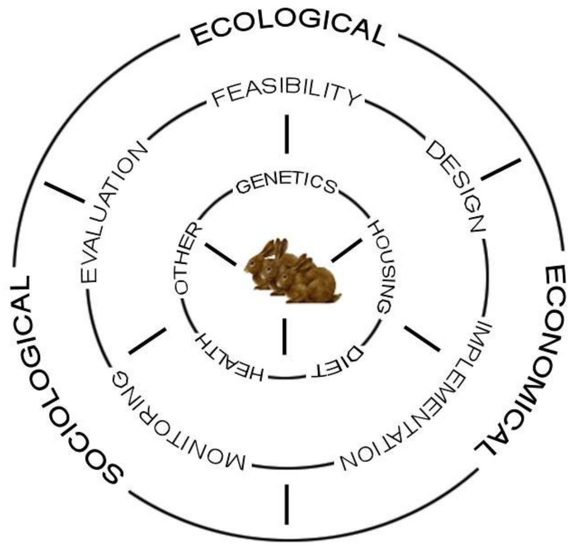
1 to 1.5 kg fryer rabbit
3 slices bacon, chopped
1 tablespoons butter
1 1/2 teaspoon salt
1/4 teaspoon pepper
1 tablespoon flour
1 medium onion, finely chopped
3 stalks celery, finely chopped
3 carrots, finely chopped
Pinch of thyme
4-5 peppercorns
1 bay leaf
1 small can tomato sauce
1 pint sour cream or yogurt
1/2 pound button mushrooms

In a Dutch oven, cook bacon until crisp. Add butter and melt. Add rabbit pieces and brown lightly. Season with salt and pepper. Blend flour into grease. Add chopped vegetables, remaining seasonings and tomato sauce. Cover and cook over low heat for about 45 minutes or until tender. Remove rabbit. Strain gravy, mix with sour cream or yogurt and pour over meat. Sauté mushrooms separately in small amount of butter and place on meat before serving.
Serves 4 to 6.

14. MANAGEMENT AND ECONOMY OF RABBIT FARMING

Technical management indexes during 2010 in Spanish rabbit farms using *bdcuni* (database of technical management in Spanish commercial rabbitries, www.ivia.es/bdcuni). Indexes obtained were positive pregnancy test (84.2%), kindling rate (79.5%), number of kindlings per doe and year (7.6), kindling interval (49.7 d), mortality during lactation (12.5%), mortality during the fattening period (8.2%), averaged slaughter weight (2.119 kg/rabbit), weaned rabbits per doe and year (60.4), produced rabbits per doe and year (55.4), kg produced per doe and year (117.4), total born alive per kindling (9.4), weaned rabbits per kindling (8.2), produced rabbits per kindling (7.4), kilograms produced per kindling (16.0), total born alive per insemination (7.5), weaned rabbits per insemination (6.6), produced rabbits per insemination (6.0), kg produced per insemination (12.8) and global feed conversion ratio (3.37). Also first results of the reference groups, geographic area (North area, South area and East area) and management (one batch and more than one) are shown.

The sustainability (Figure 17) of performance of French rabbit breeding systems was evaluated using the DIAMOND method. Seventy-six rabbit farms in 12 French regions, chosen to be representative of French production units, were surveyed to obtain 111 measured indicators as related to economic, environmental, and social issues. The farms were specialised (level of economic specialisation = 76%) and were of variable size (210 – 2,100 females). The responses obtained were transformed into scores (or sustainability units) and then pooled by objectives or sustainability goals.



Source: users.tamu.edu

Figure 17: The small-scale rabbit production model wheel of sustainability

Analysis of the data showed that economic, environmental, and social performances were highly variable among farms (means: 45, 44, and 37 points on a scale of 0-100, and CV: 27, 14 and 16%, respectively). In conclusion, results revealed that technical choices or structural characteristics of the farm influence the sustainability scores and categorises rabbit farms according to their sustainability profile.

A profit function based on a set of productive traits to estimate the profit, incomes and costs in a rabbitry with the most typical management techniques in Spain.
The absolute, standardized and relative economic weights of several traits were also estimated. The estimated cost of production was 1.79 €/kg rabbit alive, the profit per doe and year was 1.69 € and the total profit of the rabbitry was 1267 €. Major costs were feeding fattening and labour (25.9 and 18.1% respectively over total cost).
Once estimated the standardized economic weights the more important traits were feed conversion rate and number of kits born alive. The relative economic weight was 1.97 times greater for the feed conversion rate than for the number of kits born alive. Weaning and fattening survivals, daily feed intake, daily gain in fattening had little importance. The replacement rate had the lowest relative economic weight.

Reduction of feeding cost is of primary importance of rabbit producers, and the main possibilities include using efficient stock and good quality feed, besides effective farm management and the limitation of losses. On the other hand, slaughterhouses are interested in realizing yet higher profit from the products sold. By focusing on individual aspects to obtain better results, there is a lack of complex, interdisciplinary thinking along the supply chain of rabbit meat production: feed (raw materials) production, feed mill, in addition to breeding and the slaughterhouse. Influencing the development of genotypes by the evaluation of carcasses traits for merit and taking advantage of CT selection could lead to substantially improved values. Thus far, publications mainly focus on evaluating production and carcass traits. Reports on economic evaluation for growth and carcass traits are rare. Therefore, the aim of the present study was to carry out an economic evaluation of rabbit genotypes differing in growth rate and carcass characteristics based on the most important cost factors, including feed and the revenue from processed products.

To make the rabbit enterprise financially successful, you must have a way to sell your animals. The marketing methods and the price you receive may determine your ability to pay your expenses and make a profit.
By the time a litter is partly grown, you must know how you will market the animals. Select outstanding animals from a strong bloodline (desirable strain) to keep as replacements for older animals or as new additions to the colony. Sell other animals that meet breed or production standards whenever possible to other people wishing to raise rabbits.
You might sell fryers live to commercial rabbit processors or to laboratory animal suppliers. Or, dress and sell the fryers to friends, relatives, neighbours, stores or restaurants. Each of these markets requires a clean, healthy, well-fleshed animal.
Be sure to find out the country regulations governing the sale of dressed fryers.
Fryers can be sold either as a whole carcass or cut up and ready for meal preparation. It is probably best to use poorer fleshed animals at home. You can sell older animals as roasters or stewers, either live or dressed. Be sure your customers know the kind of animal they are buying and the best way to prepare the meat.
The smaller rabbit breeds are often popular on the pet market. Eye appeal, ability to adapt and a good temperament are needed for this type of sale.
Rabbit manure (by-product) is often in demand. An important part of your enterprise is the worm bed, where fishing worms and garden mulch can be produced. This practice is recommended because it allows you to use the manure in a way that minimizes odour and fly problems.
Sometimes you can sell rabbit manure to home gardeners or to people who raise worms commercially.

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