ASPECTS OF COMPARATIVE RABBIT MEAT HYGIENE

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ABSTRACT

This study involves work carried out at the abattoir in Masterton and in the laboratory of the Veterinary Faculty of Massey University, on aspects of rabbit meat hygiene and factors which may affect the quality of rabbit meat.

The European rabbit (Oryctolagus cuniculus), is the ancestor of all breeds of domestic rabbits, among which the New Zealand White is one of the best meat producers, the Angora the best fur producer and the Rex is a breed commonly used for exhibition purposes only.

The feed conversion ratio, which for an efficient commercial unit should be less than 3.5:1 (Anon, 1987), combined with the ability of the rabbit to consume fibrous food unsuitable for human consumption and the high reproductive performance, contribute to the rabbit being an excellent meat producing animal. The production of rabbit meat, is still insufficient for the demands of the world markets and efforts should be made to increase rabbit meat production.

Dislocation of the neck during slaughter of rabbits results in immobilization, but no evidence was obtained to show that this technique induced immediate insensibility. Penetrative and nonpenetrative percussive stunning, probably induced immediate insensibility but caused vigorous body movements. It was found in this study that pupillary dilatation in rabbits, generally does not occur until 8-10 minutes after slaughter, so pupillary dilatation is of no value as a criterion for the assessment of the actual time of onset of insensibility.

Investigation of carcass yields of rabbits showed that slaughtering rabbits at ages greater than eight weeks, resulted in only marginal increases in carcass yields.

Immersion of carcasses in water for periods longer than 30 minutes can result in a 10.70% increase in their weight, but the commercial technique investigated, resulted in approx. 7% increase. Washing carcasses did not reduce bacterial levels, but instead tended to increase carcass surface counts from 4.20 x $10^2/cm^2$ to 1.33 x $10^3/cm^2$.

The mean ultimate pH of rabbit meat was in the region of 5.40-6.25. Factors affecting the ultimate pH included concurrent diseases and intensive muscular activity. The rate of pH decline was affected by the degree of struggling at the time of slaughter.

The major gross lesions observed in the carcass and viscera of the rabbits studied, were those of hepatic coccidiosis and to a lesser degree, abscesses. The study of the accuracy of detection of hepatic coccidiosis in the abattoir was designed as a model for the study of similar meat inspection procedures in other animals. It was found that, based on histological examination of the liver, the sensitivity was 41% and the specificity 100%. A study of the epidemiology of hepatic coccidiosis in rabbits, revealed that under New Zealand conditions, it is unlikely that any farm is free of infection with Eimeria stiedae. However, if infections are of low intensity, rabbits may not develop macroscopic hepatic lesions. It also appears that histological lesions of the liver (biliary proliferation, fibrosis, cellular infiltration of the bile ducts with inflammatory cells, including eosinophils and lymphocytes) are pathognomonic for detecting past or present infection by E. stiedae.

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CHAPTER ONE

GENERAL INTRODUCTION

All present day strains of domesticated rabbits have been derived by selective breeding from European wild rabbits (Oryctolagus cuniculus) (Tittensor and Lloyd, 1983). The European rabbit is a member of the order Lagomorpha, which also contains pikas (Ochotona sp.), hares (Lepus sp.) and cotton tail rabbits (Sulsilepus sp.) (Tittensor and Lloyd, 1983). The order consists of nine genera and approx. 50 species, representatives of which occur on most of the major land masses of the world as well as on many islands (Walker et al, 1964).

Paleontological evidence, indicates that rabbits may have originated in North America, from where they could have spread westwards via the Aleutian land bridge into Central Asia (Thomson and Worden, 1956). It has also been suggested that rabbits are native to, and originated in, semi-arid areas of Southern France, Iberia and North-West Africa. From these areas they were introduced by man to many other parts of Europe and other continents where they established themselves successfully (Tittensor and Lloyd, 1983).

Although some believe the rabbit was domesticated by the first century B.C., others suggest that the first attempts to domesticate rabbits were made in French monasteries between the sixth and tenth centuries A.D. (Adams, 1972). Thomson and Worden (1956) state that the presence of rabbits in Britain was described in the 13th century, and Tittensor and Lloyd (1983) claim that rabbits were introduced to Britain by the Normans in 1176.

The natural distribution of the European rabbits is generally in lowland Europe, from Italy to Portugal and up to the Carpathians. Their numbers are more restricted in Denmark, the

Balkans and Italy.They have also been introduced to the Channel Islands, Norwegian Islands, and many eastern Atlantic and Mediterranean Islands. In other parts of the world rabbits have been introduced to northern Africa, the Hawaiian Islands, Chile and Argentina, in South America.

It was common for rabbits to be carried in the old sailing ships and to be released in new lands in the hope that they might breed and be a source of food for sailors at a later visit or when shipwrecked. In this way remote subantarctic islands like the Aucklands and MacQuarrie were colonised by rabbits.

Australia (including Tasmania) and New Zealand have, unfortunately, been very successfully colonised by introduced European rabbits (Tittensor and Lloyd, 1983). The introduction of rabbits to Australia and New Zealand for the sport of hunting, was particularly ill advised because of the absence of natural predators and the presence of abundant food which allowed them to multiply rapidly and cause extensive destruction of vegetation (Walker et al, 1964).

As a result of the detrimental effects of the wild rabbits on New Zealand vegetation, rabbits were classified as noxious animals and their farming and keeping as pets were banned (Anon 1987). Control programmes failed to eradicate them completely, but succeeded in reducing their numbers to a low level in most areas. Under these circumstances, the farming of rabbits in New Zealand was permitted by an order in Council of May 1985, provided local authority requirements were met.

A close relative to the rabbit is the hare, of which there are 26 species. The hare is present in most areas of Europe and Asia including Sumatra, Java, Formosa and Japan, and in most parts of Africa and North America. In South America, New Zealand, Australia and in some other countries, hares were introduced by man and have become widespread.The most common species are Lepus americanus and L. europaeus.

Lagomorpha are differentiated from rodents by their long ears and hind legs (Tittensor and Lloyd, 1983). Rabbits and hares have an additional pair of small, peg-like teeth lying directly behind the upper pair of incisors, a feature which distinguishes all Lagomorpha from rodents. The dental formula is : i 2/1, C 0/0, pm 3/2, m 3/3 x 2 = 28. (Tittensor and Lloyd, 1983).

Apart from the colour differences between the hares and rabbits, hares have longer ears, longer hind legs and lift their rumps higher than the rest of their body when moving. In terms of skull formation, rabbits are distinguished from hares by a much narrower nasal passage and in the former, the front incisors are more developed. (Tittensor and Lloyd, 1983). Confusion can arise from use of the words rabbit and hare. The names "jack rabbit" and "snow shoe rabbit" are used colloquially for North American hares and the name "Belgian hare" is applied to a strain of domesticated European rabbit (Walker et al, 1964). In some areas of Cyprus, people call rabbits hares.

The European rabbit has short dense grey-brown fur and grayish-white underparts. As many as 20% may be melanistic. Albino, long haired and silver piebald forms occur naturally as rare variants. The sexes are quite similar but the head is narrower and less rounded in profile in females than in males (Tittensor and Lloyd, 1983).

Rabbits and hares are usually more active during the evenings and nights than during the day time. If left undisturbed, rabbits move slowly around, but if threatened or chased by a predator they can move swiftly achieving speeds of up to 80 km/h. In addition to speed, rabbits have other defence mechanisms such as a keen sense of hearing and smell, nocturnal activity, burrow utilization, and the use of danger signals - rabbits drum with their hind feet (Walker et al, 1964). The scream of a rabbit may also be a defence mechanism, in that it may startle a predator.

The weight of the adult wild rabbit is between 1050-2200 g and the female is heavier than the male. The breeding pattern in rabbits is different from that of many other mammals. A sexually mature doe, under favourable conditions (adequate planes of nutrition, temperature and light duration), is in oestrous for long periods, during which Graafian follicles are continuously developing and regressing in such a way, that a fairly constant number is available for ovulation (Anon, 1980). On the first, third, fifth, tenth and fifteenth day of lactation, the does are ready to mate with the male. In terms of detection of oestrus, the enlarged and reddish-purple colored vulva and vagina is a good indication, although some does will mate even when the vulva is relatively small and pale. (Cited in Anon, 1986).

Ovulation in does is usually stimulated by coitus, but can occur under conditions which cause intensive sexual excitement. The number of copulations does not increase the number of ovulations but the latter is strongly related to the bodyweight of the doe. Approx. 25% of mated does fail to ovulate. This is probably due to a deficiency of luteinizing hormone,insufficient hours of light or increasing levels of duration of light. In the northern hemisphere, successful mating is more frequent during spring than in the late summer and autumn (Adams, 1972). The period of gestation is usually 31-32 days and the size of the litter is normally 8-10 young (Anon, 1980).

Rabbits are born blind, helpless and naked in a furlined nest, especially prepared for them, whereas hares are born in an open nest, fully furred, with open eyes and are able to run around within a few minutes of birth (Walker et al, 1964).

A point of special interest about the rabbit, is its habit of coprophagia, sometimes referred to as pseudorumination. This habit involves the reingestion of soft faecal material directly from the anus. This form of faeces is produced during the early hours of the morning and is a rich source of vitamin B, synthesized by the bacteria in the caecum. When rabbits are

prevented from practicing coprophagia, they die within three weeks (Adams, 1972). The significance of coprophagia in relation to different diseases, especially coccidiosis, will be discussed further in Chapter Nine.

The fecundity and short gestation period of rabbits, together with other characteristics such as comparative small size and ease of handling, make the rabbit an ideal laboratory animal for many purposes.

BREEDS OF RABBITS

Rabbits and hares, caught in snares, were of importance to early man as a source of food and clothing. Their thin skin and dense soft fur, were well adapted to many uses. Later, at different periods of history, as during the first and second world wars, rabbits became a more important source of meat and many people raised them in limited space, as a means of rapidly increasing the supply of locally produced meat.

Since the European rabbit was first domesticated, selective breeding has created many different breeds for meat production, for fur and pelts, and fancy breeds for exhibition (Walker *et al*, 1964).

The meat breeds include the California and Flemish Giant. These animals are usually killed for meat production before they become adult, for better economical efficiency. Flemish Giant rabbits are one of the largest breeds, but grow very slowly and are not preferred economically (Anon, 1985a).

The major fur and pelt producing breeds include the Angora, Chinchilla, New Zealand White, Rex, Silver and Fox. Among the fur breeds, the Angora is regarded as one of the best for fibre production, and is farmed in many countries including New Zealand. These fur breeds tend to be of dual purpose in that

their carcasses are also used for meat. The New Zealand White, which was developed in the United States, although a dual purpose breed, is probably the breed most commonly used for meat production, because it is early maturing and has an excellent food conversion ratio (Anon, 1985a).

Common exhibition breeds include the Tan, the Dutch and Netherlands Dwarf and Rex. These are not of significant importance in meat production and are selected mainly for their colours and body conformation in relation to somewhat artificial criteria related to exhibition (Anon,1985a).

RABBIT MEAT PRODUCTION

In New Zealand, rabbits for meat production are slaughtered at approx. eight weeks of age, when their liveweight is around 2 kg (Anon, 1987). A good average food conversion ratio of a 2 Kg rabbit is around 3.5:1 (Anon, 1987), which compared to most other meat animals, is considered favourable, with the exception of poultry (broilers) for which a good food conversion ratio is 1.8:1 (Anon, 1984a) at six weeks of age. However, with the high cost of pelleted food for rabbits, the ratio needs to be 3.2:1 to be economic in most circumstances (Anon, 1987). It was found that rabbits slaughtered up to the age of 56 days, have the best food conversion. When slaughter is delayed for even one week, the profit becomes less as a result of the extra labour involved and the decline of the food conversion ratio (Aitken and King, 1962).

Rabbit farming can be divided into two main categories. Firstly, intensive farming systems, where large numbers of rabbits of improved breeds and strains, are kept under strictly controlled environmental conditions and fed a balanced pelleted ration. Secondly, small scale or backyard level rabbit production systems, which are still important in many countries like Malta, and Spain. Such systems are suitable for developing

countries because of their low capital input, rapid financial turnover and use of locally available construction materials and feed (Owen et al, 1977).

High temperature is probably the most serious environmental problem for rabbits. The normal body temperature of the animal is 38°-39°C and the thermoneutrality zone between -5° to 30° C. When ambient temperatures reach 30 degrees or above, the fertility of the male rabbit decreases dramatically (Chen et al, 1978). The female's fertility is also decreased (Owen et al, 1977).

Among the many countries farming rabbits, China is the largest exporter of rabbit meat and Angora fibre (wool), and its farming systems are efficient. New Zealand is one of the countries which import rabbit meat from China. The price of Angora fibre is controlled by the international market but is very much influenced by China as the major world producer.

The magnitude of the rabbit industry in China is illustrated by information supplied by the Chinese Embassy in Wellington in response to a request by the author. China exports 30,000-40,000 tons of frozen rabbit meat per year, with a value of US$40-50 million. Western Europe and Japan are the major overseas markets. A quantity of 5,000-7,000 tons of raw hair is exported annually with a value of US$1.5-1.7 hundred million. The major markets are West Europe, Japan and Australia (Liu Bei Lei, pers. comm.) Presumably, a large quantity of rabbit meat is supplied to the local market. It would be interesting to know the total quantity of rabbit meat consumed by a population of about 1.2 billion people in the Republic of China, especially considering the low price of this product (Chen, pers. comm.).

Other countries with developed rabbit industries are mainly in Europe, and include Italy, Poland, Britain, Holland, Denmark, Spain, Germany, Malta, Sweden, and France. France is the largest producer of rabbit meat in the western world and Malta has the

world's highest per capita consumption of rabbit meat of 8 kg per person annually (Anon, 1987).

The United States and Canada produce rabbits for meat, fibre, skins and fur for both the home market as well as for export. In South America, Chile and Argentina are the main producers with export markets for both meat and fibre. Countries in the Middle East and Third World countries have started to develop commercial rabbit farms and "backyard" units suited for local conditions. Present world rabbit meat production is insufficient to meet world demand, and in many Asian and Pacific countries there is a demand for larger quantities that can be supplied (Anon, 1987).

DISEASES OF RABBITS AFFECTING THE QUALITY OF MEAT

From a meat hygiene viewpoint, diseases of rabbits can be considered in two broad categories. Firstly, zoonoses which could affect the health of the consumer from endogenous infection of the rabbits or from exogenous agents due to contamination of the carcass during processing. Secondly, non-zoonotic diseases which might create unacceptable aesthetic defects.

Compared with other food animals there are few zoonoses associated with the consumption of rabbit meat. Tularaemia, probably the most important of the endogenous zoonoses of rabbits, is caused by Francisella tularensis and apart from rabbits, a wide variety of other animals contract the disease. In rabbits, the disease is manifested by miliary abscesses in the parenchymatous organs including lymphnodes. The disease is transmitted to humans mainly by the consumption of insufficiently cooked rabbit meat or by handling meat from infected rabbits. Affected humans show cutaneous lesions, meningitis and septicaemia resulting in a mortality rate of 5-7% of untreated cases (cited in Anon, 1986). A number of countries including New Zealand (Blackmore,pers. comm.) and Cyprus (Anon, 1985b) are free

from tularaemia, whereas the disease is endemic in parts of the U.S.A. and Russia.

Pseudotuberculosis and toxoplasmosis are regarded as common forms of endogenous zoonoses of rabbits in New Zealand (Blackmore and Humble, 1987). Pseudotuberculosis is caused by Yersinia pseudotuberculosis and in rabbits is manifested by miliary abscesses in the liver, lungs, spleen and intestinal wall (Harkness and Walker,1983). In human beings Y. pseudotuberculosis is a meat or water transmitted disease, causing acute mesenteric lymphadenitis and rarely septicaemic illness (Blackmore and Humble, 1987).

Toxoplasmosis can affect rabbits and more than 200 different species of other animals including birds, reptiles and man. Presumably tissue cysts in rabbit meat are a potential public health problem. In humans, the disease can result in cervical lymphadenopathy, necrotizing encephalitis, meningoencephalitis, and ocular lesions.(Blackmore and Humble, 1987).

Encephalitozoonosis is a common zoonosis of laboratory rabbits, caused by the protozoan Encephalitozoon (Nosema) cuniculi (which belongs to the Microsporidia). Laboratory rabbits, as well as domestic rabbits, are affected and in Sweden the prevalence of the disease in the latter group was found to be up to 14%. Although the main host of the disease is the rabbit, other animal species including man, mice, guinea pigs, rats and dogs were found to be infected (Waller, 1979). The disease is believed to be transmitted by urine or transplacentally, and is mildly contagious in a rabbitry (cited in Anon, 1986). Waller (1979) states that although the oral route of infection is probably the most common route of infection, the disease may be also transmitted through skin wounds or by sexual intercourse. Although the disease is usually inapparent, occasionally rabbits show various slight neurological disorders including partial paralysis of the face including ears and

eyelids, or inclined head, blindness, aggressiveness, anorexia and polydipsia (Waller, 1979).

The agent is most commonly localized in the kidneys and the central nervous system in which intracellular colonies of the parasite occur usually without evidence of any inflammatory reaction. When inflammatory reactions do occur they consist of chronic, non-purulent, granulomatous changes which are pathognomonic. No successful treatment is known in rabbits. Presumably the transmission of the disease from rabbits to humans is via urine, especially through skin abrasions and is thus unlikely to be a meat transmitted disease (Waller 1979).

The theoretical range of the exogenous agents, which could contaminate rabbit meat, include enteric pathogens, like Campylobacter jejuni, Y. pseudotuberculosis, Y. enterocolitica, Salmonella spp, Clostridium perfringens and pathogens originating from external abscesses caused by Staphylococci. [The author is aware of a study in which C. jejuni was isolated in New Zealand from a rabbit originating from the small animal unit (Marshall, pers. comm.)]. Dressing faults, which lead to contamination of rabbit carcasses with intestinal content, could lead to such exogenous contamination. Insufficient cooling of the carcasses, gives the opportunity for these bacteria to multiply (Yersinia spp can grow and produce toxin even at low temperatures) and lead to food poisoning.

Staphylococcus aureus is a common aetiological factor of abscesses in rabbits (Farinha et al, 1982). Additionally Blackmore and Francis (1970) state that pathogenic staphylococci were isolated from laboratory rabbits.

Aesthetic defects of rabbit carcasses can be associated with bruising and fractures, as in other animals. Also the intermediate stages of certain cestodes, such as the larvae of Taenia pisiformis, T. multiceps, T. serialis, the Pentastomid larvae of Linguatula serrata, as well as the lesions caused by

Eimeria stiedae in rabbit liver, could be the cause of undesirable lesions.

RABBIT MEAT HYGIENE

Theoretically, the quality control of rabbit meat production should be based on the same principles as those applied to meat from other animals.

Based on conventional regulatory meat hygiene, this should include both ante and post mortem inspection, a general control of the hygiene of the abattoir and food hygiene inspection at the retail level. The Ministry of Agriculture and Fisheries in New Zealand, has produced a set of draft regulations written along these lines, which however have not yet been promulgated.

With respect to the inspection of poultry meat, public health concerns will be best met by a flock health appraisal, utilizing flock records and laboratory data collected over the life of the flock. This approach involves a move away from 100% carcass inspection, towards a "healthy life" certification, which should certify that birds have been free of disease before slaughter, have received medication only at approved rates and drug withdrawal times adhered to. In addition the animals must be slaughtered and their meat produced under sanitary and microbiologically safe conditions. (Christensen 1987).

Discussing the problem of meat inspection of domestic stock, Blackmore (1983) suggested radical changes to the conventional system, which has basically remained unaltered for more than a hundred years. He also refers to the ineffectiveness of the meat inspection methods in detecting agents that are most frequently associated with foodborne infections and intoxications. He concludes that there should be less emphasis on veterinary inspection of individual carcasses and greater attention paid to

ensuring that animals submitted for slaughter are from herds free from infections with potential human pathogens and toxic agents.

Many studies have been carried out in relation to hygienic processing of meat from the common meat animals, but published work on rabbit meat hygiene has not been found. This apparent lack of information was a major stimulation for the research work which forms the basis for this thesis.

The work in this thesis is an attempt towards:

1. Investigation of the humane aspects of different stunning methods used in rabbit slaughtering.
2. Measurement of the carcass yield of slaughtered rabbits and factors that may affect it.
3. Study of the effect of different washing situations on the water uptake and bacteriological condition of rabbit carcasses.
4. Study of the factors which might affect the pH decline rate, as well as the ultimate pH of rabbit meat.
5. Study of the prevalence and description of pathological lesions found during commercial rabbit slaughtering.
6. Assesssment of the accuracy of rabbit meat inspection procedures, with respect to liver coccidiosis.
7. Finally, the epidemiological aspects of liver coccidiosis in rabbits were studied.

CHAPTER TWO

THE PROCESSING ABATTOIR

INTRODUCTION

The abattoir at which the field observations were carried out, is a small, owner operated plant, situated at Masterton in the Wairarapa (see Figure 2.1., page 25). Normally the premises are used for the processing of poultry for the local market, but approx. every four to six weeks, rabbits are slaughtered and processed on the poultry chain.

The staff comprises four workers. The owner and one of the workers are members of the same family and they usually employ two other part time workers to assist them on the processing line. The buyer and eventual owner of the rabbit carcasses acts as both an 'inspector' and worker when rabbits are processed.

Inspectors from the Health Department, occasionally check the general plant hygiene but are usually not present during the slaughter and processing of birds or rabbits. The "meat inspector" is paying special attention to the presence of hepatic coccidiosis, gross pathological lesions such as abscesses and defects that might affect the final quality of the carcasses and viscera. Owners of rabbits, which have evidence of hepatic lesions, suffer a $1 penalty per carcass affected. This penalty is designed to stimulate higher standards of husbandry by the breeders.

All rabbits are purchased by the"meat inspector", under the trading name "Doe Bank". The breeders are paid according to the final carcass weight and whether or not they are affected with

hepatic coccidiosis. Rabbits are obtained from a wide area, ranging from Palmerston North to Wanganui and Taihape. They are collected by the "meat inspector" from a central point in Palmerston North, or from individual breeders located between Palmerston North and Masterton, on the day of slaughter. The animals are transported in wire cages in the back of a small, open "pick up" truck. During rainy days the cages are covered with a waterproof cover.

The most common breeds processed in the plant, are New Zealand White, crosses of New Zealand White with other breeds, and Angora rabbits. Rabbits coming from farms situated far away from the abattoir, commence their journey to the abattoir at 6-7 a.m. on the day of slaughter and arrive at the plant at approx. midday. Slaughter commences soon afterwards.

THE PROCESSING PLANT

The plant (see Figure 2.1, page 25) is designed for the processing of poultry, but occasionally ducks, pheasants and rabbits are also slaughtered. The general layout of the plant is shown in Figure 2.2, (page 26), together with apparatus, denoted by different figures, referred to in the following text.

Processing Room

This is the largest room of the plant (Room A). Large doors at one end open to an outside concrete pad, which serves as a load-in area (1) (see Figure 2.2, page 26). The conventional poultry chain (2) extends the length of the room. High pressure hoses are available (3). Below the first part of the chain a stainless steel trough (4) prevents blood from spilling onto the floor. Receptacles for the rubbish (5) also exist and at the end of the chain there is a scalder (7) by the side of which a defeathering machine is situated (8). Up to 96 rabbits or birds can be processed on this chain at any one time.

Figure 2.1 - The abattoir at Masterton. Load out area

Carcass Washing Room

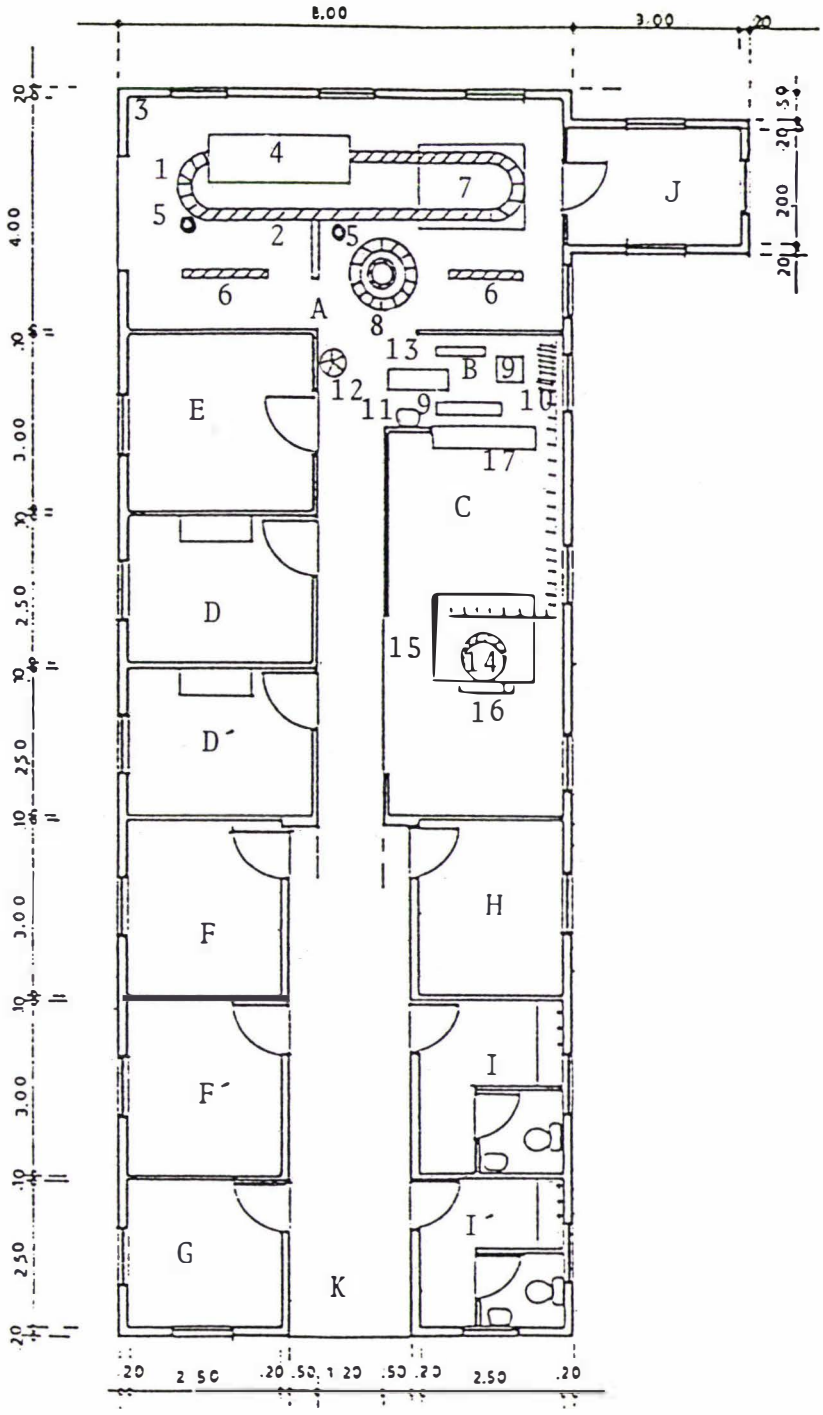
This room (B) is situated next to the processing room and has three stainless steel tanks (9), which are used as dunk baths for the washing of rabbit carcasses. Next to the tanks is a rail (10) for hanging the carcasses when they are being spray washed. A hand operated wash basin,with hot and cold water is close to one of the dunk baths (11). On the wall is a rack (12) used for protective clothing. Carcasses are subjected to a final inspection on a metal table (13) next to the washing troughs.

Packing Room

The rail from the washing room leads through an opening in the wall to the packing room(C), where the carcasses are weighed and packed. A scale balance (14) is situated on a large metal table (15) in the middle of the room together with a small,

Figure 2.2

Plan of the rabbit processing plant at Masterton



A. Processing Room

1. Covered load - in area
2. Chain
3. Water hose
4. Bleeding trough
5. Receptacles for the heads and intestines of the rabbits
6. Lights
7. Scalder
8. Defeathering machine

B. Washing Room

9. Dunk baths
10. Rail
11. Hand operated basin
12. Rack for aprons
13. Table

C. Packing Room

14. Scale Balance
15. Packing table
16. Packing apparatus
17. Cooling system

D. Other Rooms

D, D´: Freezers
E : Storeroom
F, F´: Offices
G : Kitchen
H : Locker room
I, I´: Toilets
J : Boiler
K : Covered load - out area

simple and effective manually operated packing apparatus (16) normally used for bagging poultry carcasses. A cooler, an apparatus producing cold air (17), is situated on one of the walls about 1.7m above floor level.

Blast Freezers

Two blast freezers(D,D') (approx. 20 m^3 each) are situated opposite the packing room. These freezers are placed in the center of the building.

Other Rooms

The location of ancillary rooms, such as storeroom(E), offices(F,F'), a kitchen(G), a locker room(H), toilets(I,I') and a boiler room (J) is shown in Figure 2.2.,(page 26). The floors and walls of the building are constructed of concrete and the roof of corrugated iron. Electricity and hot and cold water is supplied to the majority of rooms. A covered load out area (K) also exists.

THE PROCEDURE

STUNNING

The rabbits are slaughtered by manual dislocation of the neck followed by decapitation. They are picked up from the cages by one person and handed to the operator carrying out dislocation of the neck. This is an experienced person who holds the animal by the hindlegs with his left hand and its head directly behind the ears with his right hand. Then by pulling sharply on the head with a downward and backward twist of the hand he effectively breaks the neck. Immediately after neck dislocation the rabbits are hung on the chain by the hind legs.

Exsanguination

Exsanguination is carried out by a person standing at the beginning of the chain where the rabbits are decapitated with a sharp knife. The "stun-to-stick" interval ranges from ten seconds to five minutes. The majority of animals show no movements at any time after dislocation of the neck and the procedure is generally smooth and easy. The heads are discarded into a bin. The chain automatically carries the decapitated carcasses to the point of pelting.

Pelting-Evisceration

Removal of the pelt is carried out by the same person who dislocates the neck. After having stunned 20-30 rabbits, he changes position to the pelting area. He removes the pelt by cutting around the tibio-tarsal joints and making a longitudinal incision on the medial aspects of each hind leg. The pelt is pulled downward and inside out, thus being freed from the fascia and muscles. The pelt is cut from the carcass just above the carpal joints of both front legs (see Figure 2.3, page 29). The process of pelting is completed within 50 seconds. The uneviscerated carcasses are handed to another operator on the other side of the chain, one metre away. He shackles the carcasses by the hind legs and eviscerates them by an incision from the pubis to the xiphisternum. The gastrointestinal tract (GIT) is removed first, followed by the liver. Then by an incision to one side of the sternum the thoracic cavity is opened and the lungs and heart are removed and discarded in the same receptacle as the GIT. At this point, using a pair of secateurs, the remaining part of the neck is cut off and the front and hind legs are removed at the carpal and tarsal joints respectively. The whole process of evisceration is completed in approx. 40 seconds.

Inspection

Livers are inspected for gross lesions of hepatic coccidiosis by the purchaser of the rabbits and the carcasses are then transferred by her to the table in the washing room.

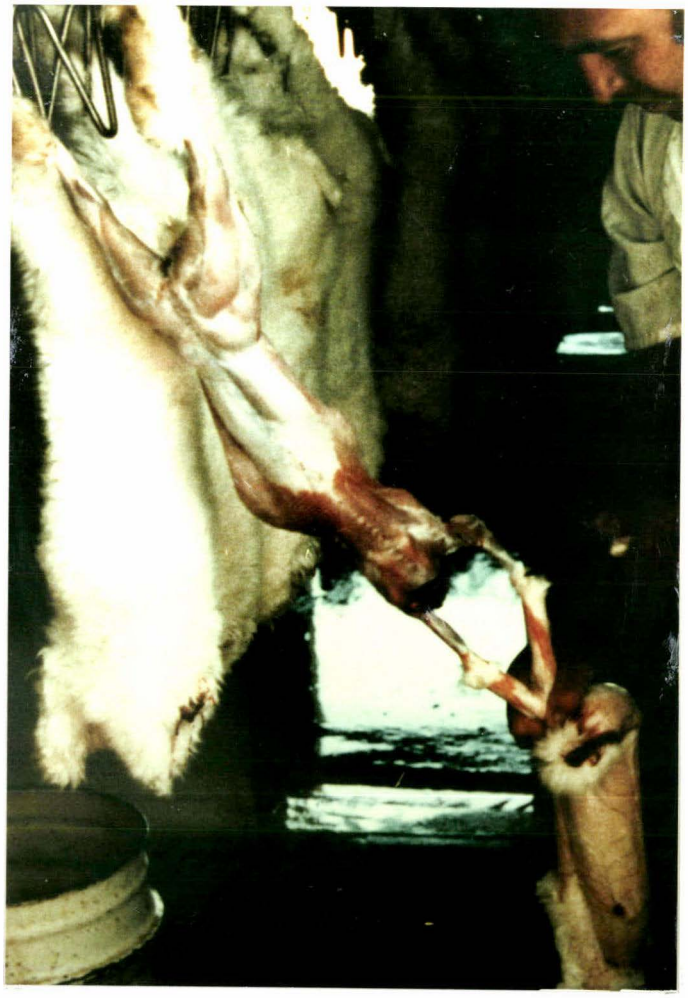


Figure 2.3. - Pelt removal showing points of detachment on legs.

Washing Carcasses

After inspection, the carcasses are hung on hooks from the pelvic bone until washed by immersion in a tank. Water is running into the tank from a tap, and is discharged from an outlet on the side. The rate of replacement is approx. ten litres per minute. The carcasses are left in the water for two to ten minutes and then transferred manually to hooks on a rail for washing by a hand held sprayer and final minor trimming. Trimming and spraying takes between 30 and 60 seconds to complete. The carcasses are then usually left on the rail for one to two hours during which time surface water is lost from the carcasses by drip and evaporation.

Packing Carcasses

The carcasses are then transferred manually, or on the rail, from the washing room to the packing room where they are weighed and the weight recorded on a label which is attached to the outside of the plastic bag containing the carcass.

In order to pack rabbits into plastic bags designed for poultry, the back of the carcass is cut at the level of the lumbar sacral junction, the spinal column broken manually and the hind legs pushed forward into the thoracic cavity. The rolled and telescoped carcass is then pushed through a metal cone (packing apparatus) into a plastic bag. Efforts are made to remove as much air as possible from the bag which is then sealed and labelled. The bagged carcasses are put in plastic boxes or cartons and sent directly to the retail market or put in the blast freezer.

Additional Information

The abattoir is small and there are no arrangements for further processing. No other products than the carcasses, livers and pelts are saved.

The water used in the abattoir is of potable quality and comes from the municipal supply. It is chlorinated and checked regularly by the local authority.

The main areas where investigations were carried out, were at the points of slaughter, evisceration, washing and packing. Investigations included observations on the slaughter process, including exsanguination and the accuracy of detection of hepatic coccidiosis. Washing procedures were investigated in terms of both microbial contamination and water uptake of carcasses, and muscle pH measurements were taken at various points in the whole operation.

Four visits were paid to the abattoir to obtain the data for this thesis. Further samples, related specifically to the study of hepatic coccidiosis, were collected during visits to three individual rabbitries. Finally, in order to collect data on specific aspects of rabbit processing, 20 New Zealand White rabbits of 2-3 Kg live weight, were bought from the Small Animal Unit at Massey University and slaughtered and processed in the undergraduate anatomy laboratory of the Faculty of Veterinary Science at Massey University. Data obtained from all these animals will be presented and discussed in relevant chapters of this thesis.

CHAPTER THREE

SLAUGHTER OF RABBITS AND RATES OF BLEEDING

INTRODUCTION

There is increasing public concern for the welfare of animals including the slaughter of stock. This has led to various statutory acts and regulations, aimed at ensuring the welfare of animals during the stunning and slaughter process. In New Zealand, the welfare of stock during slaughter, is covered by "The slaughter of stock, game and poultry regulations 1969" and amendment No.1 of the same regulations (Anon, 1977). These regulations state that "no person shall in any slaughtering place, slaughter any head of cattle (including bobby calves), horses, sheep, lambs, goats or swine, unless and until it has been rendered insensible to pain, by a method described in subclause (2) of this regulation and will remain so until death supervenes from the operation of bleeding, which shall be carried out promptly and skillfully." In subclause (2) of the Slaughter of Stock, Game and Poultry Regulation (1969), it is stated that the methods of inducing insensibility to pain shall:

a) In the case of cattle (except bobby calves), horses, goats and swine, by the means of:
   (i) A captive bolt type of stunning instrument, operated by explosive charge or compressed air;
   (ii) An instrument which causes insensibility by the administration of an electric shock; or

(iii) The use of carbon dioxide gas in a suitably enclosed chamber.

Provided that at slaughtering places (other than export slaughterhouses and abattoirs), a suitable safe firearm with a type of solid bullet or fragile bullet, which renders the animal instantaneously insensitive to pain, may be used.

b) In the case of bobby calves, be by any of the methods of inducing insensibility or by manual stunning by a single blow to the frontal region of the head.

Rabbits, being "animals" according to the Meat Act, 1981 (Anon 1981), are not covered by this section of the regulations, but by paragraph 8, which requires a slaughter method approved by the Director and by paragraph 13, which states that: (1) "The slaughter of any stock, game, or other animals in a slaughtering place or of poultry in premises licensed persuant to section 61 (a) of the Act, shall be so coordinated that the time between the stock, game, other animals or poultry being rendered insensible (where this applies) and being subjected to bleeding is kept to the absolute minimum."

Apart from the humane aspect of the stunning and slaughter procedure, this operation can also affect the quality of meat (cited in Blackmore and Delany, 1988). It was therefore considered appropriate to investigate some of the methods of slaughter which could be applied to rabbits.

A humane stunning and slaughter procedure, complying with the above regulation, should induce immediate insensibility of sufficient duration to ensure the animals do not regain sensibility, until they have been rendered permanently insensible from exsanguination. Methods of inducing insensibility can be broadly classified into three groups: (a) carbon dioxide anaesthesia, (b) electrical stunning, and (c) percussive stunning (cited in Blackmore and Delany, 1988).

Although carbon dioxide is considered effective for anaesthetizing rabbits (Adams, 1976) it would be an inappropriate method in the abattoir because of the high capital costs of equipment and high running costs associated with the loss of CO_2 removed from the CO_2 chamber trapped in the fur of the animals. There is also controversy concerning the humane aspects of the method (Blomquist,1957).

Electrical stunning can be divided into head-only and head-to-body methods. Stunning by the head-only method normally induces insensibility of approx. 30-40 seconds duration only. For this method to be humane in animals which have no connection between the vertebral artery and the rostral rete via the caudal rete, the stun-to-stick interval must be less than 20 seconds, since permanent insensibility from exsanguination may take up to eight seconds to be induced (Tidswell et al, 1987). The blood supply to the brain of rabbits is very similar to that of sheep. In this species, apart from occipito-vertebral anastomosis (O.V.A.), there is another small anastomosis between the vertebral and carotid arteries, known as the condylar artery (cited in Blackmore and Delany, 1988).

Head-to-body electrical stunning, induces permanent insensibility due to concurrent induction of cardiac dysfunction, thus stun-to-stick intervals are not theoretically important in relation to animal welfare (cited in Blackmore and Delany,1988).

Lauberger (1984) described a system for electrical stunning of rabbits and other laboratory animals, but to the knowledge of the author, the system has not been evaluated critically. In systems used for slaughtering relatively small numbers of rabbits, the high capital costs of installing such apparatus would be prohibitive.

Percussive methods of stunning are probably better suited to the commercial slaughter of rabbits and can be divided into non-penetrative and penetrative methods. Non-penetrative methods

induce insensibility by the transmission of high velocity physical distortion waves to the brain, which can cause insensibility lasting for 30-40 seconds (Blackmore, 1979), but often brain damage is sufficient to cause permanent insensibility. Penetrative methods of stunning, cause depolarization of the neurons due to percussive effects and damage to the brain tissue, which, provided vital centers are destroyed, results in permanent insensibility. Sheep and calves stunned by both methods of percussive stunning, develop tonic spasms, which occur immediately and last for at least 15 seconds. These are followed by clonic spasms, which may last for up to four minutes. (Blackmore, 1979).

In rabbits slaughtered in abattoirs, the most common methods of inducing insensibility is by dislocation of the neck, a blow to the head, or decapitation with a guillotine. Neck dislocation is performed by holding the animal by the hind legs in one hand, and with the other hand holding the rabbit's head directly behind the ears. Then by pulling sharply on the head with a downward and backward twist of the hand, the neck will be dislocated at the occipito-atlantal junction. A modification of this method is carried out by a blow to the extended neck of the rabbit. The hind legs are held in one hand while the other hand, extended and rigid, delivers a "Karate chop" to the back of the rabbit's neck. Instead of the hand, a heavy stick may be used (Scott and Ray, 1976). It has been observed that rabbits subjected to this method of neck dislocation often vocalize during subsequent bleeding, which suggests that the animals are not always rendered insensible and may suffer distress during bleeding (personal observation).

It is recommended that dislocation should be followed by severing the neck with a knife (Owen et al, 1977). Neck dislocation, as opposed to direct severance of the spinal cord, may result in pressure effects on the brain and spinal cord, both rostrally and caudally to the dislocation site, with possibly

concurrent effects on the cerebral function (Blackmore and Delany, 1988).

Decapitation by a guillotine, is also used for the slaughter of rabbits. Mikeska and Klem (1975), investigating the humane aspect of this method on laboratory rats, used electro-encephalographic (EEG) techniques. The EEG activity recorded after decapitation (low voltage, fast activity) was considered to indicate discomfort and pain. Tidswell et al, (1987), investigating EEG activity of decapitated heads of lambs, found no obvious change of the EEG pattern for eight seconds after decapitation, and subsequent changes were similar to those associated with exsanguination only. It is apparent that there is no evidence to suggest that decapitation causes immediate insensibility and that it is a humane procedure for slaughtering animals.

In the present experimental work, emphasis was paid to investigations designed to determine the humane aspects of the dislocation method, which is widely used as part of the slaughter process for rabbits. Attempts were also made to investigate percussive stunning of rabbits, with a view to the future development of a practical penetrative percussive stunner for this species. Exsanguination was investigated in terms of blood loss and the rate of bleeding.

MATERIALS AND METHODS

Methods of Slaughter

(a) Neck Dislocation and Decapitation

During the course of this study, approx. 250 rabbits were observed, which were stunned by dislocation of the neck at the abattoir at Masterton by an experienced operator. He held each animal to be slaughtered, by the hind legs with the one hand and with the other hand, the rabbit's head directly behind the ears. Then by pulling on the head with a downward and backward twist of the hand, he effectively dislocated the neck of the animals. The animals were subsequently decapitated by another butcher within ten seconds to five minutes of stunning. Ten rabbits were examined in detail immediately after neck dislocation and during the period following decapitation.

(b) Neck Dislocation and Bleeding

The necks of five New Zealand White rabbits were dislocated by the author in the laboratory and subsequently bled within ten seconds by a transverse incision of the major vessels of the neck.

(c) Non-penetrative Percussive Stunning and Bleeding

Five rabbits were stunned by a blow to the head with a steel for sharpening knives. One person restrained the rabbits while another delivered a blow to the head just caudal to the orbits. The rabbits were subsequently exsanguinated by a transverse incision of the neck within ten seconds of stunning.

(d) Penetrative Percussive Stunning

The stunning was carried out by a simple instrument consisting of a stainless steel rod, 1.2 cm in diameter and 19 cm in length. The instrument (see figure 3.1, page 38) was held in a vertical position on the head of the rabbit behind the eyes and between the base of the ears (see figure 3.2, page 39) by one person, while another person hit the protruding bolt with a

1.5 kg weight hammer, from a height of approx. 10 cm. One rabbit had to be stunned twice as the operator holding the instrument failed to place it correctly on the animal's head.

Figure 3.1 - Small hammer and steel rod and tube used for penetrative percussive stunning.

Of ten rabbits stunned by the penetrative percussive method, four were exsanguinated by a transverse incision of the neck 10 seconds later. One rabbit was inadvertently decapitated. The remaining five animals were not bled.

(e) Examination of Heads and Spinal Cords

The investigation of the superficial lesions in rabbits immobilized by neck dislocation was carried out by removing the skin of the neck area before completely pelting the animals. Further investigations were carried out by removing the skin of the head and subsequently the top of the skull in order to observe lesions in the cranial cavity. The lesions of the heads and spinal cords of animals stunned by the percussive methods were also examined. Samples of brain tissue were collected for histological examination.

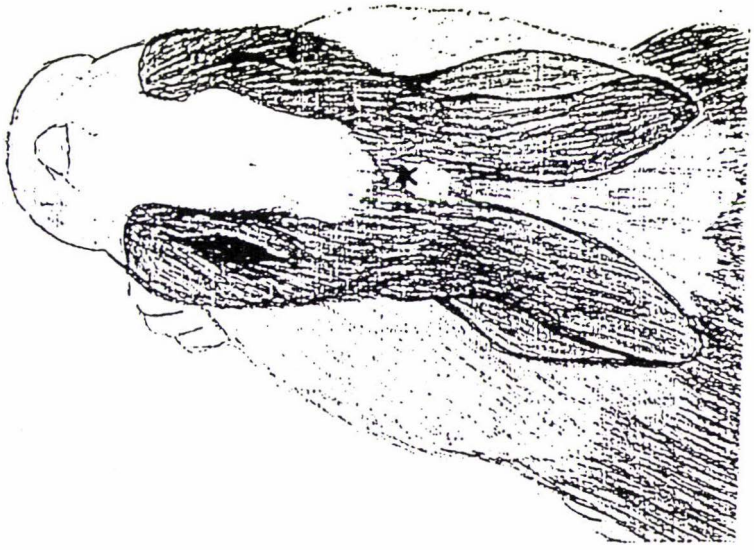


Figure 3.2 - Schematic drawing of rabbit head showing the target of penetrative percussive stunning.

(f) Recording Reflexes

The heart activity was assessed by means of a stethoscope and by palpation of the chest immediately after stunning and during exsanguination. Respiratory activity was detected by visual observation. The palpebral and corneal reflexes were assessed by touching the inner canthus of the eye and the cornea with a finger. Pupillary dilatation was estimated by visual observation of the diameter of the pupils of both eyes periodically. The pedal reflex was checked by pinching the skin between the digits of the hind and fore legs. The spontaneous body movements were visually observed.

At the abattoir, reflexes were recorded in writing at the time of observation. In the laboratory the reflexes were recorded verbally on a tape recorder which was later replayed and analyzed.

(g) Blood Collection and Rates of Bleeding

The blood was collected from the neck wound through a funnel into a 100 ml plastic measuring cylinder calibrated in 1 ml intervals. The rate of bleeding was obtained by recording verbally on a tape recorder the volume of blood recovered every five to ten seconds after bleeding had commenced. The recording was analyzed in detail later.

(h) Carcass Evaluation in Terms of Residual Blood

Five carcasses of rabbits stunned by the penetrative percussive method were used for this evaluation. Two were bled by a transverse incision of the neck. The other three rabbits were not bled but one of these lost an estimated 10-15 ml of blood from the stunning site. The carcasses were presented in random order on a table for evaluation by a panel of seven, consisting of three veterinarians, one secretary and three members of the laboratory staff. In the first trial, the carcasses were presented to the panel unwashed. The second trial was carried out using the same carcasses after each carcass had been washed in running water for two minutes and then presented on the same table, but in a different order. The third trial was carried out with one hind leg from each rabbit on the same table but in a different order. In all three cases the members of the team were told some animals had been bled and others had not, and were asked to identify the carcasses, or the legs originating from rabbits which had been bled.

RESULTS

Reflexes Associated With Slaughter

Heart Activity and Respiration

In the cases in which cardiac activity was checked, it was found to last for approx. two minutes, irrespective of stunning method. Respiration was not apparent in the majority of carcasses examined. In one rabbit which was unsuccessfully stunned by penetrative percussive stunning but restunned within a few seconds, respiratory gasps appeared four times within three minutes after stunning. The same rabbit vocalized by screaming immediately after the unsuccessful stun.

Palpebral and Corneal Reflexes

Palpebral and corneal reflexes could not be evoked at any time in the animals examined, except in one case, where the palpebral reflex persisted for up to two minutes.

Pedal Reflexes

Of the rabbits stunned by the non-penetrative percussive method, four had pedal reflexes persisting for approx. one minute, while in one rabbit, pedal reflexes could be evoked for only 30s after having been stunned by the percussive method. In the group of rabbits stunned by the penetrative percussive method, this reflex lasted for two to four minutes in eight rabbits. In two, reflex activity ceased after 50 and 100 seconds respectively.

Spontaneous Body Movements

All animals slaughtered in the laboratory, showed some degree of involuntary body movements, which appeared to be more violent and of longer duration in the animals stunned by the penetrative percussive method, compared to the other two procedures. In the group of five rabbits stunned by the penetrative percussive method and not bled, these movements were of longer duration than in those animals which were bled. For the unbled group, the mean duration of spontaneous body movements was 92 seconds (range 20-160) while for the bled group it was 40 seconds (range 10-60 seconds) (see table 3.1, page 42).

The majority of the animals stunned by the dislocation method at the abattoir did not show any spontaneous movements.

Pupillary Dilatation

In animals stunned by the dislocation method at the abattoir, full pupillary dilatation did not occur for up to 8 minutes after stunning and subsequent decapitation.

In the laboratory, pupils either constricted (see figure 3.3, page 43) or dilated (see figure 3.4, page 43) immediately after stunning, followed by a return to a half dilated state in approx. two and a half minutes, from which state they gradually became fully dilated. There was no apparent relationship between the method of stunning and the time to reach full pupillary dilatation. Full dilatation took up to eight minutes to occur in all but three animals. Two rabbits stunned by the penetrative method, developed bilateral pupillary dilatation at approx. two minutes and three minutes after stunning respectively. Six rabbits developed an asymmetrical degree and rate of dilatation of the left and right pupil.

Table 3.1

The effects of bleeding on the duration of spontaneous body movements of rabbits, stunned by the penetrative percussive method

BLED		UNBLED	
No. of Rabbit	Duration of movements (s)	No. of Rabbit	Duration of movements (s)
1	60	1	80
2	60	2A	150
3	40	3A	50
4	30	4A	160
5	10	5A	20
Mean	40	Mean	92
Range	10-60	Range	20-160

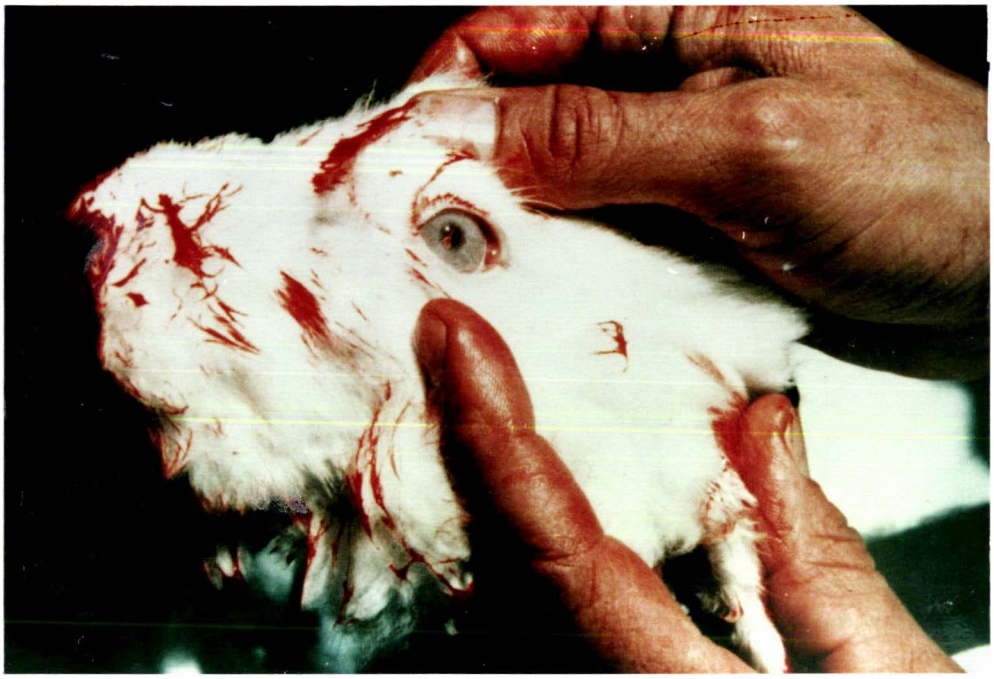


Figure 3.3 - Pupillary constriction

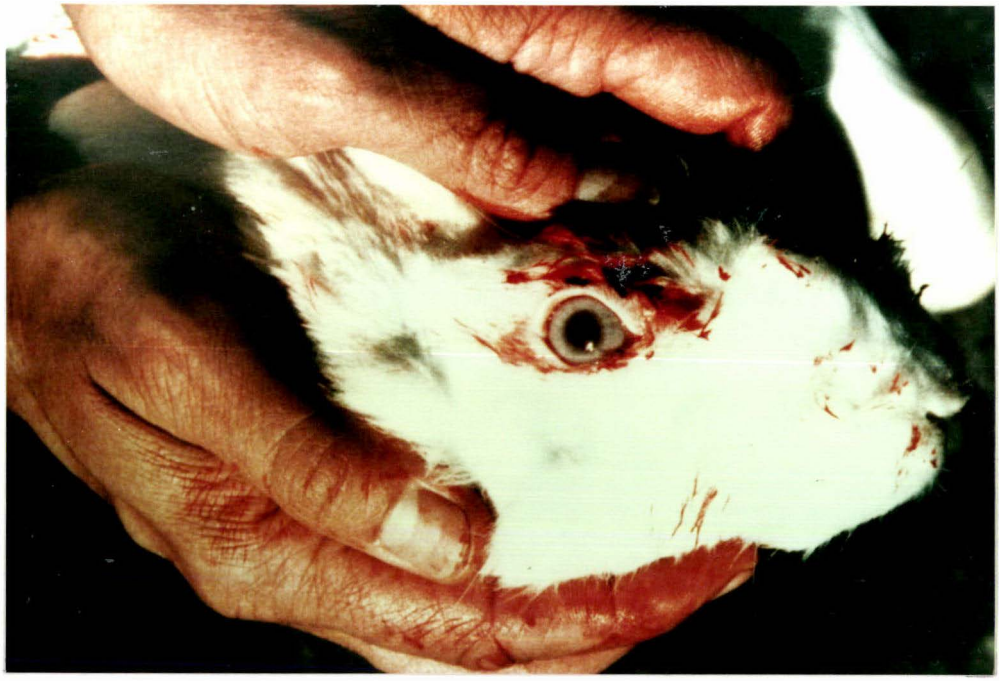


Figure 3.4 - Pupillary dilatation

Site of Lesions From Stunning

Stunning by the dislocation method, both at the abattoir and in the laboratory, resulted in localized neck haemorrhages, containing an estimated volume of up to 10 ml of blood. The neck was always found to be dislocated at the occipito-atlantal junction and in all cases the spinal cord was totally severed at this point. All animals stunned by the dislocation method in the laboratory, had haemorrhages in both the cranial cavity and the vertebral canal. Microscopical examination revealed that the haemorrhages were located extradurally.

In addition to neck lesions, the rabbits stunned by dislocation in the laboratory, had severe inter-and intramuscular haemorrhages in the shoulder regions, probably associated with forces applied to these regions during the dislocation procedure. Similar lesions were not noticed in abattoir killed rabbits.

In animals stunned by the non-penetrative percussive method, the skulls were fractured with associated haemorrhage in the cranial cavity and subcutaneous tissue.

In animals stunned by the penetrative percussion method, gross trauma of the brain and subcutaneous (see fig 3.5, page 45) and intracranial haemorrhages were present in all animals. In nine out of ten animals stunned by this method the skull was successfully penetrated. In two cases, where the site of penetration was close to the orbit, uni-or bilateral partial prolapse of the eye occurred (see fig 3.5, page 45).

Blood Loss and Rates of Bleeding

Table 3.2 (page 47), shows all the data on blood loss, blood yields, time of bleeding and rates of bleeding. The mean amount of blood lost from rabbits was 41.74 ml, with a range of 17 to 97 ml. This, in terms of bodyweight, is equal to a mean blood loss of 17.5 ml/kg, with a range of 8.5 to 28.2 ml/kg.

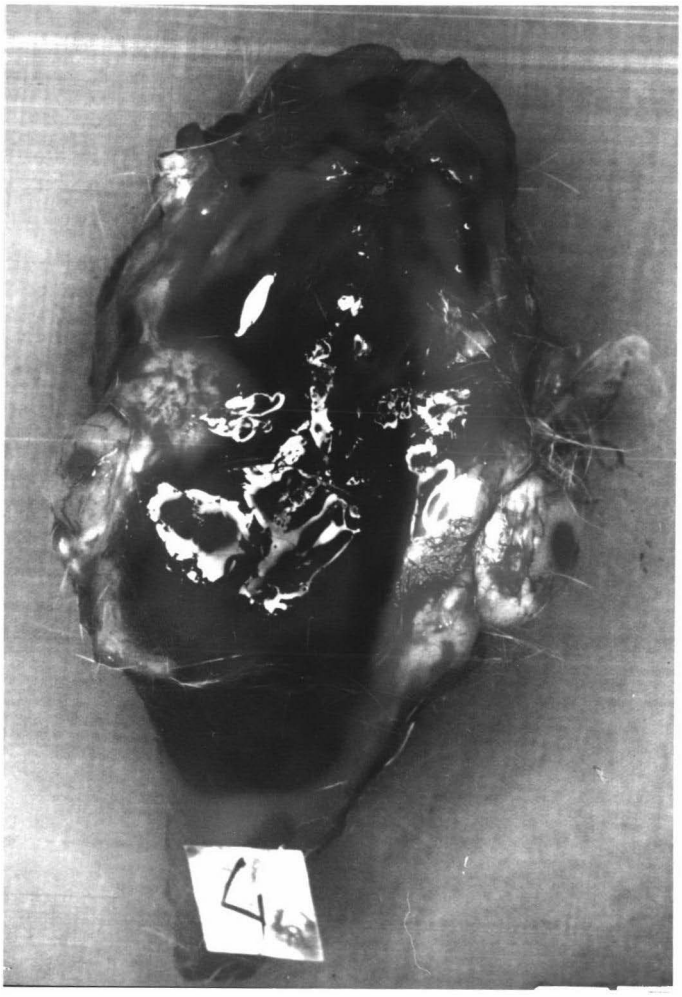


Figure 3.5 - Typical skull lesion with bilateral prolapse of the eyeballs caused by the penetrative percussive stunning.

The initial bleeding rate was high, with the majority of the blood (approx. 60%) being recovered within the first ten seconds after severance of the neck. Twenty five seconds after bleeding had commenced, 75% of the blood had been recovered. Bleeding was completed within a mean period of time of approx. 44 seconds, with a range of 19 to 70 seconds. The mean blood yield in terms of liveweight was 1.75% ranging from 0.85 to 2.82% and the rate of blood loss was 1.05 ml per second over the whole bleeding period with a range of 0.35 to 2.80 ml / second. The method of stunning did not appear to affect the volume of blood recovered or the rate of bleeding.

Regression analysis of the blood collection data, Fig 3.6, (page 49) showed the following relationship between body weight and blood volume lost at slaughter.

$$Y = - 8 + 20.91 X$$

where X is bodyweight in Kg and Y is blood volume in ml. The calculated slope constant, estimated an increase of 20.91 ml blood per kilogram increase in live weight. The value of R squared of this analysis is 0.397, which means that the regression line accounts for only about 40% of the variation observed in the experimental data. This value of the R squared indicates that there must be other factors affecting the blood loss at slaughter, which have not been examined in this study.

A similar investigation carried out on 2-6 week old calves by Cooper and Morris (1978) showed an increase in blood volume of 43.4 ml per kilogram increase in live weight.

The results obtained from the carcass evaluation are shown in Table 3.3, (page 48).

During the first trial 16 out of every 21 answers were correct with respect to the ability to differentiate between bled and unbled animals. In the second trial, the percentage of correct answers dropped dramatically to 28.57% (only six answers out of 21 were correct). The results of the third trial showed that only three out of 21 answers correctly identified the unbled animals. It is worth noticing that during the first trial, three undecided answers were given for the rabbit which lost 10 to 15 ml of blood at stunning. In the third trial, three of the 18 incorrect answers were due to one member of the panel stating that all rabbit legs appeared the same.

Table 3.2

Comparative blood loss and rates of bleeding of rabbits subsequent to a transverse incision of the neck

No.	Live Weight (g)	Blood Loss (ml)	Blood Yield (%)	Length of Bleeding (sec)	Rate of Bleeding (ml/sc)
1	2056	40	1.95	57	0.70
2	1995	17	0.85	49	0.35
3	1816	29	1.60	38	0.76
4	2407	38	1.58	36	1.06
5	1945	39	2.00	50	0.78
6	1918	53	2.76	51	1.04
7	1856	40	2.16	70	0.57
8	1804	37	2.05	38	0.97
9	3442	97	2.82	46	2.11
10	2445	45	1.84	47	0.96
11	3852	75	1.95	43	1.74
12	2628	54	2.05	30	1.80
13	2647	70	2.64	25	2.80
14	2449	45	1.84	19	2.37
15	3261	65	1.99	24	2.71
16	2513	31	1.23	56	0.55
17	2591	26	1.00	32	0.81
18	3351	40	1.19	43	0.93
19	3315	50	1.51	39	1.28
20	2317	53	2.29	40	1.33
21	2344	34	1.45	51	0.67
22	2215	40	1.81	60	0.67
23	2246	28	1.25	61	0.46
24	1863	32	1.72	32	1.00
25	2056	58	2.82	40	1.45
26	1924	35	1.82	44	0.80
27	2124	30	1.41	45	0.67
28	2221	30	1.35	52	0.58
29	2192	30	1.37	49	0.61
30	2452	24	0.98	47	0.51
31	2520	50	1.98	46	1.09
32	2750	54	1.96	42	1.29
33	2280	45	1.97	39	1.15
34	2286	35	1.53	40	0.88
35	2182	25	1.15	43	0.58
36	2168	45	2.08	61	0.74
37	2198	24	1.09	35	0.69
38	2082	25	1.20	43	0.58
39	2121	40	1.89	46	0.87
Mean	2380	41.74	1.75	43.82	1.05
Range	1804-3852	17-97	0.85-2.82	19-70	0.35-2.80

Table 3.3

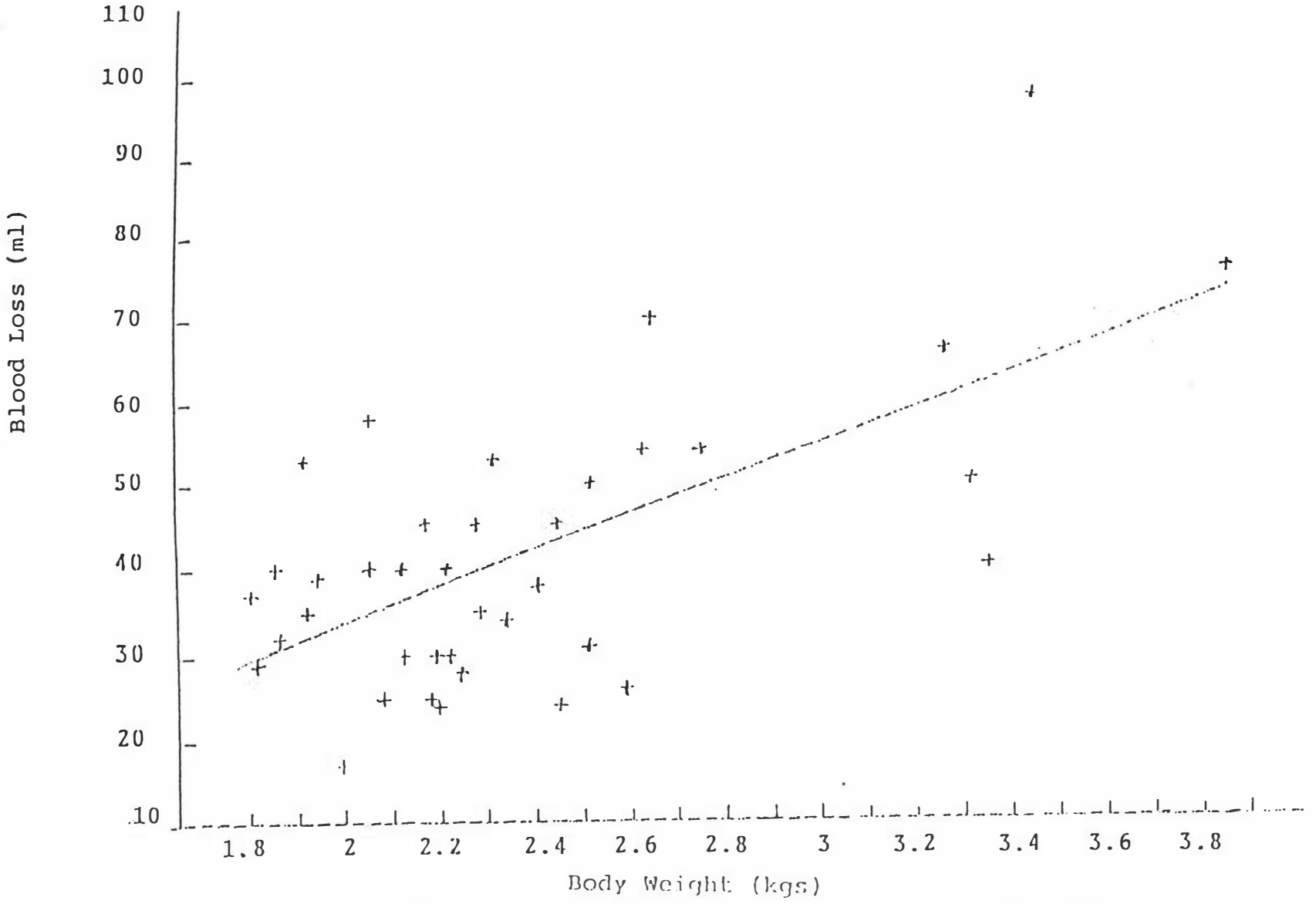
Subjective detection of whether or not rabbit carcasses have been bled

	Correct	Incorrect	Total	Correct Answers (%)
Unwashed Carcasses	16	5	21	76.19
Washed Carcasses	6	15	21	28.57
Hind Legs	3	18	21	14.29

DISCUSSION

Neck dislocation, as carried out by an experienced operator at the abattoir, was effective in terms of rendering an animal immobile before exsanguination. The same method carried out in the laboratory by an inexperienced person was not so effective, as all the rabbits exhibited a considerable degree of spontaneous body movements. The latter group of rabbits showed haemorrhages in the muscles of the caudal region of the neck and the shoulder. This was thought to be due to the excessive force applied to the animals by the author in ensuring the necks were dislocated. Both methods of dislocation were associated with similar times for the onset of pupillary dilatation, but the onset of this phenomenon occurs too late to be of any use in the assessment of the time at which insensibility first occurs.

Figure 3.6
The relatinship between live weight and volume of blood collected during bleeding.
Y = -8 + 20.91 X
(Change of blood loss per Kg change in live weight).



It is difficult to determine whether or not neck dislocation causes immediate insensibility. In humans, neck dislocation resulting from rugby accidents, causes pain at the time of the accident, and patients with neck fractures on life support systems may not lose consciousness. (Blackmore pers. comm.).

It is also difficult to determine whether the haemorrhages found in the brain and spinal cord of the rabbits had any effect on the state of sensibility. In the opinion of the author the stretching of the spinal cord during dislocation may have some effect on the motor nerves of the cord, which could have rendered the animals immobile but not insensible. However, this is contrary to an alternative hypothesis of Blackmore and Delany (1988), according to which, neck dislocation may result in pressure effects on the brain and spinal cord, both rostrally and caudally to the dislocation site, with possible concurrent effects on cerebral function.

In summary, dislocation of the neck of rabbits, when carried out by a skilled person, subjectively appears humane, but without more objective criteria, such as electroencephalographic data, the procedure cannot by assumed to produce immediate insensibility.

Both penetrative and non-penetrative percussive stunning resulted in vigorous movements in most animals, especially in the group stunned by the penetrative percussive method and not bled. It would appear that the greater degree of brain damage caused by the penetrative method resulted in the most vigorous spontaneous body movements.

The kinetic energy required to penetrate the skull was not determined but it must have been at least 1.47 kjoules. This estimate was calculated from the formula KE = mgh where:

m = the weight of the hammer used,
g = the acceleration due to gravity,

h = the height from which the blow was given.
i.e. KE = 1.5 x 9.81 x 0.1 = 1.47 kjoules

This estimated energy requirement is tenfold lower than that required to penetrate the skull of an adult sheep (15.6 kj) (Blackmore and Delany, 1988) which appears to be biologically logical.

A spring loaded bolt, operated by a trigger, would be more effective for stunning rabbits for two reasons. Firstly, because the kinetic energy required to penetrate the skull of the rabbit is small, a spring properly fixed in the instrument could easily provide such energy. Secondly, the instrument could be applied to the head lessening the chance of a poorly aimed blow. In addition, the bolt of the instrument should be pointed for easier penetration of the skull, which would cause less damage to the brain tissue and less subsequent spontaneous body movements. However it might not produce overall percussion to the head as effectively as a blunt bolt.

As discussed elsewhere, reflex reactions, apart from pupillary dilatation, are of little value in assessing the humaneness of a stunning and slaughter process (cited in Blackmore and Delany, 1988). This study indicates that in rabbits, as with other species of animals, pupillary dilatation occurs too late after stunning to be of any real value. Dr I. Schutt-Abraham, (Blackmore, pers. comm.) supports the findings of the present study, in that pupillary dilatation is a criterion of no value in assessing the onset of insensibility in rabbits.

The vocalization, in the form of a scream, which was exhibited by one rabbit during slaughter, is cause for concern. According to Lockley (1975), rabbits only vocalize when they are in distress. It must therefore be concluded that this animal suffered distress from the stunning procedure.

The mean blood loss was only 1.75% of the live body weight, which is somewhat lower than that recorded in other animals. Blackmore and Newhook (1976), recorded values for the blood yield in sheep of 3.5% of the live weight.

Assuming that the total blood volume of rabbits is 6-7% of the bodyweight (Benjamin, 1978) and that 50% of the total blood volume can be expected to be collected at slaughter (cited in Blackmore and Delany, 1988), the blood loss of 1.75% of the live weight recovered during the present experiments is lower than expected. However, the maximum blood yield from an individual rabbit was 2.82%. (see table 3.2, page 47). The lower yield can be explained partially by the approx. 10 ml of blood which diffused into the neck tissues of all rabbits stunned by the dislocation method and a similar quantity of blood found subcutaneously on the head of the rabbit stunned by the nonpenetrative percussive method. It was also noticed that fur often partially occluded the site of incision and aided the formation of a blood clot at this site, thereby reducing the amount of blood lost.

During the present experiment, it was found that the change in blood yield was 20.91 ml per kg of live weight change. However the value of R squared calculated in this analysis (0.397), means that live weight alone does not account for the bigger part of the variation observed, (only 40%). This means that there must be other factors also that affect the volume of blood lost at slaughter apart from live weight. Cooper and Morris (1978) recorded higher (43.40 ml/kg) blood loss in two to six weeks old calves at slaughter. Species difference may also account for this difference.

A common feature of all animals which were bled, was the large volume of blood recovered within the first 10 seconds after severance of the neck. This phenomenon caused difficulties in measuring the bleeding rate. The mean duration of bleeding was almost 44 seconds, which was much shorter than the 94 seconds

found by Blackmore and Newhook (1976) for lambs stunned by a captive bolt pistol and bled by bilateral severance of the vessels of the neck. It is apparent that further experiments are needed to clarify the problem of blood yield and bleeding rate in rabbits. In such experiments, groups of animals bled without prior stunning,should be included.

The results obtained from the evaluation of the panel on the effects of bleeding on the appearance of meat, show that blood remaining in the subcutaneous tissue of unbled animals affects the superficial colour of the carcass but not the meat. This finding is in agreement with that of Warriss and Leach (1978) who found that, while the amount of blood lost at exsanguination in sheep varies with different slaughter procedures, the blood retained in the muscles is unaffected. They postulated that the remaining blood may be retained by the spleen, since this organ is capable of containing up to one seventh of the total blood volume of sheep.

Warriss (1984) states that, in non-bled animals, the blood is retained in the viscera, rather than in the carcass. In sheep and cattle, in which bleeding was considerably delayed for up to 30 minutes after stunning, some small extra retention of blood in the carcass may occur. However, there have been no direct measurements of where in the carcass (muscle, fat or bone) such retained blood may be located, and it was considered that the amount would be too small to affect meat quality in any way.

It is obvious that the limited extend of the experiment regarding the effects of bleeding on the quality of rabbit meat, cannot give a definite and clear answer to the problem. Only an indication is given that it affects in a certain degree the appearance of the carcass when rabbits are not bled. However this may be of importance as, unlike mutton and beef, rabbit meat is usually marketed in carcass form.

CHAPTER FOUR

CARCASS YIELDS AND RELATIVE ORGAN WEIGHTS

INTRODUCTION

The demand by consumers for lean meat with little fat, has resulted in producers having to pay more attention to carcass yields and carcass composition.

The main components of meat are water, protein, fat and carbohydrates. Chen et al, (1978) found that rabbit meat contains 18.6-19.4% protein and 7.9-10.9% fat and Bendall (1962), states as water content for the same animals 77%. Evans (1983), states that rabbit meat contains higher levels of protein and half the amount of fat and cholesterol than poultry meat, but fails to substantiate this statement. The fat and water content of chicken meat is 14.4 - 30.2% and 52.8 -64.7% respectively, and the protein content is 18.6% (Moreng and Avens, 1985). Although venison is considered low fat meat it still contains 20.8% fat (Drew 1985), thus rabbit meat has approx. only half as much fat as venison.

The carcass yield (C.Y.) (dressing percentage) is defined as the carcass weight as a percentage of the liveweight of the animal:

The C.Y. varies between species. Pigs, for example, have an average carcass yield of 75% (Thornton and Gracey, 1986). Romans and Ziegler (1966), recorded C.Y. for beef ranging from 52% to 58% and for lamb, an average of 50%, while poultry C.Y.s may be as high as 69.3% (Mulder et al, 1981). The higher yields for pigs compared with cattle and sheep are due partially to the head, skin and kidneys remaining on the pig carcass, but also because pigs have a lower bone to muscle ratio than cattle and sheep (Gracey, 1986).

For all species, the C.Y. is higher if at the time of slaughter the content of the gastrointestinal tract (GIT) is low (Cheek et al, 1982). Thus, in general terms, ruminants would be expected to have lower C.Y.s than monogastric animals, since their GIT tracts are larger.

Well grown rabbits of good conformation have a C.Y. of about 55% and a meat to bone ratio of 5:1 (Anon 1987). However, Chen et al, (1978) recorded slightly lower C.Y.s for rabbits, ranging from 46.6-50.3%. As 80% of the dressed rabbit carcass is edible and the proportion of the carcass which is edible in poultry is 50-75% (Anon 1976), rabbits compare favorably with chickens with regards to edible C.Y. (Anon, 1987). Investigating the effect of age on C.Y., Aitken and King (1962) found that with increasing age, there is a slight increase in C.Y. of up to 55-65%, which Deltoro and Lopez (1987) attribute to an increased deposition of fat. Mulder et al, (1981) showed a similar age associated change in C.Y. in poultry.

Body conformation also affects the C.Y. of rabbits. Animals with well sprung ribs and deep chest, with a uniform width and depth of the body from shoulders to the pelvis give a higher C.Y. than narrow rangy animals (Cheek et al, 1982). In this respect the New Zealand White is regarded as superior to other breeds (Cheek et al, 1982).

Apart from the factors already mentioned, the method of processing can affect the C.Y. of rabbits. In some countries (England and Cyprus) the head, neck and liver remain on the carcasses and the yields measured are therefore higher than in countries such as New Zealand where these parts are removed during dressing.

Other factors affecting C.Y. are discussed, in relation to the evaluation of data presented later in this chapter.

MATERIALS AND METHODS

Forty six rabbit carcasses were examined, 24 of which were of rabbits slaughtered and processed at the abattoir and 22 were slaughtered and processed in the laboratory. Twenty of the latter group were eight to ten weeks of age. The remaining two were young adults (16-18 weeks of age). The latter were treated as a separate group, in order to examine differences, which could be related to weight and/or age. All rabbits slaughtered in the abattoir, originated from commercial rabbitries. Six were Angora and 18 New Zealand White. The rabbits slaughtered in the laboratory were all New Zealand White.

The animals were weighed immediately before slaughter and again after dressing. The following organs and parts were removed from the carcass and weighed, and the relative weights calculated: head, neck, pluck (lungs, heart, trachea and oesophagus), liver, feet, GIT and pelt. C.Y. and blood loss were calculated for all 46 rabbits but the relative weights of the head, neck, pluck, liver, feet, GIT and pelt were calculated only for the 22 rabbits slaughtered in the laboratory.

A "Mettler PC 4400, Delta range" electronic balance (Watson victor Ltd.), with an accuracy $\pm$o.o1 g was used for all measurements.

RESULTS

Carcass Yields

The live weights, C.Y.'s, blood loss, and relative organ weights of all the rabbits examined, are presented in tables 4.1, 4.2 and 4.3. The C.Y.'s are summarised in table 4.4, (page 62).

The mean C.Y. of the New Zealand White rabbits processed at the abattoir and in the laboratory, were similar being 44.6% and 46.0% respectively. The mean C.Y. of the two young adult New Zealand Whites purchased from a breeder and the six Angora rabbits were 51.9% and 53.5% respectively.

In spite of these differences in mean C.Y., the range of the values for each of these groups, showed a considerable degree of variation and overlap. The highest yield of 62.9% was recorded in an Angora rabbit and the lowest of 37.3% in a New Zealand White rabbit slaughtered at the abattoir.

Blood Loss

The mean blood loss of the 18 New Zealand White rabbits slaughtered at the abattoir was 36 ml per rabbit (range 24-58 ml) corresponding to a mean yield of 1.6% (range 1.0-2.8%). (see table 4.1, page 58).

The blood loss of the 13 New Zealand White rabbits slaughtered in the laboratory and in which the blood loss was measured, was 44 ml per rabbit (range 17-70ml) corresponding to a mean yield of 1.9% (range 0.9-2.8%). (see table 4.2, page 59).

The mean blood loss of the two young adult New Zealand White rabbits killed in the laboratory was 86 ml (range 75-97 ml) corresponding to a mean yield of 2.4% (range 1.9-2.8%). (see table 4.3, page 60).

Table 4.1

Live weights (g), carcass yields (g) and blood loss (ml) of 24 rabbits slaughtered at the abattoir

Breed	Live	Carcass	C.Y.	Blood	Blood yield
Angora	2513	1261	(50.2)	31	(1.2)
"	2591	1282	(49.5)	26	(1.0)
"	3351	1779	(53.1)	40	(1.2)
"	3315	1554	(46.9)	50	(1.5)
"	2317	1457	(62.9)	53	(2.3)
"	2344	1448	(61.8)	34	(1.5)
Mean	2739	1464	53.5	39	(1.4)
Range	2317-3351	1261-1779	(44.9-62.9)	26-53	(1.0-2.3)
N.Z. White	2115	943	(44.6)	45	(2.1)
"	2246	1087	(48.4)	28	(1.2)
"	1863	901	(48.4)	32	(1.7)
"	2056	954	(46.4)	58	(2.8)
"	1924	803	(41.7)	35	(1.8)
"	2124	1091	(51.4)	30	(1.4)
"	2221	981	(44.2)	30	(1.4)
"	2192	1011	(46.1)	30	(1.4)
"	2452	1058	(43.1)	24	(1.0)
"	2520	1072	(42.5)	50	(2.0)
"	2750	1251	(45.5)	54	(2.0)
"	2280	1056	(46.3)	45	(2.0)
"	2286	1009	(44.1)	35	(1.5)
"	2182	814	(37.3)	25	(1.1)
"	2168	902	(41.6)	45	(2.1)
"	2198	953	43.4)	24	(1.1)
"	2082	915	(43.9)	25	(1.2)
"	2121	941	(44.4)	40	(1.9)
Mean	2210	986	(44.6)	36	(1.6)
Range	1863-2750	803-1251	(37.3-51.4)	24-58	(1.0-2.8)

( ) = Relative Weight as % of live Weight.

Table 4.2

Live weights (g), carcass yields (g), blood loss (ml), weights (g) and relative weights of organs of 20 New Zealand White rabbits slaughtered in the laboratory.

Live	Carcass	Head	Liver	Blood	Feet	Pluck	Pelt	Neck	GIT
2056	1016	195	55	40	73	23	241	44	350
	(49.4)	(9.5)	(2.7)	(1.9)	(3.6)	(1.1)	(11.7)	(2.1)	(17.0)
1995	965	172	47	17	70	19	262	55	343
	(48.4)	(8.6)	(2.4)	(0.9)	(3.5)	(1.0)	(13.1)	(2.8)	(17.2)
1816	805	150	68	29	64	22	198	41	394
	(44.3)	(8.3)	(3.7)	(1.6)	(3.5)	(1.2)	(10.9)	(2.3)	(21.7)
2126	950	206	85	Not	69	28	268	65	405
	(44.7)	(9.7)	(4.0)	bled	(3.2)	(1.3)	(12.6)	(3.1)	(19.0)
2153	1015	207	100	Not	70	18	265	46	400
	(47.1)	(9.6)	(4.6)	bled	(3.3)	(0.8)	(12.3)	(2.1)	(18.6)
2407	1063	189	116	38	67	32	356	41	413
	(44.2)	(7.9)	(4.8)	(1.6)	(2.8)	(1.3)	(14.8)	(1.7)	(17.2)
1945	874	187	53	39	65	13	243	38	374
	(44.9)	(9.6)	(2.7)	(2.0)	(3.3)	(0.7)	(12.5)	(2.0)	(19.2)
1918	861	187	50	53	70	17	232	36	399
	(44.9)	(9.7)	(2.6)	(2.8)	(3.6)	(0.9)	(12.1)	(1.9)	(20.8)
1856	811	176	49	40	63	15	216	35	373
	(43.7)	(9.5)	(2.6)	(2.2)	(3.4)	(0.8)	(11.6)	(1.9)	(20.1)
1804	784	174	49	37	64	14	205	30	363
	(43.5)	(9.6)	(2.7)	(2.1)	(3.5)	(0.8)	11.4)	(1.7)	(20.1)
2245	1108	227	146	45	65	18	278	31	498
	(45.0)	(9.3)	(6.0)	(1.8)	(2.7)	(0.7)	(11.4)	(1.3)	(20.4)
2607	1115	206	149	Not	73	23	295	43	572
	(42.8)	(7.9)	(5.7)	bled	(2.8)	(0.9)	(11.3)	(1.6)	(21.9)
2424	1177	294	113	Not	73	23	203	58	499
	(48.6)	(12.1)	(4.7)	bled	(3.0)	(0.9)	(8.4)	(2.4)	(20.6)
2628	1230	215	83	54	76	25	315	46	490
	(46.8)	(8.2)	(3.2)	(2.1)	(2.9)	(1.0)	(12.0)	(1.8)	(18.6)
2553	1216	229	135	Not	77	28	238	63	507
	(47.6)	(9.0)	(5.3)	bled	(3.0)	(1.1)	(9.3)	(2.5)	(19.9)
2647	1226	192	90	70	70	24	375	48	496
	(46.3)	(7.3)	(3.4)	(2.6)	(2.6)	(0.9)	(14.2)	(1.8)	(18.7)
2449	979	242	76	45	86	19	265	35	638
	(40.0)	(9.9)	(3.1)	(1.8)	(3.5)	(0.8)	(10.8)	(1.4)	(26.1)
1984	931	182	48	Not	101	24	242	43	143
	(46.9)	(9.2)	(2.4)	bled	(5.1)	(1.2)	(12.2)	(2.2)	(7.2)
3261	1767	300	59	65	62	23	455	44	148
	(54.2)	(9.2)	(1.8)	(2.0)	(1.9)	(0.7)	(14.0)	(1.3)	(4.5)
2944	1296	256	118	Not	90	27	346	47	478
	(44.0)	(8.7)	(4.0)	bled	(3.1)	(0.9)	(11.8)	(1.6)	(16.2)
Mean 2301	1059	209	84	44	72	22	275	44	414
	(46.0)	(9.1)	(3.7)	(1.9)	(3.1)	(1.0)	(12.0)	(1.9)	(18.0)
Range 1816-3261	784-1767	150-300	47-149	17-70	62-101	13-32	198-455	30-65	143-638
	(40.0-54.2)	(7.3-12.1)	(1.8-6.0)	(0.9-2.8)	(1.9-5.1)	(0.7-1.3)	(8.4-14.8)	(1.3-3.1)	(4.5-26.1)

( ) = Relative Weight as % of live weight.

Table 4.3

Live weights, carcass yields, blood loss, weights and relative weights of organs of two young adult New Zealand White rabbits killed in the laboratory

	Live	Carcass	Blood	Liver	Feet	Pelt	Pluck	Head	GIT	Neck	Total
	g	g	ml	g	g	g	g	g	g	g	g
	3442	1670 (48.5)	97 (2.8)	77 (2.2)	121 (3.5)	504 (14.6)	29 (0.8)	168 (4.9)	528 (15.3)	74 (2.1)	3268 (94.9)
	3852	2112 (54.8)	75 (1.9)	95 (2.5)	126 (3.3)	679 (17.6)	31 (0.8)	193 (5.0)	409 (10.6)	82 (2.1)	3802 (98.7)
Mean	3647	1891 (51.9)	86 (2.4)	86 2.4)	124 (3.4)	592 (16.2)	30 (0.8)	181 (5.0)	469 (12.9)	78 (2.1)	3537 (97.0)

( ) = Relative weight as % of live weight.

The mean blood loss of the Angora rabbits killed at the abattoir was 39ml (range 26-53ml) corresponding to a mean yield of 1.4% (range 1.0-2.3%). (see table 4.1, page 58).

The blood loss of the two young adult New Zealand White rabbits was significantly higher ($p<0.05$) than the blood loss in rabbits of all the other groups. There was no significant difference between the other three groups.

Relative Weights of Organs

The mean relative weights of the head, liver, feet, pluck, pelt, neck and GIT, were 8.5%, 3.5%, 3.2% 0.9, 12.5%, 2.0%, and 17.3% respectively. The range of these relative weights was for : the head 4.9 - 12.1% (150-300g), the liver 1.8 - 6.0% (47-149g) the feet 1.9 - 5.1% (62-126g), the pluck 0.7-1.3% (13-32g), the pelt 8.4 - 17.6% (198-679g), the neck 1.3-3.1% (30-82g) and the GIT 4.5-26.1% (143-638g) (see table 4.5, page 63 and Fig. 4.1, page 66). It was found that the carcass yield and the relative weights of the pelt were higher for the bled animals, while the relative weights of GIT, liver, feet, pluck, head and neck were higher for the unbled animals (see table 4.6, page 64, and table 4.7, page 65). However, these differences were not significant at the 0.05 level. It was also found that the C.Y., blood loss and the relative weight of pelt were higher for the heavier group,while all the other relative organ weights were lower. However, these differences were not significant at the 0.05 level (see table 4.8, page 65 and Figure 4.2, page 67).

Table 4.4

Mean live weights and carcass yields of different groups of rabbits

Breed	No. of Rabbits	Live weight mean g	Carcass yield mean %	Range %
N. Z. White **	18	2210	44.6	37.3-51.4
N. Z. White **	20	2301	46.0	40.0-54.2
Young adult N. Z. White *	2	3647	51.9	48.5-54.8
Angora ** (Adults)	6	2739	53.5	46.9-62.9

* : slaughtered in the laboratory.

** : slaughtered at the abattoir

Table 4.5

Mean values of carcass yields, blood loss and relative organ weights of 22 rabbits with a mean liveweight of 2423 grams, slaughtered in the laboratory

		Carcass g	Head g	Liver g	Blood ml	Feet g	Pluck g	Pelt g	Neck g	GIT g
Mean	Actual Weight (g)	1134.7	206.7	84.6	49.6	77	22.5	303.7	47.5	419
	Relative Weight (%)	46.8	8.5	3.5	2.0	3.2	0.9	12.5	2.0	17.3
Range	Actual Weight (g)	784-2112	150-300	47-149	17-97	62-126	13-32	198-679	30-82	143-638
	Relative Weight (%)	40.0-54.8	4.9-12.1	1.8-6.0	0.9-2.8	1.9-5.1	0.7-1.3	8.4-17.6	1.3-3.1	4.5-26.1

Table 4.6

Live weight (g), carcass yield (g), blood loss (ml) and relative organ weights of 15 bled rabbits

Live	Carcass	Blood	Liver	Feet	Pelt	Pluck	Head	GIT	Neck	Total
2445	1100 (45.0)	45 (1.8)	146 (6.0)	65 (2.7)	278 (11.4)	18 (0.7)	227 (9.3)	498 (20.4)	31 (1.3)	2408 (98.5)
2628	1230 (46.8)	54 (2.1)	83 (3.2)	76 (2.9)	315 (12.0)	25 (1.0)	215 (8.2)	490 (18.6)	46 (1.8)	2534 (96.4)
2647	1226 (46.3)	70 (2.6)	90 (3.4)	70 (2.6)	375 (14.2)	24 (0.9)	192 (7.3)	496 (18.7	48 (1.8)	2591 (97.9)
2449	979 (40.0)	45 (1.8)	76 (3.1)	86 (3.5)	265 (10.8)	19 (0.8)	242 (9.9)	638 (26.1)	35 (1.4)	2385 (97.4)
3261	1767 (54.2)	65 (2.0)	59 (1.8)	68 (2.1)	455 (14.0)	24 (0.7)	300 (9.2)	148 (4.5)	44 (1.3)	2930 (89.8)
2056	1016 (49.4)	40 (1.9)	55 (2.7)	73 (3.6)	241 (11.7)	23 (1.1)	193 (9.4)	350 (17.0)	44 (2.1)	2035 (99.0)
1995	965 (48.4)	17 (0.9)	47 (2.4)	70 (3.5)	262 (13.1)	19 (1.0)	172 (8.6)	343 (17.2)	55 (2.8)	1950 (97.7)
1816	805 (44.3)	29 (1.6)	68 (3.7)	64 (3.5)	198 (10.9)	22 (1.2)	150 (8.3)	394 (21.7)	41 (2.3)	1771 (97.5)
2407	1063 (44.2)	38 (1.6)	116 (4.8)	70 (2.9)	356 (14.8)	32 (1.3)	189 (7.9)	413 (17.2)	41 (1.7)	2318 (96.3)
1945	874 (44.9)	39 (2.0)	53 (2.7)	65 (3.3)	243 (12.5)	13 (0.7)	187 (9.6)	374 (19.2)	38 (2.0)	1886 (97.0)
1918	861 (44.9)	53 (2.8)	50 (2.6)	70 (3.6)	232 (12.1)	17 (0.9)	187 (9.7)	399 (20.8)	36 (1.9)	1905 (99.3)
1856	811 (43.7)	40 (2.2)	49 (2.6)	63 (3.4)	216 (11.6)	15 (0.8)	176 (9.5)	373 (20.1)	35 (1.9)	1778 (95.8)
1804	784 (43.5)	37 (2.1)	49 (2.7)	64 (3.5)	205 (11.4)	14 (0.8)	174 (9.6)	363 20.1)	30 (1.7)	1720 (95.3)
3442	1670 (48.5)	97 (2.8)	77 (2.2)	121 (3.5)	504 (14.6)	29 (0.8)	168 (4.9)	528 (15.3)	74 (2.1)	3268 (94.9)
3852	2112 (54.8)	75 (1.9)	95 (2.5)	126 (3.3)	679 (17.6)	31 (0.8)	193 (5.0)	409 (10.6)	82 (2.1)	3802 (98.7)
Mean 2435	1151 (47.3)	50 (2.1)	74 (3.0)	77 (3.2)	322 (13.2)	22 (0.9)	198 (8.1)	414 (17.0)	45 (1.8)	2353 (96.6)

( ) = Relative weights as percentage of live weight.

Table 4.7

Live weight, carcass yield and relative organ weights in grams of seven unbled rabbits

	Live g	Carcass g	Liver g	Feet g	Pelt g	Pluck g	Head g	GIT g	Neck g	Total g
	2607	1115 (42.8)	149 (5.7)	73 (2.8)	295 (11.3)	23 0.9)	206 (7.9)	572 (21.9)	43 (1.6)	2476 (95.0)
	2424	1177 (48.6)	113 (4.7)	73 (3.0)	203 (8.4)	23 (0.9)	204 (8.4)	499 (20.6)	58 (2.4)	2350 (96.9)
	2553	1216 (47.6)	135 (5.3)	77 (3.0)	238 (9.3)	28 (1.1)	229 (9.0)	507 (19.9)	63 (2.5)	2493 (97.6)
	1984	931 (46.9)	48 (2.4)	101 (5.1)	242 (12.2)	24 (1.2)	182 (9.2)	143 (7.2)	43 (2.2)	1714 (86.4)
	2944	1296 (44.0)	118 (4.0)	90 (3.1)	346 (11.8)	27 0.9)	256 (8.7)	478 (16.2)	47 (1.6)	2658 (90.3)
	2153	1015 (47.1)	100 (4.6)	70 (3.3)	265 (12.3)	18 (0.8)	207 (9.6)	400 (18.6)	46 2.1)	2121 (98.5)
	2126	950 (44.7)	85 (4.0)	69 (3.2)	268 (12.6)	28 (1.3)	206 (9.7)	405 (19.0)	65 (3.1)	2076 (97.6)
Mean	2399	1100 (45.9)	107 (4.5)	79 (3.3)	265 (11.0)	24 (1.0)	213 (8.9)	429 (17.9)	52 (2.2)	2269 (94.6)

( ) = Relative weight as % of live weight.

Table 4.8

Comparison of the mean values of live weights, carcass yields, blood loss and relative organ weights of nine rabbits › 2000g live weight, with the mean values of six rabbits ‹ 2000g live weight

	Live g	Carcass g	Head g	Liver g	Blood ml	Feet g	Pluck g	Pelt g	Neck g	GIT g
>2000g	2798	1351	213	88	58	83	25	385	37	470
		(48.3)	(7.6)	(3.1)	(2.1)	(3.0)	(0.9)	(13.8)	(1.3)	(16.8)
<2000g	1889	850	174	53	36	66	17	226	39	374
		(45.0)	(9.2)	(2.8)	(1.9)	(3.5)	(0.9)	(12.0)	(2.1)	(19.8)

( ) = Relative weight as % of live weight.

Figure 4.1

Carcass Yield and Blood loss of 24 rabbits slaughtered at the abattoir

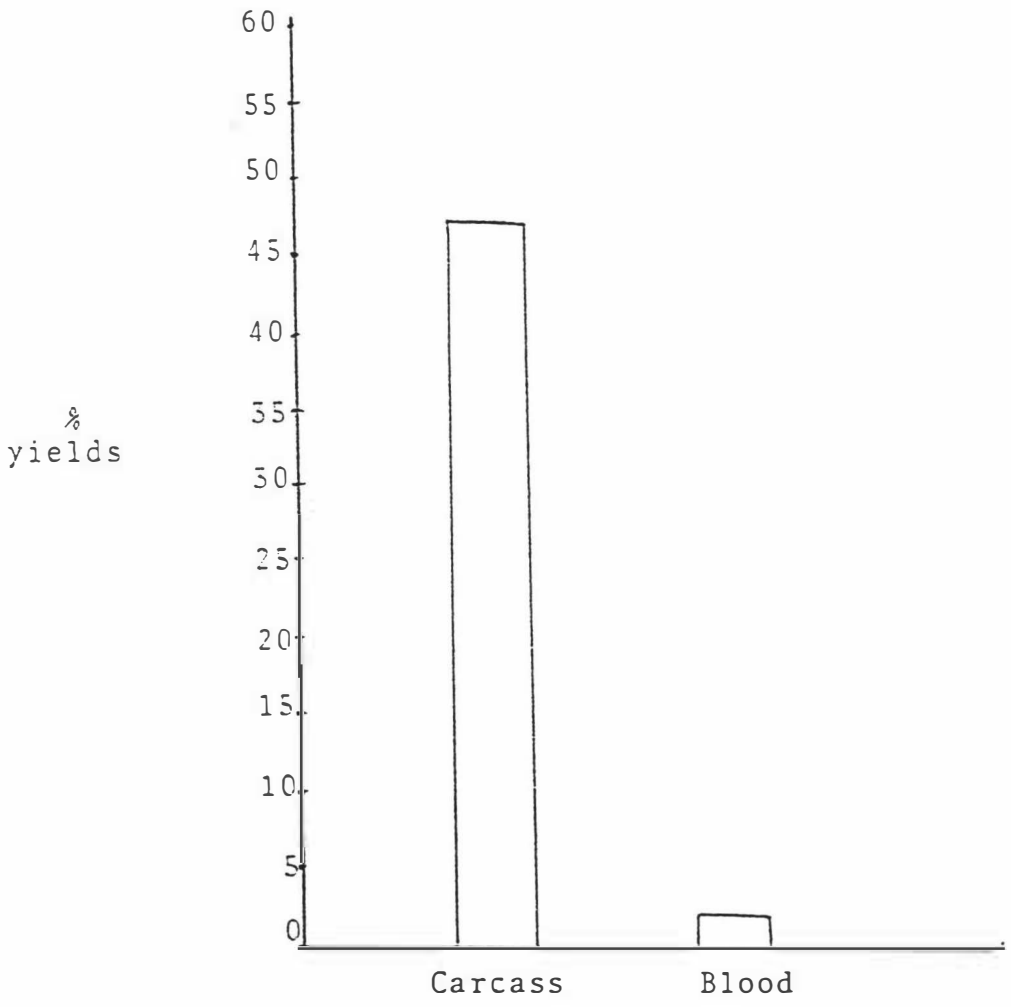
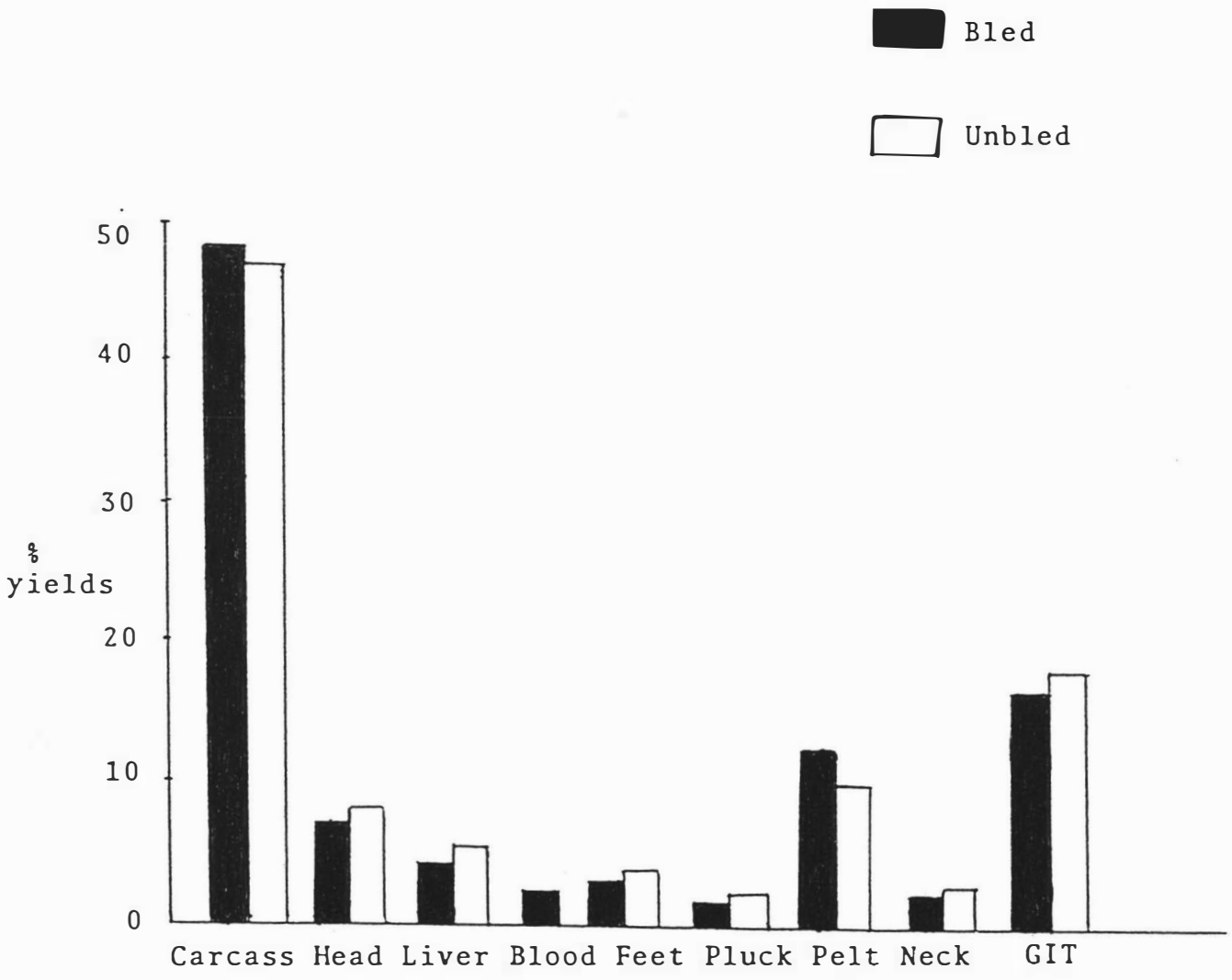


Figure 4.2
Carcass yield and relative organ weights
of 15 bled and seven unbled rabbits



DISCUSSION

The results presented, indicate a great variation in C.Y., especially in the group of adult Angora rabbits (46.9%-62.9%). The high C.Y. (53.5%) recorded in this group may be due to the combined effect of an empty GIT and age, while the great variation may be due to the fact that the group consisted of culled does at various stages between weaning and slaughter. Age and live weight, appears to have a significant effect on C.Y., since a difference of almost 7% was observed between the C.Y.'s of the commercial rabbits on the one hand and the culled Angora does and young adult New Zealand Whites on the other.

The C.Y.s of the commercial rabbits, although lower than the other groups, are similar to C.Y. of pigs, if the weights of the head, neck and skin, which accounted for approx. 23% of the total weight of the animal, are included in the C.Y.. Thus the adjusted figure for rabbits of 68%, compares with the figure of 70-80% quoted for pigs (Gracey, 1986). Rabbit C.Y. also compares well with those of poultry if the neck, skin and liver of the rabbits are included in the C.Y. as they are in poultry. However, by comparing the mean C.Y. of a group of heavy rabbits (>2000g), to a group of light rabbits (<2000g) killed in the laboratory, an increase of only 3.3% in C.Y. was found in the group of the heavy animals, although the mean live weight of this was approx. 50% higher than the light group (see table 4.8, page 65). This small increase in C.Y. is negligible considering the large increase of live weight. However, in addition to that, the food conversion ratio decreases after the age of eight weeks, and considering the extra labour and the space the animals need if they are kept longer, it is advisable to slaughter rabbits at the age of eight weeks. Exceptions to this, are if the animals are kept for pelt production or breeding stock.

The results of this study indicate that neither age nor live body weight have a significant effect on the amount of blood

recovered during exsanguination. By comparing blood yields of a group of rabbits weighing more than 2000g, with a group weighing less than 2000g, an increase in yield of only 0.2% in the heavy group was recorded.

Regarding the relative weights of other organs, it was found that the pelt weight was 1.8% higher in the group of heavy animals. This increase was expected since the age affects the thickness of the pelt considerably. The higher the age at slaughter, the heavier and better the pelt is. Thus, animals farmed for fur production must be slaughtered at about 30 week of age for prime pelt, or at about 16 week of age for intermediate quality pelts (Anon 1987).

In terms of the effect of bleeding on the relative weight of the pelt, it was found unexpectedly that the relative pelt weight of the bled animals was higher than the unbled animals.This finding is contrary to that of Gregory et al, (1985), who found that the skin from sheep, which had been dead for about 15 minutes, but not bled, contains twice as much blood as skin from animals which have been slaughtered in a normal manner. These authors also found that a beating heart is not required for the loss of blood from the skin at slaughter and that with normal slaughtering procedures the amount of blood retained in the skin should be the same, whether the heart is in fibrillation or beating normally at the time the animal is stuck. Kirton et al, (1981) found that head-back electrical stunning in lambs, which stops the heart, results in the skin, head and feet, being an average 128g heavier in sheep than with a beating heart. They postulated that this increase was mainly accounted for by blood adhering to the wool, particularly in the region of the neck. This blood had been spilled onto the floor after the initial 2-minutes collection time and adhered to the wool of the neck.

The higher relative weight of pelts, unexpectedly obtained from the group of bled animals, is due to the high relative pelt

weights of the two young adult New Zealand White purchased from a farm. These two rabbits being older and heavier than the other rabbits killed in the laboratory, showed relative pelt weights of 14.6% and 17.6% which raised the mean of the relative weight of pelts from animals bled in the laboratory to 13.2% (2.2% higher than the unbled group). After excluding these two rabbits from the group, the mean relative weight of the pelts of the bled rabbits drops to 10.9% which is 0.1% lower than that from the group of the unbled animals.

The present study showed that the relative weight of the liver was 1.5% higher in the unbled animals compared to those which had been bled. This finding supports the hypothesis that in unbled animals the residual blood is retained by the internal organs (Warriss 1984). This would also account for the higher relative weights of the feet, head and neck of the unbled animals.

In the present study the relative weight of the GIT showed a very wide range (4.5-26.1%) which was probably due to the variations in the amount of the contents of GIT at the time of slaughter. It is likely that the shorter the time between the rabbit being presented with food and slaughter, the higher the relative weight of the GIT will be. The higher relative GIT weight by 3% found in this study for the group of light animals (<2000), (see table 4.8, page 65), compared to the heavy animals, can be explained in two ways. First, the rabbits had been eating almost up to the time of slaughter. Secondly, young growing animals, which would be lighter than older animals, would be consuming relatively greater amounts of food.

In general, the results reported in this chapter concerning relative organ weights of rabbits and factors affecting them, are similar to those recorded from other species.

CHAPTER FIVE

EFFECTS OF CARCASS WASHING ON RABBIT MEAT QUALITY

INTRODUCTION

The washing of carcasses after dressing, including those of rabbits, is regarded as a necessary procedure to remove visual dirt and other forms of contamination from the meat surface.

Contamination can be transferred to the meat surface from the environment, the pelt or hide of the animals, the hands of the operators and instruments which have contact with the carcass during processing. As total avoidance of contamination must be considered unattainable in the abattoir, modern systems of dressing and hygiene have been designed to reduce contamination to acceptably low levels.

The major principles of hygienic dressing as related to sheep include:

First, the proper handling and washing of stock prior to slaughter to avoid contamination from the fleece. Secondly, carrying out the initial cuts of the pelting operation in a manner that will minimize the contamination of the skinned area. Thirdly, the removal of the pelt in such a way that outer surfaces of the pelt do not come in contact with the carcass. Finally, avoidance of contamination of the carcass from contents of the alimentary and urinary tracts.

Other factors, such as the restriction on holding periods of stock in yards awaiting slaughter, will assist the prevention of a build up of pathogens, such as Salmonellae, in the stock, the environment and or carcasses (Turner 1987).

Petersen (1983) found that the ideal time to slaughter lambs, is 18-24 hrs after removal from pasture and gives as reason, an increase of the fluidity of ruminoreticular contents after this period, which increases the risk of carcass contamination during dressing.

Proper positioning of hand washes and equipment 'sterilizing' facilities at dressing stations, assists in the reduction of cross contamination from handling the fleece and the carcasses by the workers during dressing (Turner,1987).

Cattle and sheep are generally washed in the lairage before slaughter, but other species of meat animals such as pigs, deer, rabbits and poultry are not, although carcasses of cattle, sheep,pigs and rabbits are washed at least once during the dressing operation. Deer carcasses are not washed at any time.

Carcasses which are washed during, and/or after dressing gain water, some of which is subsequently lost by evaporation during chilling and freezing. From a consumer's point of view, the gain or loss of water in meat is important for two reasons. First, as meat is sold by weight, the consumer pays more for any extraneous water. Secondly, excess water in meat may affect its palatability through changes in juiciness, texture and flavour. (Offer,1984).

Although there is an abundance of information on the water loss from cattle, sheep and pig carcasses after processing, only two investigations were found to be concerned with the actual water uptake resulting from spray washing. An increase in carcass weight of 0.25% after spray washing of beef carcasses was found by Longdill (1982), whereas Cain (1980) found a water uptake of 0.38% of the dry carcass weight of beef sides. The latter author

suggests that the weight increase caused by washing can be calculated by the following formula:

$$\text{Water uptake} = \frac{(0.52 - 0.028 \times t) \times Wt}{100}$$

Where t = time in minutes between washing and reweighing, and Wt=weight in kg before washing. While this equation relates carcass weight and time between washing and weighing to the amount of water taken up, no consideration was given to the effect of variations in washing time on the water uptake, as in Cain's experiments, where a constant washing time of 15 seconds was used.

The washing of rabbit carcasses is carried out by immersion in water followed by spray washing while poultry carcasses are washed by immersion in water only. The procedure is different for carcasses of cattle and sheep, which are washed by the spray method only.

The quantity of water gained by carcasses as a result of washing has not received much attention and has largely been ignored except for poultry. Regulations are in force in some countries regarding the washing of poultry, aimed mainly to protect the consumer from buying meat containing water in excessive quantities.

The U.S.D.A. regulations (Anon 1984b), state that poultry washing, chilling and draining parameters and procedures, shall be such that absorption and retention of water will be minimized. The amount of water gained by carcasses of poultry should not exceed 8.7% of the carcass weight up to four and a half lbs and 6.7% for carcasses more than four and a half lbs. Tests on at least ten birds shall be conducted daily by inspectors to assure compliance with these requirements.

In the 1970's a study was carried out by the European Community member states, in order to regulate the immersion chilling operation in poultry plants (Bolder, 1987). The outcome was that a counter flow system was chosen (E.C. directive 71/118) in which the hygienic status of the carcasses could be measured and the amount of extraneous water absorbed by the carcasses could be controlled. Three methods were chosen to estimate the amount of extraneous water.

By one of these methods, water taken up during the washing and chilling procedures is measured in the processing plant (plant control). This method is carried out by deducting the prewash weight of a poultry carcass from the weight of the same carcass after washing. This is a simple method by which it is possible to quickly assess if the process complies with regulations. The directive, gives details of two other physical and chemical methods which can be used for a more detailed assessment of the water uptake.

As long ago as 1955, Ayres (1955) suggested that "washing carcasses probably reduces the amount of contamination - even though it may only be a more uniform redistribution of the bacterial population from local areas where numbers may be high".

Water used for spray washing at a meat works must meet the standards laid down in "International Standards for Drinking Water" W.H.O. Geneva, 1971 (cited in Petersen 1979).

Emswiler et al, (1976), testing the effects of water containing chlorine at concentrations of 100,200 and 400 ppm, found a reduction of more than 95% in the total aerobic and psychrotrophic bacterial surface counts. The effectiveness of chlorinated water in reducing bacterial loads varies directly with the pressure at which it is applied and the temperature of the water (Kotula et al, (1974)).

Skelley et al, (1985) spraying pork carcasses with a 200 ppm sodium hypochlorite solution for 10 minutes, reduced the bacterial load by a log 1.53 per cm^2.

Kriaa et al, (1985) found that after washing of beef carcasses, 50% of the bacteria were retained on the carcass and postulated that the proportion of bacteria attached to the muscle tissue depends on the carcass and the microflora involved.

No specific bacteriological methods are designed for the evaluation of the bacterial status of rabbit meat. Methods used for other meat animals are usually designed to estimate the number of psychrotrophic bacteria, as well as the total number of viable aerobic bacteria, and to detect the presence of certain pathogenic bacteria. The total surface count and the number of psychrotrophs, are regarded as indicators of the spoilage potential of the meat tested, while the presence of pathogenic organisms is of public health significance.

As already mentioned, there is a lack of information on the amount of extraneous water taken up by rabbit carcasses during processing. This, stimulated the interest of the author to test the effect of length of washing time on the amount of water retained by rabbit carcasses. The main emphasis was on the washing method used during commercial rabbit meat production, with emphasis on the effect of the length of time of immersion on water uptake. In addition to the study of water uptake, an attempt was made to clarify the general effect of washing by immersion on the bacterial status of rabbit carcasses. The results of these experiments and their commercial implications will be discussed in this chapter.

MATERIALS AND METHODS

(1) Water Uptake

In order to investigate the water uptake, 32 domestic and one wild rabbit carcasses, and four hind legs of rabbits were used.

In experiments, "b" and "c", saturation point was considered to be reached at least when three sequential measurements of water uptake showed an unchanged result. The first experiment "a", which was regarded as a preliminary investigation, was carried out at the abattoir in Masterton with four groups of three rabbit carcasses each. Groups 1 and 2 were adult Angora rabbits, with carcass weights ranging from 1448-1716 g. Groups 3 and 4 were New Zealand Whites with carcass weights ranging from 803 g to 1091 g. The weight of each carcass was measured on a balance and recorded as soon as possible after processing. Carcasses in group 1 were simultaneously immersed for one minute in water. After immersion, the carcasses were blotted with absorbent paper to remove surface water and weighed approx. two hours later at the time of packaging. The same procedure was used for groups 2,3 and 4 except that these carcasses were immersed for two, three and four minutes respectively.

In the second experiment "b", the carcass of a wild rabbit weighing approx. 1000g was immersed in water for one minute and weighed after it had been shaken vigorously until no more water was dripping from the carcass. This procedure was repeated until no further increase in the weight of the carcass was recorded.

In the third experiment "c", four hind legs from domestic rabbits were treated as described in (b) above.

In the fourth experiment, "d", 15 rabbit carcasses, with a pH of approx. 6.0 (three to four hours after slaughter) were immersed in water for periods varying from one to 18 minutes.

In the fifth experiment, "e", five rabbit carcasses, with a pH of approx. 6.7 (30 minutes to one hour after slaughter), were immersed in water for periods varying from ten to 18 minutes.

(2) **Microbial Methods**

Bacteriological sampling of ten rabbit carcasses was carried out at the abattoir in Masterton.

An area of five cm^2 of the external surface of the right hind leg of each of the ten carcasses, was sampled before washing using sterile metal templates and sterile swabs. The template was positioned on the lateral surface of the right hind leg and cotton swab soaked in sterile tryptone water was then rubbed over the site. The same area was swabbed again with a dry, sterile cotton swab and both swabs were placed in a vial containing nine ml of tryptone water. The same procedure was carried out on the left hind leg of the carcasses after washing. The samples were transported to the laboratory on ice and after shaking, 0.1 ml of the medium was plated directly on the nutrient agar.

Four samples of water were taken in sterile ten ml bottles from tap water to the wash basins and four similar samples were taken from the effluent water from the washing tanks. The samples were transported to the laboratory on ice. After arrival each sample was shaken for approx. two minutes, and 0.1 ml from each sample was plated directly on nutrient agar. It was assumed that the bacteriological status of the tap water would be the same as the water entering the wash tank. After 48 hours incubation at 37 °C colonies on each plate were counted. If the colonies on the plate were numerous the plate was divided into quarters and the total count reached by multiplying the quarter counts by four.

It was estimated that approx. ten litres of water was entering the washing bath per minute.

RESULTS

(1) Water Uptake

The results obtained from the experiments on water uptake were as follows:

Experiment "a"

There was a wide variation in the degree of % water uptake ranging from 0.48 - 31.16% of the carcass weight (see table 5.1, page 80). In two cases (one Angora and one New Zealand White rabbit) the packed weight was found to be higher than the wet

weight. In three other cases the % water uptake by one Angora and two New Zealand White rabbit carcasses was very high, ranging from 13.33 to 31.16%.

Experiments "b" and "c"

It was found that after 23 one minute immersions of the carcass of a wild rabbit (experiment "b"), the water uptake of the carcass was 10.63%, which was close to the "saturation point" (10.70%), reached after 30 one minute immersions (see table 5.2, page 81). On the contrary (experiment "c"), the same water uptake (10.63%), was obtained by the four legs within only 14 minutes (see table 5.3, page 82). Saturation point (12.33%) was higher than that of the whole carcass and it was reached after 21 one minute immersions. Figure 5.1 (page 86), illustrates the increase in % water uptake by the carcass and the four hind legs at five-minute immersion intervals as well as the differences between them.

Experiments "d" and "e"

The results of experiment "d" on the % water uptake of 15 New Zealand White carcasses with pH-values of 6.00, are presented in table 5.4 (page 83), whereas table 5.5 (page 83), shows the results of experiment "e", water uptake of five New Zealand White carcasses with high pH (6.70). The % water uptake in experiment "d", (see Table 5.4, page 83), was ranging from 1.86% after one minute immersion, to 6.91% for 14 minutes immersion. From the data it can be noted that, on an individual basis, gross inconsistencies can be noted (smaller uptake is noted in some for longer immersions). However if we take the average uptake for the pairs of carcasses immersed for the same length of time, then we note an increasing tendency up to the eightth minute, after which a rather decreasing tendency is observed.

A statistical analysis of the data using the multiple regression method, gave the following equation:

$$Y = 1.41\ X_1 - 0.012\ X_2 + 39.13$$

where Y = water uptake in ml,

X_1 = immersion time in minutes and

X_2 = weight in Kgs.

However the probability that the coefficient of X_2 is equal to zero is very high and the coefficient of X_1 is only bordering significance at the 10% level. In the author's opinion such an experiment should be carried out on a much larger scale, which was beyond the available means.

In experiment "e" the % water uptake for ten to 18 minute immersions, ranged from 3.67-7.05. In this experiment the two highest % water uptake levels, 7.05% and 6.98%, were reached after 12 and 18 minute immersions while for the 14 and 16 minute immersions it was 4.87% and 6.33% respectively. The % water uptake of the two groups is illustrated in Figure 5.2 (page 87).

Statistical analysis of the % water uptake gained by the two groups of equal time of immersions (10-18 minutes) in experiments "d" and "e", showed that there is no significant difference between the low pH (6.00) and the high pH (6.70) group.

(2) Microbial standards

There was an approx. three times increase in the mean total aerobic counts on carcasses after washing (1.34×10^3 c.f.u./cm^2) (colony forming units) compared with prewash counts (4.20×10^2 c.f.u./cm^2) (see Table 5.6, page 84). However two samples had higher counts before than after washing.

An approx. 50 fold, increase in bacterial count was found in the effluent water from the washing tank (4.95×10^2 c.f.u/ml) as compared with the affluent water sample (0.10×10^2 c.f.u./ml) (see table 5.7, page 85).

Table 5.1
Water Uptake of rabbit carcasses after different periods of immersion
(Experiment "a")

Group 1 - Angora - Immersion 1 Minute				
Dry Weight (g)	Wet Weight (g)	Packing Weight (g)	Water Uptake (g)	Water Uptake %
1467	1469	1474	7	0.48
1705	1734	1722	17	1.00
1716	1746	1734	18	1.05
Group 2 - Angora - Immersion 2 Minutes				
Dry Weight (g)	Wet Weight (g)	Packing Weight (g)	Water Uptake (g)	Water Uptake %
1564	1764	1740	176	11.25
1457	2050	1911	454	31.16
1448	1653	1636	188	12.98
Group 3 - N. Z. White - Immersion 3 Minutes				
Dry Weight (g)	Wet Weight (g)	Packing Weight (g)	Water Uptake (g)	Water Uptake %
943	1083	1090	147	15.59
1087	1117	1104	17	1.56
901	948	915	14	1.55
Group 4 - N. Z. White - Immersion 4 minutes				
Dry Weight (g)	Wet Weight (g)	Packing Weight (g)	Water Uptake (g)	Water Uptake %
954	1014	986	32	3.35
803	973	910	107	13.33
1091	1114	1109	18	1.65

Table 5.2

Water Uptake by the carcass of a wild rabbit (Experiment "b")

	Dry Weight																
Number of one minute immersions	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Weight g	993.7	1000.4	1013.3	1015	1021.8	1028	1037.4	1035.2	1048.3	1050.8	1056.2	1061.4	1067.8	1071.8	1072	1070.7	
W.U.%		0.67	1.97	2.14	2.83	3.45	4.40	4.18	5.49	5.75	6.29	6.81	7.46	7.86	7.88	7.75	
Number of one minute immersions		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Weight g		1080.7	1083.7	1092.6	1085.3	1086.4	1088.2	1095.4	1099.3	1091.4	1092.9	1094.5	1096.2	1099.1	1100	1100	1100
W.U.%		8.76	9.06	9.95	9.22	9.33	9. 51	10.23	10.63	9.83	9.98	10.14	10.31	10.61	10.70	10.70	10.70

W.U.% : percentage water uptake.

"Saturation point" is considered when at least three measurements in sequence of the water uptake resulted in unchanged measurements.Table 5.2

Table 5.3

Water uptake by four hind legs from two domestic rabbits (4-5 hrs after killing) (Experiment "c")

No. of leg	Before immersion (g)	Duration of immersion (min.) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Weight (g) 53.16	54.94	55.46	55.88	56.30	56.67	56.96	57.55	57.86	58.07	58.30	58.58	58.78	58.85	58.95	59.18	59.35	59.58	59.78	59.78	59.78	59.78	59.78	59.78
	W.U.%	3.35	4.33	5.12	5.91	6.60	7.15	8.26	8.84	9.24	9.67	10.20	10.57	10.70	10.89	11.32	11.64	12.08	12.45	12.45	12.45	12.45	12.45	12.45
2	Weight (g) 52.00	53.30	53.70	54.40	54.87	55.13	55.38	55.67	56.18	56.32	56.43	56.80	57.05	57.20	57.23	57.38	57.48	57.50	57.55	57.62	57.63	57.63	57.63	57.63
	W.U.%	2.50	3.27	4.62	5.52	6.02	6.50	7.06	8.04	8.31	8.52	9.23	9.71	10.00	10.06	10.35	10.54	10.58	10.67	10.81	10.83	10.83	10.83	10.83
3	Weight (g) 55.87	57.06	57.54	58.25	59.11	59.33	59.69	60.07	60.69	60.79	61.02	61.39	61.60	62.05	62.46	62.46	62.84	63.67	63.18	63.70	63.75	63.89	63.89	63.89
	W.U.%	2.13	2.99	4.26	5.80	6.19	6.84	7.52	8.63	8.81	9.22	9.88	10.26	11.06	11.80	11.80	12.48	13.96	13.08	14.01	14.10	14.35	14.35	14.35
4	Weight (g) 62.52	63.48	64.15	64.80	65.37	65.39	65.94	66.51	66.81	67.18	67.48	67.80	67.98	68.37	68.83	68.86	69.12	69.36	69.67	69.94	69.82	69.82	69.82	69.82
	W.U.%	1.54	2.61	3.65	4.56	4.59	5.47	6.38	6.86	7.45	7.93	8.45	8.73	9.36	10.09	10.14	10.56	10.94	11.44	11.87	11.68	11.68	11.68	11.68
	Mean W.U.%	2.38	3.30	4.43	5.45	5.85	6.49	7.35	8.09	8.45	8.84	9.44	9.82	10.28	10.63	10.90	11.31	11.62	11.91	12.31	12.27	12.33	12.33	12.33

W.U.% : Percentage Water uptake
"Saturation point" : Is considered when at least three measuremetns in sequence of the water uptake resulted in unchanged measurements.

Table 5.4

Water uptake by 15 N.Z. White carcasses with low pH (6.00) (Experiment "d")

Duration of Immersion (min)	Dry Weight g	Wet Weight g	Water Uptake g	Water Uptake %	Mean % *
1	1019	1038	19	1.86	
2	969	1000	31	3.20	
4	810	848	38	4.69	
4	1060	1081	21	1.98	3.34
6	1077	1127	50	4.64	
6	871	904	33	3.79	4.22
8	1014	1062	48	4.73	
8	858	899	41	4.78	4.76
10	807	854	47	5.82	
10	1213	1249	36	2.97	4.40
12	780	822	42	5.38	
12	1237	1275	38	3.07	4.23
14	1115	1192	77	6.91	
16	1158	1197	39	3.37	
18	1093	1129	36	3.20	

* : For more than one immersions. (4,6,8,10 and 12 minutes).

Table 5.5

Water uptake by five N.Z. White carcasses with high pH (6.70) (Experiment "e")

Duration of Immersion (min)	Dry Weight g	Wet Weight g	Water Uptake g	Water Uptake %
10	1226	1271	45	3.67
12	979	1048	69	7.05
14	1767	1853	86	4.87
16	1296	1378	82	6.33
18	931	996	65	6.98

Table 5.6

Bacteriological results from swabbing ten carcasses before (right hind leg) and after (left hind leg) washing (incubation at 37°C)

	Counts/cm^2		
Carcass	Before Washing	After Washing	Difference
1	750	3744	+2944
2	171	2880	+2709
3	690	792	+ 102
4	210	1050	+ 840
5	6	1974	+1968
6	500	1132	+ 632
7	402	0	- 402
8	160	206	+ 46
9	1294	150	-1144
10	20	1420	+1400
Mean	420 or $4,20x10^2$	1335 or $1.34x10^3$	

Table 5.7

Bacteriological restults from four water samples taken before and after carcass washing

Counts/ml	
Tap Water (affluent)	Effluent Water From Tanks
0	1200
30	760
0	11
11	7
Mean 10.25 or 0.10×10^2	495 or 4.95×10^2
Total 41.0 or 0.41×10^2	1978 or 1.98×10^3

Figure 5.1

Illustration of the water uptake by the carcass of a wild rabbit (Experiment "b") and four rabbit hind legs (Experiment "c")

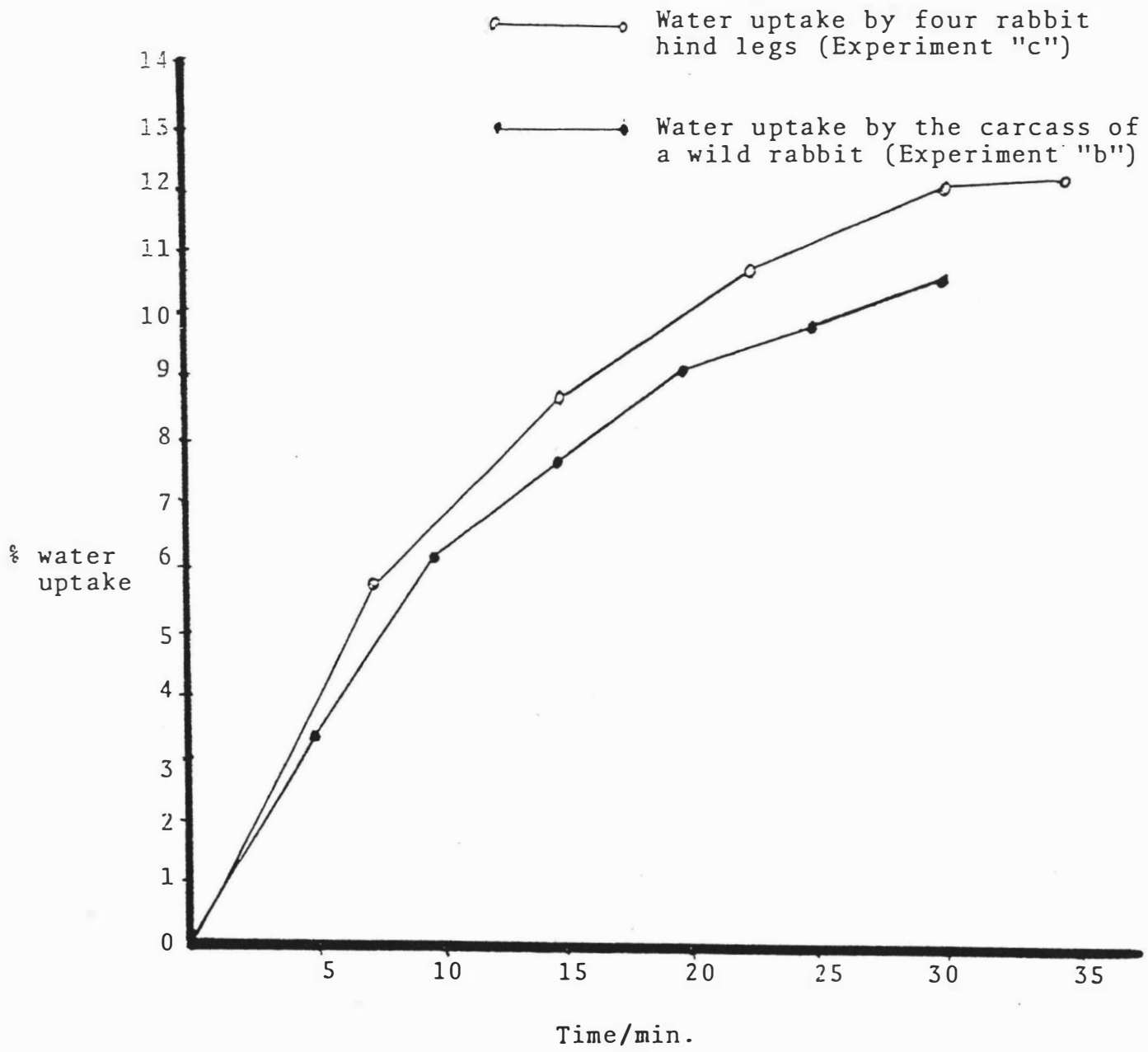
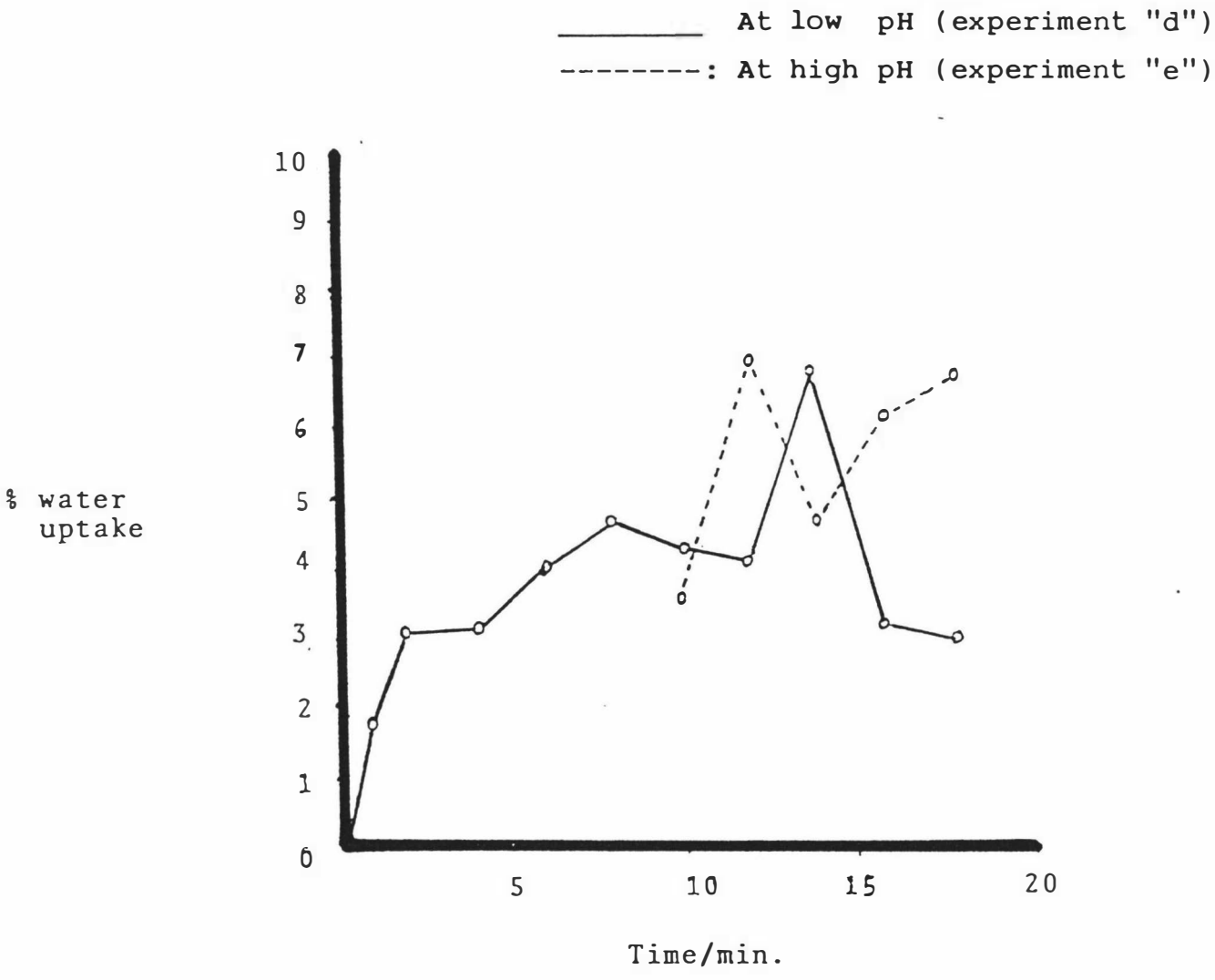


Figure 5.2

Water uptake by tame rabbits (experiments "d" and "e")



DISCUSSION

The two cases in experiment "a" showing higher packaging than wet weight, are presumably due to measurement errors. Similarly the three cases in the same experiment, which showed very high water uptake, may be due to water trapped in water pockets created in the carcasses during dressing and evisceration. The carcasses, as explained, were not shaken to remove trapped water but only blotted dry with absorbent paper to remove surface water. The above factors already mentioned may also explain the great variation observed (including inconsistency) in the water uptake generally.

The results of the water uptake in experiments "b" and "c" show that in experiment "b" the water uptake rate was, slower and the amount absorbed was lower compared to experiment "c". This can be attributed primarily to the larger surface of the legs in relation to their weight and secondly to the cut surface of the legs through which, absortion of water is easier, due to the abscence of a fascia. The inconsistency in % water uptake which appeared during the immersion of the wild rabbit in the water, was presumably due to lack of precision regarding the blotting technique. The water uptake by the wild rabbit carcass continued to increase for almost 30 minutes, finally exceeding 10%. Presumably the same phenomenon would have occurred in the carcasses of domestic rabbits if they had been immersed in water for longer than 18 minutes. However in practice carcasses are usually not washed for more than a few minutes.

Results from experiment "d" and "e" showed that the highest % of water uptake was gained by rabbit carcasses after 12 and 18 minutes immersions (7.05 and 6.98 respectively) and that the lighter carcasses gained relatively more water. This could be attributed to the relatively larger surface of the lighter carcass. The exceptionally high uptake rate of 6.91 % recorded in one sample in experiment "d", despite its relatively high

weight, was most probably due to water, trapped in water pockets created during dressing-evisceration.

In the above two experiments it was also found that rabbit carcasses with pH 6.00 and pH 6.70, show non-significant difference in their water uptake capacity. This finding is surprising, as it would be expected that carcasses with high pH, could take up more water than low pH carcasses, because of the higher water binding ability of high pH meat (Lawrie 1985). However, the pH difference between the two groups was probably too small to affect the water uptake and retention to a measurable degree. The water uptake and retention, associated with a comparatively short time of immersion may not be affected by the deep muscle pH but more by the superficial pH of the muscle, which was not measured.

No bacteriological standards have been established for rabbit meat in New Zealand. Those for beef and lamb carcasses vary from one processing plant to another, but general guidelines, in the form of so called recommended limits, suggest that at least 80% of the samples examined should not exceed a total aerobic count (T.A.C.) of $10^4/cm^2$ and no more than 20% should be between 10^4 to 10^6 (TAC/cm^2) (Anon 1979). For chilled meat, the recommendations are: 80% of the samples should not exceed $10^5/cm^2$ (TAC) for beef and mutton, while for samples taken shortly after dressing, no counts should be higher than 10^5 TAC/cm^2. If these levels are exceeded sampling from the same lot is repeated, and in cases where the bacterial count is found to be the same or higher than at the first sampling, the meat is either downgraded or condemned. (Anon 1979).

The number of samples, the frequency of sampling as well as the sampling sites for each kind of meat are usually determined by official recommendations. In case the meat is to be exported, regulations and suggestions of the importing country are always taken into consideration.

In two of the samples examined for surface contamination (No. 7 and 9, Table 5.6, page 84), gross inconsistencies can be spotted. For No. 7, it is obvious that some laboratory accident has happened. It would seem very strange indeed to obtain a sterile surface. For No. 9, either a switching of the before and after swabs has occured, or a much higher contamination of the left leg, compared to the right one, existed before immersion, due to bad handling.

Although the bacteriological results of the rabbit carcasses, produced at the Mastertom plant, fall within the recommended limits for lamb and beef and actually indicate a very high level of hygiene, the results of this study show that carcass washing, results mostly in an increase in the total number of surface bacteria. The three fold increase found in the mean total aerobic counts on carcasses after washing, compared with pre-wash counts, showed that the washing procedure affected negatively the surface bacterial counts of rabbit meat. This appears not to be in agreement with findings of Kriaa et al, 1985, who reported that spray washing of beef carcasses results in lower counts. However, our findings must be treated with caution, because the results can be affected by the rate of replacement of the water used for washing. Presumably by increasing the rate of water replacement in the washing bath, or by adding chlorine in the water, as it happens with poultry, and by moving the carcasses contrary to the water flow in the bath, or using spray washes, the picture of the bacterial counts could improve. This method was found to be effective for poultry carcass washing (Kakoyiannis pers. comm.) and it seems that the procedure at Masterton needs to be improved in this way in order to achieve a more favourable surface contamination picture after washing. The other solution-carcass trimming - is not applicable to rabbit carcasses because rabbit meat is generally sold in carcass form and any major trimming would therefore be obvious to the consumer. It is more likely that another alternative and less expensive solution, than the above mentioned, would be the combination of careful dressing and evisceration (avoiding

unnecessary handling of the carcasses) with minor trimming, aiming to remove visual contamination.

Under commercial rabbit meat production, washing should result in a water uptake not exceeding approx. 7% of the carcass weight for up to 18 minutes immersion (see table 5.5, page 83). This is the maximum acceptable level for poultry as already stated in the introduction of the present chapter (Anon 1984b). So in an effective control system the length of water immersion must be under control, in order to avoid excessive water uptake.

Finally, the results regarding bacterial counts, could probably be more precise if pre-and after-wash swabbings were carried out on the same leg in order to avoid differences in counts from surfaces distant to each other. However, the selection of samples from left and right leg was due to the limited surface of the rabbit leg.

CHAPTER SIX

THE pH OF RABBIT MEAT

INTRODUCTION

The term pH is defined as the negative logarithm of the hydrogen ion concentration (Barth, 1975). In the living animal, the pH of muscle is around neutral (7.00). After death the pH declines, resulting in ultimate values in most mammals of approx. 5.50 after rigor mortis has occurred. This fall is due to muscle glycogen being gradually depleted as it is used in the 'anaerobic glycolytic cycle', in which the glycogen is converted to lactic acid (cited in Graafhuis, 1986). The rate of glycolysis is linked directly to the rate of breakdown of adenosine triphosphate (ATP) in the muscle. This has been demonstrated by Bechtel (1986) in a reconstituted muscle glycolytic system, in which all enzymes, substrate and cofactors were mixed together at concentrations similar to those found in the muscle. If the enzyme ATP-ase was added to the model system, the glycolytic rate increased in direct proportion to the amount of ATP-ase added.

The rate of decline of pH is species characteristic. Pig muscle-pH, declines at rates of up to 0.64 units/hr at 37 °C while beef, sheep and rabbit muscle pH, drops between 0.27 to 0.40 units per hr (Hallund and Bendall, 1965).

The ultimate pH occurs when either all the glycogen has been used up, or sufficient lactic acid has been formed to drop the pH to around 5.50, thereby inactivating some of the enzymes involved in the glycolytic processes. At ambient temperatures the ultimate pH of beef is normally reached at about 36 hrs, of sheep and pigs around 24 hrs and of poultry 12 hrs after slaughter (Graafhuis, 1986).

The ultimate pH is affected by the glycogen level of the muscles at the time of slaughter. Inadequate feeding, stress associated with transport and yarding, the mixing of animals and pre-slaughter washing of animals, will cause a reduction of the glycogen level of the muscles at the time of slaughter. Thus in such animals the rate of pH decline after slaughter will be slower and the ultimate pH reached will be higher than normal, due to non-availability of glycogen for transformation into lactic acid. (Kenney and Tarrant 1988).

With respect to the effects of feeding on the ultimate pH, it has been shown by Bate and Bendall (1949) that,the fasting of rabbits for only 48-72 hrs, lowers the glycogen content of the psoas muscles of the animals sufficiently, to raise the ultimate pH from the normal values of 5.90 to 6.50 (Lawrie 1985).

Yarding condition may have a pronounced effect on muscle glycogen levels. Holding pigs overnight, in a well lit lairage has been associated with more dark, firm and dry meat, (DFD), the condition associated with high ultimate pH, as compared with holding them in a dark lairage (Gregory, 1985). The reason for this effect is that pigs kept in darkness, tend to settle down better, are less active, and therefore use less muscle glycogen, whereas pigs held in bright light tend to interact and exercise more.

Violent excitement in pigs immediately before slaughter, or the slow cooling of pork carcasses, can result in meat having a low ultimate pH (Lawrie, 1985). This meat known as "PSE" (pale, soft and exudative), is the result of a rapid decline in pH while the carcass temperature remains high. The combination of high temperature and rapid pH decline, cause a denaturation of sarcoplasmic and myofibrillar proteins leading to a reduction in the water holding capacity of the meat.

The stress produced by mixing different groups of young bulls, can cause a more than 50% reduction in muscle glycogen and

results in high ultimate pH values (Tarrant and Sherington (1980), Fjelkner and Ruderus (1983)). Gregory (1985), reports that DFD beef, occurs most commonly in bulls, particularly when they are held over night in lairage and allowed to interact with each other. He suggests, that in practice, the best solution to the DFD problem is to slaughter the animals either as soon as they arrive at the plant, or to hold them for at least 48 hrs to allow muscle glycogen repletion. Kenney and Tarrant (1988), found that in cattle, mounting behavior (intensive muscular exercise) can be a major factor in the depletion of muscle glycogen, thereby raising ultimate pH post oestrus in heifers.

Fjelkner and Ruderus (1983) found experimentally, that the mean decline in pH during the first few hours after slaughter, was the same for rested and stressed cattle, but that the pH variation between carcasses was much greater in the group of stressed animals, compared to those which had been rested.

DFD meat can also occur in lambs, but it is rare. A case has been reported from Australia, where flocks of lambs are gathered by drovers on horse back (cited in Gregory, 1985). Petersen (1983) found that pre-slaughter washing of lambs increases the pH value from 5.52 to 6.03, with some lambs showing values of up to 6.50 after being washed for five minutes.

The ultimate pH of meat is of paramount importance for meat quality because some of the most valued characteristics of meat are related to pH. The pH affects the color, tenderness, shelf life and juiciness of meat. (Graafhuis 1986).

Meat is broadly divided into red and white, depending mainly on the amount of myoglobin it contains. The concentration of muscle myoglobin varies between the major meat producing animal species, with beef having the highest concentration and therefore the darkest meat, and pork the lowest concentration and the lightest in colour (Seideman et al, (1984). Rabbit meat, together with fish and poultry, are considered white meats and contain

lower levels of myoglobin than sheep and beef. The colour of meat is determined by the relative proportion and distribution of myoglobin,oxymyoglobin and metmyoglobin. The red colour of fresh meat is due to oxymyoglobin. If meat contains 60% or more of myoglobin it will be dark purple in colour (DFD), but if the predominant pigment is metmyoglobin (oxydised myoglobin) the colour is brownish (Seideman et al, 1984).

The quality of meat can be affected, if prerigor red muscle is exposed to temperatures below approx. +12 °C. In this case actin and myosin contract, forming permanent actomyosin bonds (cold shortening), thereby reducing the tenderness of the meat (Lawrie 1985).

Shortening also occurs when pre-rigor muscle is held at temperatures above 20 °C (so-called heat shortening). (Bechtel 1986).

The effect of the pH on the keeping quality of meat is also important. As the growth rate of microorganisms is dependent on the pH of the substrate on which they grow, the pH of meat can affect the type of spoilage organism dominating the surface microflora and thereby the spoilage pattern. Meat with a high ultimate pH contains little or no glycogen. Microorganisms on the meat surface, will therefore attack aminoacids causing spoilage earlier than of meat with normal pH (Graafhuis, 1986). Because the breakdown products of aminoacid metabolism are foul smelling compounds like ammonia (NH_3) and hydrogen sulphide (H_2S) signs of spoilage of high pH meat are evident at cell densities of 10^6 - 10^7 per cm^2, whereas in meat with normal ultimate pH, spoilage does not occur until bacterial numbers on the surface reach $10^8/cm^2$. (Lawrie, 1985).

Vacuum packed meat with a high pH spoils faster than vacuum packed meat with normal pH, due to the growth of not only the facultative anaerobes such as Brochothrix thermosphacta and Enterobacter species, but also due to Enterobacter liquefaciens

(causing off odours) Alteromonas putrefaciens (green discoloration), and Yersinia enterocolytica (Graafhuis, 1986).

In the present study the pH decline and the ultimate pH of domestic and wild rabbit meat were investigated. The results are discussed in relation to rabbit meat quality.

MATERIALS AND METHODS

A Solomat electronic pH meter with a Broadly-James combination pH probe was used for the pH measurements. All measurements were made after inserting the probe approx. 1 cm into the meat. The pH values were read when the digital read out on the meter had stabilized (50 - 60 seconds). The pH meter was calibrated using buffer solutions of known pH values (colourkey buffer solution pH 4 $\pm$ 0.02 at 20°C, colourkey buffer solution pH 7 $\pm$ 0.02 at 20°C). The precision of the probe was found to be $\pm$ 0.02 of a pH unit.

Sixty eight New Zealand White rabbits and crosses with this breed were used in this study.

All pH measurements were taken of the semitendinosus (STM) and the psoas muscles (PM). These measurements with the exception of a third group of carcasses (see below) were carried out at ambient temperature.

The first part of the experiment was carried out at the abattoir where the pH values of 40 rabbits were measured. In a group of 12 animals the pH was measured only once, three hours after slaughter. The pH values of 25 other rabbits were measured at 20 minutes, two hours and 24 hours after slaughter.

The pH of three rabbit carcasses, condemned for yellow fat (2) and emaciation (1), was also measured. The pH values were measured at intervals of approx. 10 - 20 minutes during the first

hour after slaughter followed by intervals ranging from 30 minutes to 24 hours, until the third day after slaughter.

The second group of experiments were carried out in the laboratory, on 20 New Zealand White obtained from the Small Animal Unit, at Massey University, on two young adult rabbits of the same breed purchased from a farm and on six wild rabbits shot by the author.

In order to study the effect of the method of stunning on the decline of pH and ultimate pH of rabbit meat, the 20 animals were split into four groups of five. Animals in group I were stunned by dislocation of the neck, while animals in Group II were stunned by the non-penetrative percussive method and Groups III & IV by the penetrative percussive method. The pH of Group I was measured every 30 minutes for four hours, and at nine and 24 hours after the time of slaughter. Group II carcasses were measured every 30 minutes for four hours, and at nine, 13 and 24 hours after slaughter.

The pH measurements of the third group of carcasses were carried out as follows. The first pH value was measured at ambient temperature and the rest in a cold room operating at -1 ^{o}C. The pH values and meat temperatures were measured at the same time. A Koch digital thermometer was used for the temperature measurements.

The pH of the carcasses from group four was only measured once at a time ranging from one to three hours after slaughter.

The pH values of the two young adult domestic rabbits, were measured at 30 minutes, two, four, ten, 20 and 24 hours after slaughter.

The pH of four of the six wild rabbits, was measured only once, 24 hours after being shot and the pH of one was measured at five, seven, nine and 24 hours. In the sixth animal, which

died after considerable running and struggling after being shot, the pH was measured at three, five, seven and 24 hrs after death.

The effect of the stunning method on the rate of pH decline was evaluated by multiple regression analysis of the data. The parameters used were: a) X_1 for the stunning method, taking the values of 1 for neck dislocation, 2 for non-penetrative percussive method and 3 for penetrative percussive method and b) X_2 for time after slaughter in hours.

RESULTS

The results of the pH measurements are shown in Tables 6.1-6.10.

The study of 12 rabbits slaughtered by neck dislocation followed by decapitation at the abattoir, showed that the mean pH declined approx. 0.40 of a pH unit assuming a 7.00 start, over a three hour period, in both muscles (see table 6.1, page 99). At 20 min. the mean pH of the other 25 rabbits slaughtered at the abattoir was for (PM) and (STM) 6.86 and 6.97 respectively, at two hours after slaughter for the same muscles 6.61 and 6.74, while the ultimate pH was 5.72 and 5.76 respectively (see table 6.2, page 100).

In the three condemned rabbits the ultimate pH of PM and STM was between 6.12 and 6.50 and the rate of decline during the first four hours after slaughter, was approx.the same as for the other rabbits slaughtered in the abattoir. However, the rate of decline after four hours was very much slower. In one case (PM of rabbit No. 3) the pH value measured on the third day after slaughter was slightly higher (0.08 of a pH unit) than the one measured two and a half to four hours after slaughter. (see table 6.3, page 101).

Table 6.1

pH values of the muscles of 12 domestic rabbits three hours after stunning by the neck dislocation method at the abattoir

	Number of Rabbit												
	1	2	3	4	5	6	7	8	9	10	11	12	Mean
PM	6.67	6.59	6.65	6.59	6.58	6.77	6.41	6.67	6.29	6.48	6.73	6.61	6.59
STM	6.65	6.79	6.65	6.90	6.90	6.57	6.36	6.68	6.41	6.66	6.51	6.49	6.63

PM : Psoas muscle.

STM : Semitendinosus muscle.

Table 6.2

pH values of the muscles of 25 domestic abattoir rabbits stunned by the neck dislocation method

Time after slaughter	Muscle	Number of rabbit 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Mean
20 min	PM	6.54	7.02	7.02	6.84	7.10	6.76	7.00	6.80	6.99	6.78	7.14	6.94	7.55	6.90	6.97	6.91	6.84	7.30	6.49	6.57	6.62	6.73	6.62	6.68	6.42	6.86
	STM	6.93	6.92	6.46	7.00	7.11	7.05	7.57	7.00	7.53	6.80	7.71	6.70	6.66	6.84	7.11	7.11	6.80	6.78	7.11	6.81	6.71	6.39	6.68	6.74	6.75	6.97
2 hours	PM	6.47	6.87	6.80	6.97	6.64	6.80	6.63	6.77	6.73	6.59	6.86	6.88	6.84	6.73	6.48	6.43	6.29	6.31	6.58	6.32	6.55	6.17	6.40	6.59	6.50	6.61
	STM	7.52	6.43	6.99	7.14	7.07	7.11	6.86	6.98	6.78	6.94	6.98	6.96	6.80	6.82	6.81	6.75	6.37	6.36	6.62	6.37	6.41	6.05	6.63	6.33	6.32	6.74
24 hours	PM	5.70	5.86	5.84	5.42	5.45	5.51	5.67	5.77	5.70	5.71	6.07	6.01	5.47	5.45	5.81	5.45	5.84	5.84	5.82	5.76	5.95	5.56	5.83	5.71	5.73	5.72
	STM	5.67	5.86	5.77	5.43	5.50	5.55	5.78	5.84	5.77	5.83	6.13	6.05	5.54	5.50	5.88	5.54	5.78	5.76	5.93	5.90	6.22	5.58	5.77	5.70	5.80	5.76

PM : Psoas muscle.
STM : Semitendinosus muscle.

Table 6.3

pH values of the muscles of three rabbits condemned at the abattoir (No.1 and 2 with yellow fat, No. 3 emaciated)

No. of rabbit	Muscle	Time of measurement													
		0-2 (min)	20-37 (min)	40-47 (min)	1-2 (hrs)	2.5-4 (hrs)	4.5-6 (hrs)	6.5-7.5 (hrs)	8-9 (hrs)	9.5-10 (hrs)	10.5-20 (hrs)	21-30 (hrs)	31-40 (hrs)	41-50 (hrs)	51-60 (hrs)
1	PM	6.74	6.61*	n.d	6.22	6.47	6.47	6.35	n.d	6.21	6.32	6.34	6.32	n.d	6.40
	STM	6.80	7.12*	n.d	6.97	6.78	6.65	6.20	n.d	6.04	6.25	6.12	6.16	n.d	6.12
2	PM	n.d	6.77	6.90	6.49	6.39	n.d	6.30	n.d	6.23	6.38	6.22	6.26	6.32	n.d
	STM	n.d	6.80	7.06	6.92	6.56	n.d	6.18	n.d	6.04	6.31	6.16	6.15	6.24	n.d
3	PM	n.d	6.64	n.d	6.45	6.40	n.d	6.35	6.22	n.d	6.57	6.47	6.45	n.d	6.48
	STM	n.d	6.69	n.d	6.63	6.60	n.d	6.32	6.17	n.d	6.49	6.44	6.43	n.d	6.50

PM : Psoas muscle
STM : Semitendinosus muscle
* : Mean value of more than one measurements.
n.d : Not done.

In the five rabbits, stunned by dislocation of the neck in the laboratory, the mean ultimate pH of the STM and PM was 5.79 and 5.76 respectively. The decline of the mean pH was one pH unit (5.97 and 5.99 respectively) over the first three hours after slaughter, assuming a pH 7.00 at the time of slaughter. In one rabbit however (No 5 Table 6.4, page 103), the ultimate pH was reached within one hour after slaughter, compared to 24 hours for the other rabbits in the group. The ultimate pH of rabbits of this group was similar to those measured at the abattoir.

In the rabbits stunned by the non-penetrative method the mean ultimate pH measured was 6.06 for the STM and 6.13 for the PM muscles. The mean pH values of the two muscles reached 6.06 and 6.17 respectively, at approx. nine hours after slaughter, although the STM and PM muscles of a rabbit reached ultimate pH values 5.99 and 6.12 respectively as early as three to four hours after slaughter (see Table 6.5, page 104 and fig 6.1, page 110 and Fig 6.2, page 111). In the two young adult rabbits also stunned by the non-penetrative percussive method, the mean ultimate pH of the STM and PM was 6.04 and 6.03 respectively (see Table 6.6, page 105).

In the five rabbits stunned by the penetrative method in the laboratory and kept refrigerated (-1 °C) after the first measurement, the ultimate pH of the STM and PM were 5.91 and 5.85 respectively. The temperature of these same muscles was 12°C four hours and 4°C 24 hours after slaughter. (see Table 6.7, page 106). The rate of pH decline was fast and the lowest mean pH values (5.82 and 5.83 respectively) were reached at about two and a half hours after slaughter (see Fig 6.1, page 110 and Fig 6.2, page 111).

In the five rabbits of group IV, stunned by the penetrative method, the mean pH values of STM and PM measured one to three hours after slaughter were 6.60 (range 6.23-6.73) and 6.74 (range 6.52-6.88) respectively (see Table 6.8, page 107).

Table 6.4

pH values of the muscles of five domestic rabbits after stunning by the neck dislocation method

		Time after slaughter (hrs)									
Rabbit	Muscle	0.5	1	1.5	2	2.5	3	3.5	4	9	24
1	STM	6.26	6.28	6.24	6.11	6.19	6.26	6.24	6.25	6.26	5.75
2	"	6.19	6.14	6.37	6.06	6.02	5.96	6.01	6.04	5.94	5.95
3	"	6.13	6.33	5.85	5.74	5.70	5.80	5.73	5.75	5.76	5.78
4	"	6.78	6.58	6.34	6.15	6.16	6.10	6.14	6.10	5.82	5.73
5	"	5.92	5.68	5.71	5.72	5.86	5.74	5.84	5.76	5.76	5.75
Mean		6.26	6.20	6.10	5.96	5.99	5.97	5.99	5.98	5.91	5.79
1	PM	6.19	6.16	5.94	5.90	5.92	5.92	5.96	5.80	5.95	5.74
2	"	6.23	6.23	6.09	5.82	5.93	6.24	5.90	5.93	5.89	5.81
3	"	7.00	6.62	6.55	6.25	6.13	5.94	6.03	6.05	5.83	5.73
4	"	6.86	6.73	6.38	6.26	6.22	6.16	6.14	6.09	5.91	5.78
5	"	5.88	5.67	5.79	5.83	5.85	5.71	5.78	5.72	5.72	5.75
Mean		6.43	6.28	6.15	6.01	6.01	5.99	5.96	5.92	5.86	5.76

STM : Semitendinosus muscle
PM : Psoas muscle

Table 6.5

pH values of the muscles of five domestic rabbits after stunning by the non-penetrative percussive method

		Time after slaughter (hrs)										
Rabbit	Muscle	0.5	1	1.5	2	2.5	3	3.5	4	9	13	24
1	STM	6.87	6.77	6.83	6.58	6.27	6.21	6.17	6.08	5.94	5.78	5.78
2	"	6.97	6.91	6.62	6.33	6.36	6.23	6.20	6.13	6.18	6.16	6.23
3	"	6.98	6.84	6.51	6.40	6.45	6.38	6.38	6.21	6.25	6.21	6.25
4	"	6.92	6.57	6.64	6.59	6.27	6.21	6.11	6.16	6.04	6.19	6.10
5	"	6.76	6.69	6.24	6.16	6.12	5.99	6.01	5.91	5.90	6.08	5.92
Mean		6.90	6.76	6.57	6.41	6.29	6.20	6.17	6.10	6.06	6.08	6.06
1	PM	6.55	6.64	6.57	6.59	6.43	6.46	6.15	6.07	5.73	5.81	5.74
2	"	6.87	6.74	6.77	6.70	6.61	6.56	6.46	6.38	6.24	6.15	6.13
3	"	6.62	6.77	6.66	6.59	6.40	6.38	6.42	6.41	6.40	6.40	6.41
4	"	6.88	6.82	6.70	6.52	6.50	6.49	6.42	6.31	6.30	6.25	6.16
5	"	6.59	6.57	6.22	6.19	6.18	6.15	6.12	6.16	6.19	6.18	6.22
Mean		6.70	6.71	6.58	6.52	6.42	6.41	6.31	6.27	6.17	6.16	6.13

STM : Semitendinosus muscle
PM : Psoas muscle

Table 6.6

pH values of the muscles of two domestic rabbits after stunning by the non-penetrative percussive method

		Time after slaughter (hrs)						
No.	Muscle	0.5	2	4	6	10	20	24
1	PM	6.60	5.93	5.90	5.90	5.92	6.00	6.01
1	STM	6.96	5.97	5.91	5.97	5.88	5.95	5.92
2	PM	6.86	6.21	6.14	6.08	6.08	6.09	6.04
2	STM	6.64	6.12	6.15	6.22	6.22	6.19	6.15
Mean	PM	6.73	6.07	6.02	5.99	6.00	6.05	6.03
	STM	6.80	6.05	6.03	6.10	6.05	6.07	6.04

PM : Psoas muscle
STM : Semitendinosus muscle

Table 6.7

pH values of the muscles of five domestic rabbits storaged at -1 °C after the first measurement after stunning by the penetrative percussive method
Mean carcass temperature at four hrs = + 12 °C and at 24 hrs = + 4 °C

No.	Muscle	0.5	1	1.5	2	2.5	3	3.5	4	9	13	24
1	STM	6.32	6.36	6.13	5.92	5.75	5.78	5.77	5.82	5.79	5.79	5.78
2	"	6.57	6.38	6.12	6.00	5.91	5.88	5.85	5.89	5.83	5.80	5.82
3	"	6.48	6.50	6.26	6.08	5.92	5.95	5.93	5.92	5.90	5.94	5.93
4	"	6.27	6.18	5.86	5.71	5.72	5.79	5.80	5.86	5.97	5.96	5.96
5	"	6.36	6.16	5.88	5.72	5.79	5.80	5.87	5.88	5.98	6.00	6.07
Mean		6.40	6.32	6.05	5.89	5.82	5.84	5.84	5.87	5.89	5.90	5.91
1	PM	6.18	5.93	5.94	5.80	5.79	5.82	5.79	5.90	5.79	5.80	5.77
2	"	6.54	6.31	6.06	5.78	5.82	5.84	5.86	5.91	5.84	5.83	5.82
3	"	6.54	6.52	6.27	6.10	5.99	6.00	6.04	5.95	5.91	5.98	5.93
4	"	6.12	6.06	5.78	5.73	5.73	5.76	5.83	5.79	5.82	5.79	5.83
5	"	6.38	6.13	5.86	5.88	5.82	5.84	5.94	5.89	5.97	5.97	5.89
Mean		6.35	6.19	5.98	5.86	5.83	5.85	5.89	5.89	5.87	5.87	5.85

STM : Semitendinosus muscle
PM : Psoas muscle

Table 6.8

Ph values of the muscles of five domestic rabbits one to three hours after stunning by the penetrative percussive method

No.	Semitendinosus	Psoas
1	6.73	6.84
2	6.68	6.70
3	6.69	6.88
4	6.68	6.74
5	6.23	6.52
Mean	6.60	6.74

Table 6.9

pH values of the muscles of four wild rabbits 24 hrs post-mortem

No. of rabbit	No. of measurement	PM	Mean PM	STM	Mean STM
1	1	5.76	5.79	5.75	5.78
	2	5.65		5.76	
	3	5.96		5.84	
2	1	5.69	5.73	5.80	5.78
	2	5.74		5.84	
	3	5.76		5.71	
3	1	5.73	5.74	5.81	5.77
	2	5.74		5.80	
	3	5.76		5.70	
4	1	5.77	5.76	5.94	5.95
	2	5.76		5.96	
	3	5.76		5.96	
Mean			5.76		5.82

Table 6.10

Muscle pH of two wild rabbits

No. of rabbit	Muscle	Time after killing (hrs)				
		3	5	7	9	24
1	PM	n.d	5.67	6.72	6.04	5.77
	STM	n.d	5.75	5.86	6.03	5.84
2*	PM	6.06	6.04	5.96	n.d	5.95
	STM	6.22	6.03	6.01	n.d	6.02

PM : Psoas muscle
STM: Semitendinosus muscle
* : Shot while running
n.d: Not done (measurements were not taken)

Figure 6.1
Decline in pH of Semitendinosus muscles of groups of rabbits, five per group, stunned by three different methods.

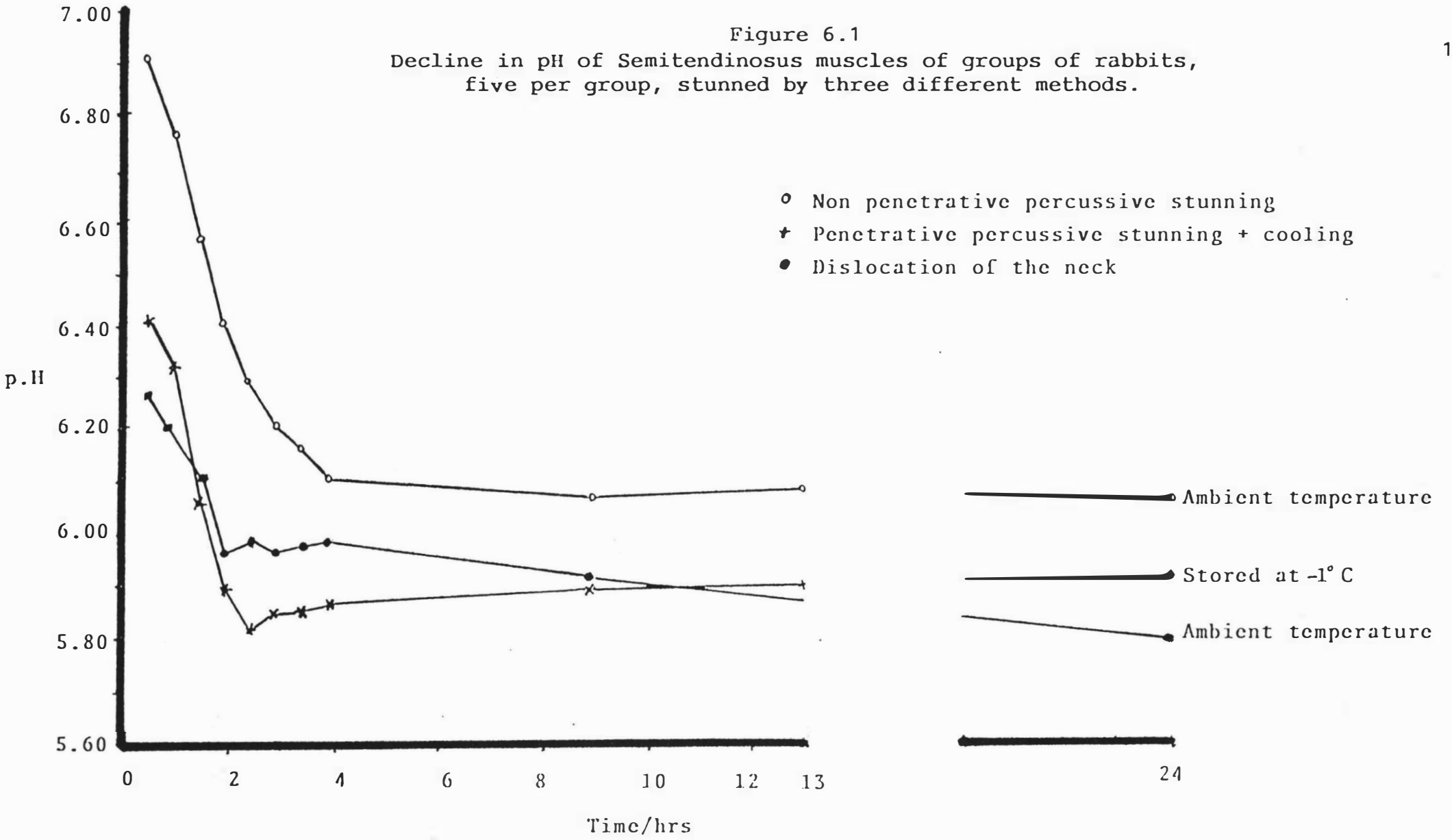
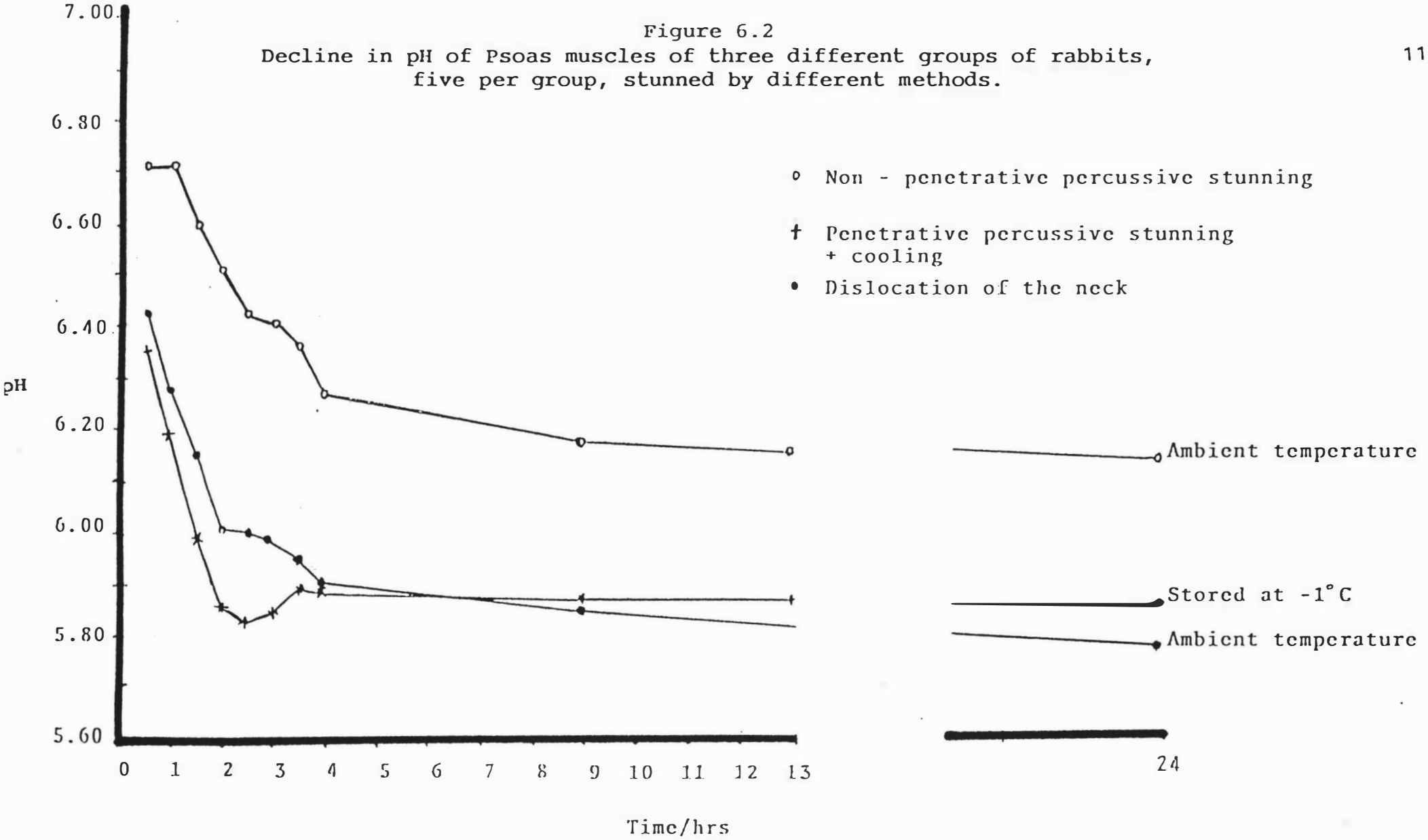


Figure 6.2
Decline in pH of Psoas muscles of three different groups of rabbits, five per group, stunned by different methods.



In the four wild rabbits the mean ultimate pH of the STM and PM was 5.82 (range 5.70-5.96) and 5.76 (range 5.65-5.96) respectively (see Table 6.9, page 108). These figures are similar to those obtained from the commercial rabbits at the abattoir. The wild rabbit which died after considerable struggling showed higher ultimate pH values (STM 6.02 and PM 5.95) than the rabbit that died instantly (STM 5.84, PM 5.77) (see Table 6.10, page 109). The pH decline of the former rabbit was also slower than of the latter.

DISCUSSION

The data presented show that with two exceptions, the farmed, laboratory and wild rabbits killed under normal conditions without pre-slaughter stress, showed similar ultimate pH values. The two exceptions were the group of five rabbits (see table 6.5, page 104) and the two young adult farmed rabbits (see table 6.6, page 105), all stunned by the non-penetrative method, which had ultimate pH values slightly higher than 6.00, for reasons which remain unexplained. Generally, with the exceptions already mentioned the ultimate pH values of the rabbits as it appears from the present study are about 5.80 (range approx. 0.40 of a unit) which is higher compared to other meat producing animals (5.30-5.50) (Graafhuis 1986). However it is similar to that of the white muscle (breast) of the chicken for which the pH is 5.80, but lower than that of the red (leg) muscle of the same birds which is about 6.40 (cited in Newton and Gill 1980).

This study showed that, as in other meat producing animals, pre-slaughter stress can affect the ultimate pH of muscles. The three diseased rabbits at the abattoir and the wild rabbit struggling prior to death after having been shot appear to have had depleted muscle glycogen reserves resulting in carcasses with high ultimate-pH values.

The ultimate pH of the two groups of rabbits stunned by the dislocation method at the abattoir and in the laboratory were similar. However, there was a difference regarding the rate of pH decline between the two groups stunned by this method. In the group which was stunned by an experienced person at the abattoir, the rate, as already stated previously, was slow because nearly all the animals did not show any movements after neck dislocation. Contrary to this, animals stunned by the same method in the laboratory by an inexperienced person, showed vigorous and longer lasting body movements, which most probably was the reason which increased the rate of pH decline. Similarly rabbits stunned by the penetrative method had fast rate of pH decline because they showed vigorous and longer lasting body movements compared to the non-penetrative method. For the last one, the rate of pH decline was slow and the ultimate pH high, something which remains unexplained as has been already stated.

From the analysis presented already, it is clear that the rate of pH decline varies considerably between the different groups of animals, but whether the stunning method has any effect on the pH decline rate, has been analysed and the results of the analysis shows that it does not.

To examine this effect multiple regression analysis was used. The equations derived from the analysis are the folllowing:

For the STM

$$Y_1 = 6.23 - 0.016\ X_1 - 0.016\ X_2 \qquad \text{Eq. (1)}$$

For the PM

$$Y_2 = 6.30 - 0.04\ X_1 - 0.017\ X_2 \qquad \text{Eq. (2)}$$

where

Y_1 and Y_2 = Estimated pH values of STM and PM respectively.

X_1 = Stunning method taking the values of

1: for neck dislocation

2: for the non-penetrative percussive method

3: for the penetrative percussive method

X_2 = time after slaughter in hrs.

The calculation of Student's t-value for the coefficients of X_1 gave the following values:

Eq. (1): t = -0.27148
Eq. (2): t = -0.69203

These values are well below the critical values of significance ($|2.052|$ for 27 d.f.) for ($p < 0.05$), which means that it cannot be excluded that the coefficients may actually be equal to zero, which would mean that the parameters (stunning methods) do not have any effect on the value of the dependent variable (pH).

The same statistic calculated for the coefficients of X_2 (time after slaughter), gave the following values:

Eq. (1) t = -2.18701
Eq. (2) t = -2.32025

These values are significant at the 0.05 and 0.025 levels of significance respectively. This conclusion is in line with the well established fact that time after slaughter affects the pH decline.

The fact that, the concurrent analysis of both stunning methods and time, has confirmed the well established fact of the effect of time on the pH decline as significant and the stunning method as insignificant, strengthens the conclusion that the stunning methods compared here has no effect on the rate of pH decline after slaughter.

However Mc Laughlin (1971) comparing the rate of glycolysis between pigs stunned with a captive bolt which penetrated the brain, to pigs bled without stunning found that the former struggled violently and showed more rapid glycolysis than the latter.

In the present study an attempt was made to investigate the effect of temperature on the rate of pH decline. Shorthose (1978), postulates that the rate of glycolysis is affected by the cooling rate of the muscles. In the present study the effect of the low temperature on the pH decline at two and four hours after slaughter was negligible and due to other difficulties it was not persued further.

Bendall (1978), investigating the effect of low temperatures on the rate of pH fall in four major muscles of beef, found that the time taken to reach a pH value of 6.00 from an initial value of about 7.10, varied between 8 and 16 hours. Apart from the delaying effect of low temperature on the rate of pH decline, he postulated that the variability was due to different rates of cooling between muscles in the same animal. The same author also noticed that the variability of the rate of pH fall was about two fold higher in the pH range of 7.00 - 6.70 than in the lower range of 6.60 -5.80. Bendall (1978), suggested that the variability recorded was likely to be due to varying levels of intracellular free Ca^{++} ions exerting a stimulating effect on the actomyocin ATP - ase, which regulates the ATP turnover, and thereby the rate of pH decline.

In summary, the findings presented in this chapter showed ultimate pH values, higher than those of other species of animals, with the exception of the red muscles of chicken. It was also found that rabbit carcasses with serious defects, showed comparatively higher ultimate pH values (up to 6.50). Multiple regression analysis showed that the rate of pH decline is not affected by the stunning methods studied here. This rate is extremely fast the first two to three hours after slaughter, leading to almost ultimate pH values at about this time.

CHAPTER SEVEN

PATHOLOGICAL LESIONS OF THE CARCASSES AND VISCERA OF RABBITS

INTRODUCTION

The ante and post mortem inspection of stock and carcasses carried out at the meat works are the most important aspects of meat hygiene. The purposes of post mortem inspection are: first, to segregate and/or identify diseased or defective animals; second, to prevent cruelty to the animals and finally, to diagnose exotic or infectious diseases dangerous for the animal population of the country.

The post-mortem inspection of meat is carried out after dressing is completed. Wholesomeness and safety of the meat are the main aims of the procedure. This means that any product containing endogenous or exogenous infectious agents, or other defects rendering the product unwholesome, must not reach the market (Petersen 1979).

The post mortem inspection procedures vary from country to country but are generally based on the principles that the presence of disease in carcasses can be seen and palpated and that lymphnodes reflect the health status of the animals. While inspection procedures based on these principles will identify many diseases and defects, some of the most serious conditions of considerable public health significance (yersiniosis, campylobacteriosis) go undetected through the inspection system.

Post mortem inspection of rabbit carcasses does not appear to have received the same attention as inspection of the major meat producing animals and is not generally incorporated in meat inspection protocols.

Meat inspection of rabbits at the Masterton rabbit abattoir, was carried out by "The inspector" of "Doe bank", by careful visual examination and palpation of the liver, followed by visual examination of the carcass. The 'inspector' paid special attention to the presence of abnormal colour and lesions on the carcass, carcass conformation, as well as the presence of any liver lesions.

Common Diseases of Rabbits Detected at Post Morten Inspection

(a) Hepatic coccidiosis: this disease will be described in detail in Chapters Eight and Nine.

(b) Contagious catarrh (snuffles): Contagious catarrh or snuffles, is very common in rabbits. It is generally caused by Pasteurella multocida, but other bacteria including Staphylococcus spp., Bordetella bronchiseptica and Streptococcus spp. may also be involved. Pneumonia is the common feature of the disease with the anterior lobes of the lungs mostly affected. Pleurisy, pericarditis and acute tracheitis may also be present (Wilson, 1985).

A large scale microbiological investigation of almost four thousand lungs, from 8-10 week old rabbits slaughtered at several abattoirs in the U.S.A., revealed a 20% prevalence of Pasteurella multocida infection. Some of the lungs presented atelectasis, consolidation or abscesses (Flatt and Dungworth, 1971).

(c) Cysticercosis (Cysticercus pisiformis): Cysticercosis in rabbits is manifested by small cysts approx. 5-10mm in diameter in the abdominal cavity of infected animals. The

cysts represent the intermediate stage of the tapeworm Taenia pisiformis. The final host is the dog in which the 2 mm long tapeworm inhabits the small intestine. At post mortem inspection, depending on the number as well as the size of the lesions, the whole carcass, or the affected organs only, are rejected (Wilson, 1985). Cysticercosis also occurs in the musculature of cattle (C. bovis), sheep (C. ovis) and pigs (C. cellulosae).

(d) Coenuriasis is a parasitic disease of the rabbit, manifested by the presence of cysts up to 5 cm in diameter in the intermuscular and subcutaneous tissue of the jaw. The cysts, called Coenurus serialis, are the intermediate stage of the tapeworm Multiceps serialis, inhabiting in the small intestine of the dog. At post mortem inspection,the affected part may be removed and the remainder passed for food if only a few cysts are present,but if the cysts are numerous,the carcass should be condemned (Gracey, 1986).

(e) Staphylococcosis: Staphylococcal disease in rabbits is manifested as pneumonia, septicaemia, osteomyelitis, pododermitis, subcutaneous abscesses, exudative dermatitis, purulent rhinitis and conjunctivitis in the newborn and abscesses of the mammary gland. The bacteria may however, be present in the flora of the upper respiratory tract, and the skin without causing disease; (Okerman et al, 1984).

Staphylococcal abscesses and skin lesions are common in most animals, including lambs (Fuente and Suares, 1985), pigs (Shazados, 1985), goats and cattle (Menes et al 1984). In Spain, Menes et al, (1984), isolated a total of 71 strains of Gram positive, catalase positive cocci from 112 abscesses found during post mortem inspection of slaughtered animals (sheep, cattle, pigs and goats), and in a large survey, Snyder et al, (1976), found that during a three year period of investigation, 7.6% of the necropsied rabbits had abscesses caused by Staphylococci.

Staphylococcal lesions are not confined to domestic rabbits but are also commonly found in laboratory animals, including rabbits, even when these are kept under specific pathogen free (SPF) conditions. Blackmore and Francis (1970) isolated Staphylococci from 50% of SPF rabbits and found by phage typing, that the most likely source of infection was humans handling the rabbits.

Fuente and Suarez (1985), found in lambs up to four months of age an "abscess disease" with a mortality rate of 65.7% due to Staphylococcus aureus, whereas abscesses in pigs, according to Shazados (1985), are mostly associated with Actinomyces pyogenes and beta haemolytic Streptococci rather than with Staphylococci.

Other conditions, like gastroenteritis, yersiniosis, myxomatosis, nephritis, rabbit syphilis, and tuberculosis are rare findings at post mortem inspection (Wilson, 1985).

The intention of this study was to investigate any lesions found at post mortem inspection of rabbits at the Masterton abattoir.

MATERIALS AND METHODS

The material for this investigation was collected from approx. 250 rabbits killed during four visits to the abattoir in Masterton. After carcasses and offal had been inspected by the "inspector", they were re-examined visually and by palpation by the author. Lesions were transported to the laboratory in plastic bags and kept in a refrigerator overnight until further investigation the following day.

In addition, a female Angora doe with a swelling on the right jaw was submitted to the author by a breeder. After the animal had been killed, the lower jaw with the attached lesion

was cut into 3-4mm thick sections with an electric saw. These sections, were decalcified in R.D.O. solution (Du Page Kinetic Laboratory), for three to four days and subsequently wax embedded sections were cut and stained by hematoxylin and eosin (H+E) for microscopical examination.

Smears of the contents from all lesions were stained by the Gram method and cultures were also carried out aerobically at 37°C for 24 hrs, on blood and McConkey agar. Further investigations were carried out, using catalase test (Cruickshank et al, 1975) as well as slide coagulase and DNA-ase tests (Devriese and Hajek 1980).

The liver lesions collected from the abattoir were fixed in 10% formalin for at least three days and stained by H + E and examined microscopically, as explained in greater detail in Chapter Eight.

RESULTS

Of approx. 250 rabbits examined at the abattoir, only two carcasses, each with one abscess, and 57 livers with lesions resembling those of hepatic coccidiosis, were found.

One of the abscesses was located on the ventral aspect of the front leg, while the other was in the lumbar area. Both lesions were ovoid in shape, approx. 2x3 cm, were soft in consistency and the content was thick and whitish in colour. Examination of Gram stained smears, revealed Gram positive cocci. Bacteriological investigation of cultures from both abscesses, revealed that the organisms isolated were catalase, coagulase and DNA-ase positive indicating that the organisms were strains of Staphylococcus aureus.

The lesion found in the Angora rabbit, involved the right angle of the lower jaw, was hard in consistency and approx. five cm in diameter (see Fig. 7.1, page 121).

After the lesion was cut open, content similar to that from the two abscesses described earlier drained out. It was also noticed that this abscess was divided into irregular chambers by trabeculae of bone. The methods used for bacteriological investigation of the content of this abscess were the same as for the other two abscesses and the results were identical. The histological examination of the sections taken from this abscess, showed areas of necrosis and fibrosis, as well as a massive infiltration of inflammatory cells with a predominance of neutrophils and macrophages. This lesion was diagnosed as a chronic staphylococcal osteomyelitis.

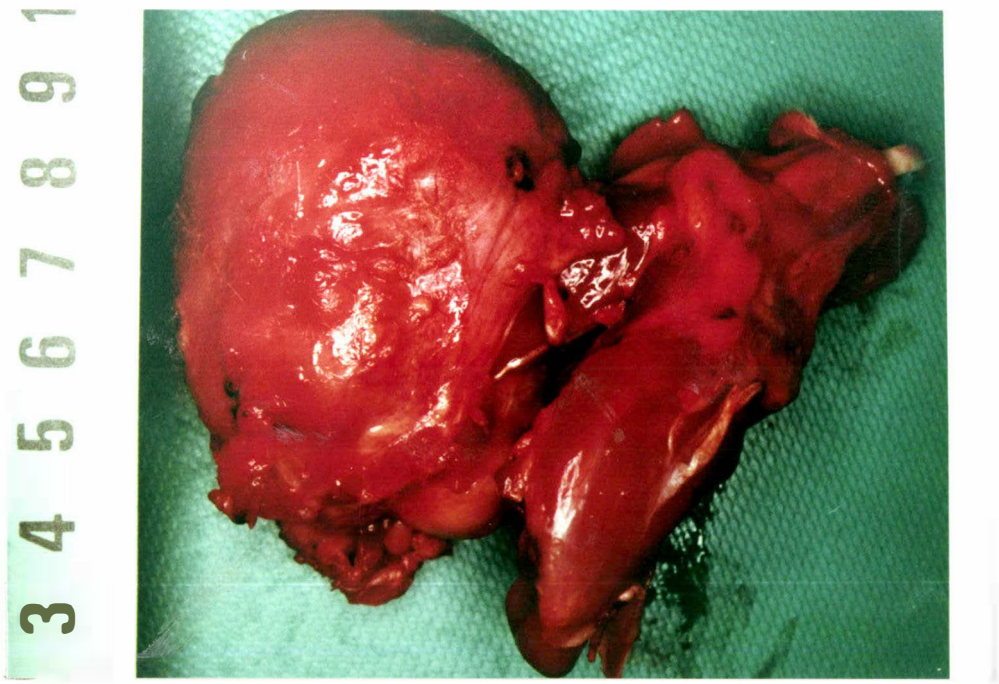


Figure 7.1 -Abscess involving the mandible of an Angora rabbit- Side numbers indicate centimeters

All the lesions found in 57 livers (see table 8.2, page 133) from commercial rabbits at the abattoir, were classified as chronic lesions of hepatic coccidiosis. (See Chapter Eight).

None of the laboratory rabbits examined showed any macroscopic lesions.

DISCUSSION

The abscesses observed in rabbits at the abattoir most likely originated from traumatic skin injuries, associated with fighting, protruding wires in cages, wood splinters and other sharp or pointed parts of the cages. Infection of such wounds by Staphylococci or other bacteria is common.

In most cases abscesses in rabbits are located in the lumbar area or on the hind and front legs, indicating that they are the results of fighting. Rabbits, like other animals, at an age of approx. six to eight weeks, are trying to establish a hierarchy order within the colony. Especially the males become aggressive and often spend considerable time running after other males biting them, usually in the lumbar area. As soon as this fighting starts, the rabbits must either be slaughtered or if of breeding stock, be confined to individual cages, otherwise this situation may lead to considerable losses (personal observation).

The staphylococcal osteomyelitic abscess, affecting the lower jaw of an Angora rabbit, was probably caused by the microorganisms gaining entrance through a tooth socket. However the public health significance of the Staphylococci originating from animals is limited, because probably less than six percent of Staphylococci of animal origin are enterotoxigenic (Kato et al,1978). Such abscesses may be removed, but carcasses are inevitably aesthetically affected. Large or numerous abscesses may lead to condemnation of the whole or part of the carcass.

Based on the macroscopic lesions resembling hepatic coccidiosis, observed in 57 out of 250 inspected carcasses, it can be concluded, that hepatic coccidiosis is a problem affecting approx. 23% of slaughtered rabbits.

can be concluded, that hepatic coccidiosis is a problem affecting approx. 23% of slaughtered rabbits.

Regarding the most important lesions in cattle, it was reported that in the meat export works in New Zealand, for the slaughter period of 1986-87, cysticercosis, tuberculosis and septicaemia counted for less than 0.1%, and less than 0.04% of these carcasses were condemned (cited in Blackmore 1988). For sheep, the same author records a prevalence for arthritis 1.68%, for pleurisy 24.31% and for pyogenic lesions 1.09%, which lesions led to 0.07, 0.17% and 0.38% condemnations respectively.

Lesions in rabbit carcasses are a greater problem than in the carcasses of the large meat animals, because serious trimming of a small rabbit carcass may result in a non-marketable product, or in a product of lower price.

CHAPTER EIGHT

ACCURACY OF INSPECTION PROCEDURES IN RELATION TO HEPATIC COCCIDIOSIS

INTRODUCTION

Hepatic coccidiosis is a disease of the liver of rabbits, which occurs after ingestion of the sporulated oocysts of Eimeria stiedae resulting in either clinically inapparent infection, or overt disease, which may result in death. In the latter case the affected animals often show signs of anorexia, a rough coat, loss of weight, fever and meteorism. Various stages of E. stiedae develop in the biliary system, resulting in macroscopic small, yellowish white nodules, or cysts throughout the parenchyma of the liver. It is considered that such lesions are almost pathognomonic (cited by Anon, 1986). Further information on the pathogenesis and epidemiology of the disease will be discussed in Chapter Nine.

Regulatory meat hygiene aims to ensure the production of wholesome meat, by procedures, such as ante mortem inspection of the live animals and post mortem inspections of carcasses, and a general inspection of plant hygiene. Ante mortem inspection is generally based on the inspection of individual animals. In such circumstances, the absence of any individual clinical history, makes the likelihood of detecting clinical disease much less than with a conventional clinical examination (Blackmore, 1988). The accuracy and precision of post mortem meat inspection may be affected by the speed at which inspection procedures are carried out, the limitations of visual examination and of palpation of the carcass and viscera and the incision of certain specified

lymphnodes and tissues. The inspection of general standards of hygiene in the plant should lead to the prevention of gross contamination of carcasses and meat products, during the production process.

At present, post mortem inspection is usually regarded as the most important component of the inspection process. For this procedure to be critically evaluated, the following factors need to be known.

(a) The precision (repeatability) of the procedure.

(b) The sensitivity (ability to detect diseased animals) and specificity (ability to detect non-diseased animals) of the procedure.

(c) The validity (predictive value) of the final results, or in other words, what is the percentage of the condemned carcasses that were not diseased and what is the proportion of the passed carcasses that were diseased?

Although sensitivity and specificity are innate attributes of the test and do not change with prevalence, the predictive value fluctuates according to the prevalence of the disease in the population. The predictive value positive (PV+) shows how many animals condemned at post mortem inspection were, in fact, diseased. This feature is of major importance from the farmer's point of view, because, in case its value is less than 100%, it would show that a proportion of the condemned animals would be falsely condemned. The predictive value negative, (PV-), is of public health concern, because it gives a measure of the proportion of diseased animals, which were passed as fit for human consumption.

To determine the accuracy of a test, a benchmark has to be chosen to which the test under investigation can be compared. If, for example, one wishes to investigate the accuracy of inspection

for tuberculosis, then all the lymphnodes from carcasses condemned for tuberculosis should be cultured. It must also be borne in mind that the results from such cultural techniques are not 100% accurate. In other diseases, such as infestation with Cysticercus bovis, which is identified by the presence of macroscopic "lesions" (the cysts), results from meat inspection procedures can be compared with more meticulous dissection techniques, e.g. by cutting the muscles of the carcass into thin slices.

Some parasitic lesions, e.g. young sarcocysts, may be too small to be observed with the naked eye. In such circumstances, the results of detection of Sarcocystis by gross examination of carcasses can be compared with the results of microscopic examinations of muscle. It was decided to use a similar approach as the last described, to investigate the accuracy of the inspection of hepatic coccidiosis in rabbits.

Histological features associated with hepatic coccidiosis, include the presence of all stages of the parasite in the epithelium of the bile ducts, cellular infiltration, including eosinophils, plasma cells, lymphocytes and neutrophils and, peribiliary fibrosis (Davies et al, 1963). Although, apart from the presence of parasites, these changes are not pathognomonic, it was believed they would provide reasonable criteria on which the accuracy of the diagnosis of hepatic coccidiosis by the detection of gross lesions could be based.

Although the importance of hepatic coccidiosis to the economy of the rabbit meat production in New Zealand is relatively trivial, it was decided to carry out the present study because hepatic coccidiosis was regarded as a suitable model for the study of the accuracy of other meat inspection procedures. Furthermore, such a study could be carried out with a minimum of expense and with relative ease.

MATERIALS AND METHODS

A total of 201 livers were examined both macroscopically and by histological methods. The livers originated from rabbits from three sources; 186 from the abattoir at Masterton (8-14 weeks of age), ten from the Small Animals Unit at Massey University (8-10 weeks of age) and five wild rabbits shot by the author on a private property in the Manawatu (two young of 5-6 weeks of age and three adults more than one year of age). Rabbits, from which livers were collected at the abattoir, originated from eight different farms. All the samples collected from the abattoir were taken following post mortem inspection by the "inspector" and reexamination by the author. Lesions considered to be indicative of hepatic coccidiosis were small yellowish white nodules or cysts within the parenchyma of the liver and visible through the serosal surface.

A preliminary histological examination of nine different sites from eight livers condemned for the presence of macroscopic lesions was carried out, in order to determine the most appropriate part of the liver to be examined histologically in the main study. Apart from the wild rabbits, one block of tissue from the caudate lobe was examined histologically from every other rabbit. Nine blocks of tissue from the liver of two adult and one young wild rabbit, and four blocks of tissue from the remaining two wild rabbits (one adult, one young) were examined.

Histological Examination

Portions of liver, no greater than 1 cm^3, were fixed in 10% buffered formalin for at least 78 hrs. Sections of wax embedded tissue were cut at approx. 3-4 µm thickness and stained with hematoxylin and eosin (H + E).

For the preliminary trial, nine blocks were examined from each one of eight livers, which had macroscopic lesions. The sites examined were:

(1) The left lobe 5 mm from the dorsal edge.
(2) The right lobe 5mm from the dorsal edge.
(3) The middle of the left lobe 5mm from the lateral edge.
(4) Five mm from the edge of the ventral part of the left lobe.
(5) The ventral part of the right lobe 5mm from the edge.
(6) The middle of the right lobe 5mm from the edge.
(7) and (8) Five mm from the ventral part of the quadrate lobe and 5mm from the dorsal edge of the quadrate lobe respectively, and
(9) The complete caudate lobe (see Figure 8.1, page 128).

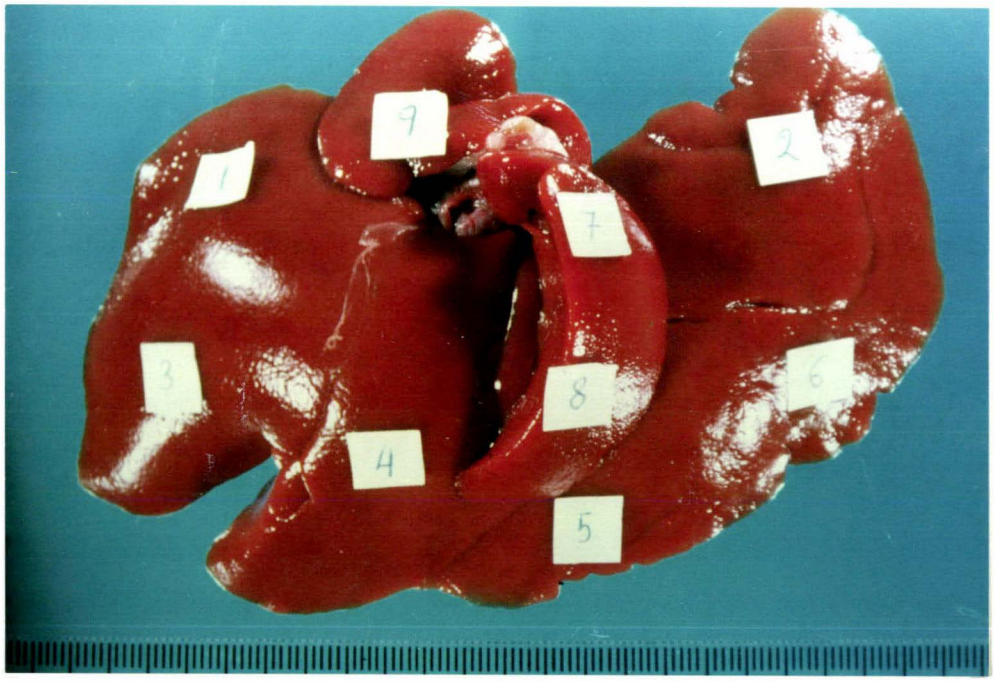


Figure 8.1 - Rabbit liver showing the nine sites from where sections were taken for the preliminary histological investigation

In subsequent examinations and for reasons explained later, only one block from the caudate lobe was examined from each liver.

The accuracy of the detection of liver coccidiosis by the inspector was calculated, by using the results of histological examination as the definitive diagnostic criterion.

RESULTS

Abattoir Survey

Detection of Macroscopic Lesions

All the liver samples collected from the abattoir were examined by the inspector and re-examined by the author. No gross lesions typical of those associated with E. stiedae were observed in any liver passed by the inspector, and no livers condemned by the inspector for coccidiosis had lesions which were considered to be due to other causes. Thus the inspection procedure for detecting gross lesions of hepatic coccidiosis was both 100% sensitive and specific.

Histological Lesions

Comparison of different sites from the same liver.

The histological changes observed in nine different sites from eight different livers, which had macroscopic lesions, were all similar. The general changes were as follows.

The larger bile ducts were surrounded by a capsule partly representing the preformed periportal connective tissue, with remnants of the hepatic tissue and newly formed fibrous tissue. The epithelium of the smaller bile ducts, showed proliferative change with protrusion into the lumen of the ducts. (see figure 8.2, page 130). There was also peribiliary cellular infiltration of varying intensity comprising eosinophils, lymphocytes, plasma cells and occasional neutrophilic leukocytes.

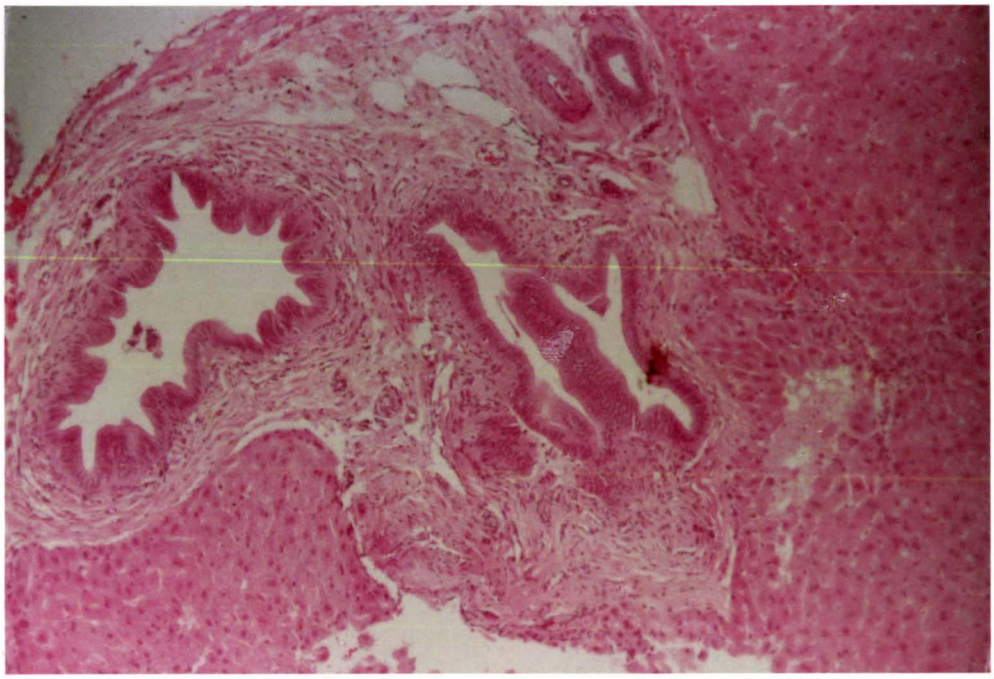


Figure 8.2 - Section from a liver showing proliferation of the bile duct epithelium and fibrosis around the bile ducts (x 75)

Peribiliary fibrosis and proliferation of the bile duct epithelium in these eight livers was the most prominent feature. Cellular infiltration with lymphocytes and other inflammatory cells (plasma cells, and neutrophils) was a more variable and less obvious reaction. No more than five eosinophils were noted per microscopic field and this was regarded as too few to consider as a sign of local eosinophilic reaction as opposed to a general eosinophilia. No parasites were found in any of the sections examined. The most prominent features observed in all eight livers examined, were biliary proliferation and fibrosis of varying degree. In five livers infiltration with lymphocytes and other inflammatory cells was also observed. In one of the livers, three sections did not show any histological changes. These results are summarized in table 8.1 (page 132).

No significant difference in overall histological changes was found to exist between different sites within the same liver ($p<0.05$) and it was decided that a single section from the caudate lobe would provide an accurate evaluation of the liver as a whole.

Main Survey

Results from the main survey showed that the farms could be divided into three groups with respect to the prevalence of lesions indicative of previous hepatic coccidiosis.

In the first group (farms 1,3,4, and 5) there was a 100% prevalence of histological lesions (see Table 8.2, page 133). In the second group (farm 7), there was no evidence of infection, (see fig. 8.3, page 134). In the third group (farms 2, 6, and 8) the prevalence rates were less than 100% being 92% - 80% - 46% respectively. These data indicate that in most cases the rabbits had been infected by the time of slaughter or not infected at all. However, 14 of 71 livers from farms 2,6 and 8 had no microscopic lesions, indicating that some animals in an infected colony may avoid becoming infected. These latter circumstances will be discussed further in Chapter Nine. It is interesting to note that the majority of rabbits from farms 5,6 and almost 50% from farm 8, had histological changes without any gross lesions. As discussed in Chapter Nine, these rabbits were probably exposed to a lesser infective challenge than those with macroscopic lesions. The histological changes noted in the rabbits in the main trial were basically similar to those already described for animals in the preliminary trial.

Table 8.1

Comparison of specific histological changes associated with *E. stiedae* infection at different sites within the liver (nine sites from each of eight livers with macrosopic lesions)

Sampling site*	Eosino-phils	Lympho-cytes	Other inflam-matory cells	Fibrosis	Biliary prolife-ration	Parasites
1	0	3	3	8	7	0
2	0	3	3	8	7	0
3	0	2	2	7	7	0
4	0	2	2	7	8	0
5	0	3	3	7	8	0
6	0	3	4	5	5	0
7	0	2	2	7	8	0
8	0	3	3	6	7	0
9	0	2	2	7	6	0
Mean	0	2.6	2.7	6.9	7.0	0

* See Figure 8.1 (page 128).
Numbers denote number of livers showing specified feature.

Table 8.2

Comparison of prevalence of macroscopic and microscopic lesions in rabbits submitted for slaughter

No. of farm	Total number of examined samples	Number with macroscopic lesions	Number with microscopic lesions	rabbits with lesions (%)
1	14	3	14	100
2	38	24	35	92
3	22	4	22	100
4	18	18	18	100
5	20	0	20	100
*	8	8	8	100
6	20	0	16	80
7	31	0	0	0
8	13	0	6	46

* Eight rabbits from different lines from which 9 blocks of livers were examined from each.

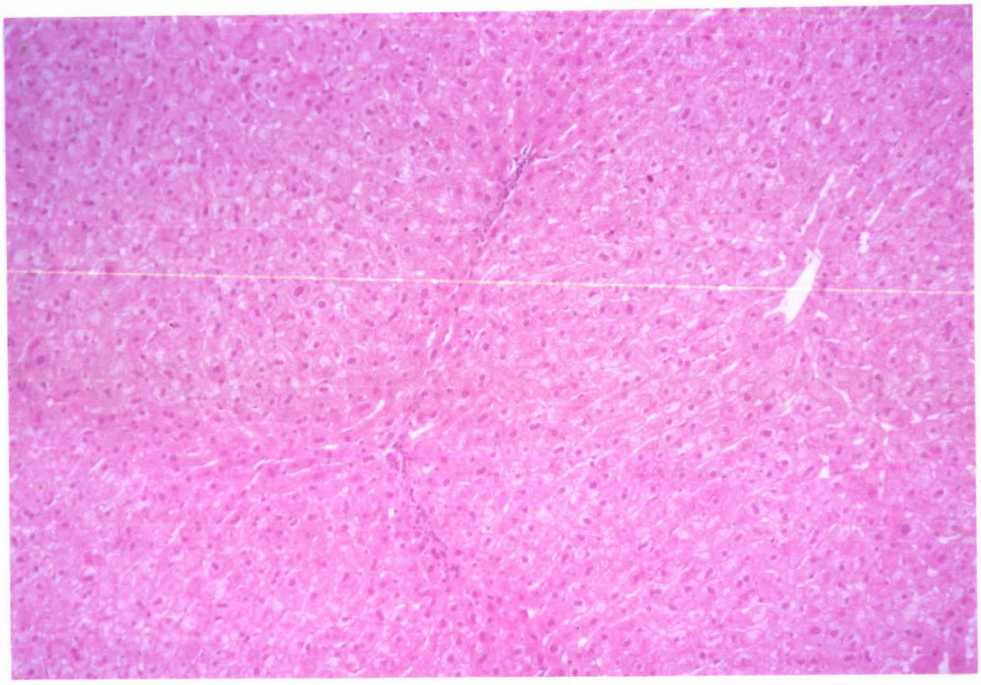


Figure 8.3 Liver section without any histopathological changes (X 75).

A comparison of the histological changes of livers from lines with gross lesions (farms 1,2,3, and 4), indicates that cellular infiltration with inflammatory cells, lymphocytes and eosinophils is observed more often than is fibrosis and biliary proliferation in both rabbits with and without macroscopic lesions. Oocysts of E. stiedae (see fig 8.4, page 135 and Fig 8.5, page 136) were only demonstrated in one liver with gross lesions (see farm 4, Table 8.3, page 137).

A similar comparison for the lines of rabbits without gross lesions (farms 5, 6, 8, and 9), as a whole, showed that biliary proliferation is more prevalent than the cellular infiltration lesions.

Only one line of 31 animals was found to have neither gross nor histological lesions of the liver of any rabbit (see farm 7, Table 8.3, page 137).

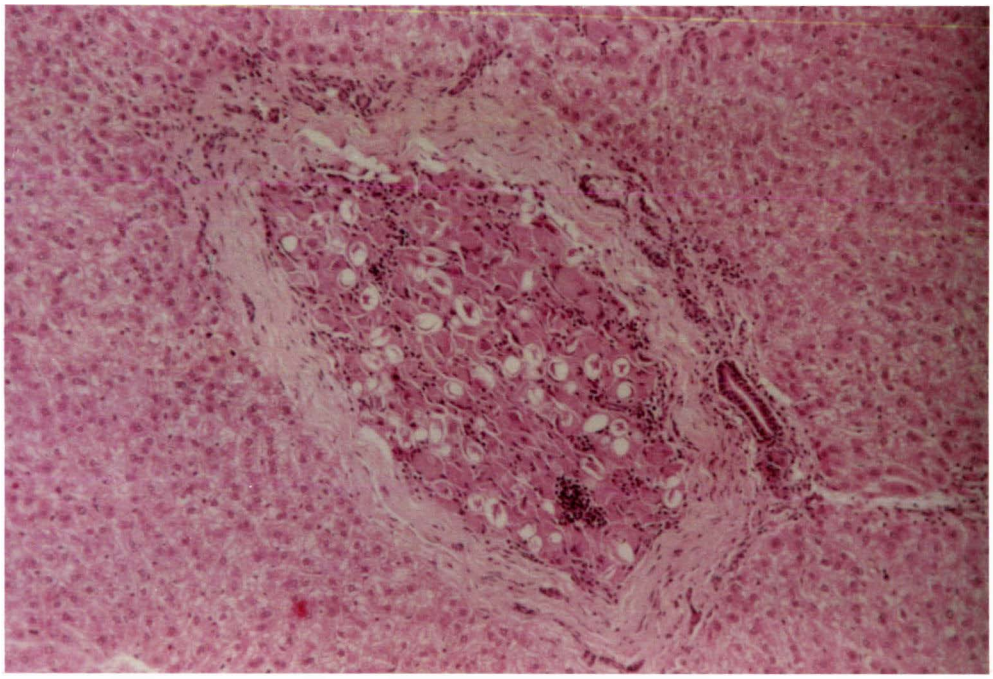


Figure 8.4 - Oocysts of E. stiedae in the bile duct of a rabbit liver. The bile duct shows fibrosis (X 75).

Results From Laboratory Rabbits

None of these rabbits had gross lesions and the Chief Technician of the Small Animal Unit was unaware of gross lesions having been detected in the past. The histological changes observed, were associated with fibrosis and biliary proliferation rather than inflammatory cells. No parasites were observed in any of the sections (see farm 9, Table 8.3, page 137).

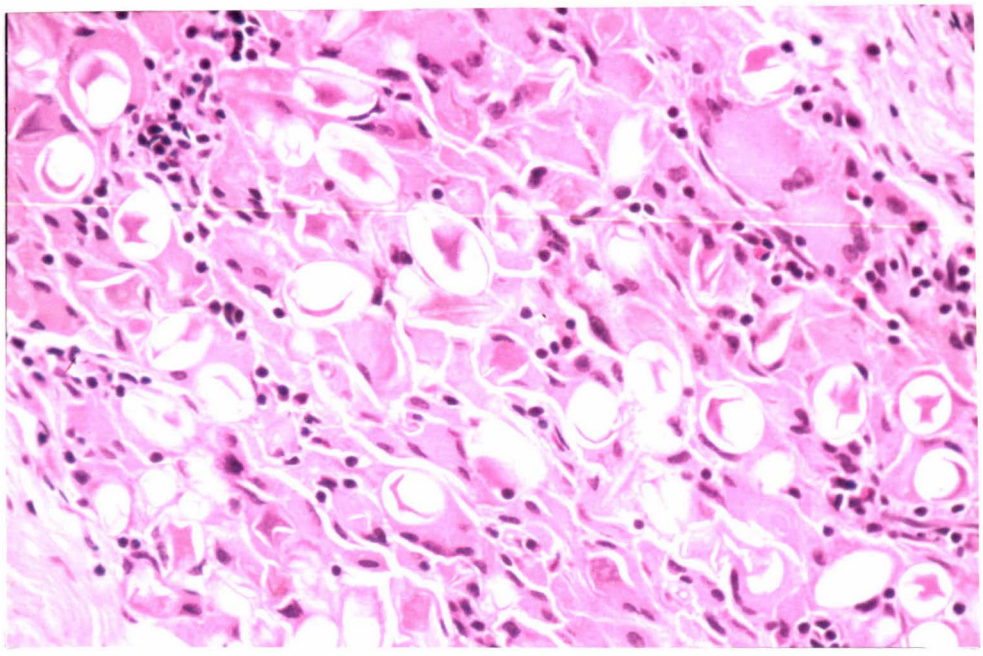


Figure 8.5 - Oocysts of E. stiedae in the bile duct lumen of rabbit liver (X 300)

Results From The Wild Rabbits

The results of the histological examinations of three adult and two young wild rabbit livers, for lesions due to E. stiedae infection are as follows:

In the case of the three adult wild rabbits, it seems that the situation differs from the one observed in domestic rabbits. Biliary proliferation and fibrosis were present in only one, two and three sections out of nine, nine and four sections examined respectively.

Contrary to the above, in the two young wild rabbits, histological lesions comprising fibrosis, biliary proliferation, infiltration with lymphocytes and other inflammatory cells, were observed in almost all sections examined.

Table 8.3

Specific histological changes in rabbit livers from groups with and without macroscopic lesions

No. of farm examined	Total No.	ML	No. in subgroup	No. with specific microscopic changes					
				Eos	Lymp	Inflam	Fibr	Prol	Par
1	14	+	3	1	3	3	3	2	0
		-	11	5	11	11	9	5	0
2	38	+	24	9	23	23	13	11	0
		-	14	7	11	11	3	1	0
3	22	+	4	4	4	4	0	0	0
		-	18	18	18	18	3	4	0
4	18	+	18	17	18	18	2	0	1
		-	0	-	-	-	-	-	-
5	20	+	0	-	-	-	-	-	-
		-	20	0	20	20	16	16	0
6	20	+	0	-	-	-	-	-	-
		-	20	0	2	4	14	16	0
7	31	+	0	-	-	-	-	-	-
		-	31	0	0	0	0	0	0
8*	13	+	0	-	-	-	-	-	-
		-	13	2	3	3	5	5	0
9**	10	+	0	-	-	-	-	-	-
		-	10	0	3	3	8	9	0

* Farm without gross lesions for 12 months before sampling.
** Small Animal Unit Massey University.
Abbreviations ML (macroscopic lesions), Eos (eosinophils), Lymp (lymphocytes), Inflam (neutrophils and plasma cells), Fibr (fibrosis). Prol (biliary proliferation) and Par (parasites).

In general, the histological lesions in the livers of the young wild rabbits resembled those of the domestic rabbits.

DISCUSSION

It is apparent from the results presented, that if rabbits show gross lesions post mortem, then almost the whole line of rabbits from which they come has been infected. It is also interesting that the line of rabbits from which gross lesions had not been observed post mortem for at least one year, did not have macroscopic lesions at the time of the survey, although approx. 46% had microscopic lesions. This finding may be associated with low levels of environmental contamination with oocysts of *E. stiedae*, reflecting the level of management methods and cleanliness prevailing in the farm.

Thus, it would appear that, the histological changes of the liver noted in this study could be used as an accurate baseline, or benchmark, on which the accuracy of inspection procedures for hepatic coccidiosis could be based. To calculate the sensitivity and specificity of the gross inspection procedure, the following table can be constructed based on data of lines of rabbits examined by both gross and histological methods. In this table $\overset{+}{D}$ and $\overset{-}{D}$ denote the presence or absence of histological lesions and $\overset{+}{T}$ and $\overset{-}{T}$ denote whether or not the 'inspector' detected macroscopic lesions.

Accuracy of the inspection procedure
in detecting hepatic coccidiosis.

	$^{+}_{D}$	$^{-}_{D}$	Totals
$^{+}_{T}$	57	0	57
$\bar{T}$	82	45	127
Totals	139	45	184

Sensitivity = 57/139 x 100 = 41%
Specificity = 45/45 x 100 = 100%
PV+ = 57/57 x 100 = 100%
PV- = 45/127 x 100 = 35.4%

Based on the examination of individual rabbits from a farm, endemic infection by E. stiedae on the property, could apparently be based on, either demonstrating the presence of typical microcopic lesions in the liver of animals submitted for slaughter, or by the demonstration of E. stiedae oocysts in the faeces of the rabbits. Based on the results of this survey, detection of microscopic lesions in the liver of individual rabbits, would have been above 80% sensitive in identifying infected farms in six cases (farms 1, 2, 3, 4, 5, 6), but only 46% sensitive in one (farm 8, see table 8.2, page 133). However, it would appear that if the livers of more than 20 rabbits were examined, all infected farms would have been detected. As discussed in Chapter Nine, it was later shown that this assumption was not completely correct.

These results, clearly demonstrate that detection of oocysts in liver tissue is not a criterion of any value in detecting lesions associated with hepatic coccidiosis in rabbits at the time of slaughter. The value of detection of oocysts in faeces as a diagnostic criterion will be discussed in Chapter Nine.

The sensitivity of 41% of this inspection procedure, was higher than the 15% found for the detection of carcasses of sheep infected with C. ovis (cited in Blackmore, 1988). It is commonly accepted that meat inspection procedures with a sensitivity lower than 50% are not acceptable (Blackmore, 1988). This low sensitivity is particularly important in the present case because, as mentioned earlier, the farmers were penalized one dollar for every rabbit detected as having macroscopic lesions at post mortem. This penalty was for having infected rabbits, rather than an unsalable liver. Yet there was no significant difference, in terms of histological lesions, between passed and condemned groups of rabbits originating from infected farms. The low sensitivity of the post mortem inspection procedure and the insignificant nature of hepatic coccidiosis from a public health point of view, make this form of penalization an action without a scientific basis. The basis of this penalization was to encourage farmers to improve husbandry in order to avoid infection with E. stiedae. However, as reported in Chapter Nine, infection was demonstrated on the farm from which livers of rabbits submitted for slaughter had neither gross nor microscopic lesions.

The only logical reason for condemning livers with macroscopic lesions, is that they constitute an aesthetic defect. The author happened to be present in Cyprus where people slaughtering rabbits with lesions of E. stiedae were undecided as to whether or not the whole carcass should be condemned. As has been stated repeatedly, during the present study the reason for which this investigation was carried out was not related to the public health significance of the disease, but as a model for the investigation of the accuracy of meat inspection procedures for more important diseases in other meat animals.

The general methods used in the present study for the calculation of the inspection procedure for the detection of hepatic coccidiosis, could be used to study the accuracy of inspection for other diseases such as sarcocystis and hydatid

disease. A similar approach could be used to investigate the accuracy of inspection procedures for detecting squamous cell carcinoma of the eye of cattle including the presence of metastases.

CHAPTER NINE

EPIDEMIOLOGY OF HEPATIC COCCIDIOSIS OF RABBITS

INTRODUCTION

An understanding of the epidemiological features of a disease is essential, before any control programme can be instigated, and this concept is of particular importance in relation to the detection and control of hepatic coccidiosis in rabbits.

From investigations carried out on wild rabbit populations in New Zealand (Bull, 1958), it was found that several ecological parameters such as population density and moisture of the environment and vegetation, acting separately or in combination, contribute to the morbidity and mortality of young rabbits from liver coccidiosis. Similarly, in the rabbit farming industry, the introduction of young breeding stock with subclinical hepatic coccidiosis, together with different systems of management, can affect the incidence of clinical disease within the colony.

Most species of *Eimeria*, the main genus associated with coccidiosis, are parasites of the intestinal tract of the hosts they infect. There are very few known exceptions where the parasites affect other organs of the body. These include *E. stiedae*, *E. hiepei* and *E. truncata*, which invade the epithelium of the bile duct of rabbits and mink (Fitzerald, 1972) and the kidneys of geese (cited by Anon, 1986). A coccidium, probably an *Eimeria* spp, has been found in the gallbladder of a goat (Dubey 1986). This infection was associated with a generalized

cholecystitis characterised by necrosis and infiltration by mononuclear cells. More recently, a coccidium infecting the liver has been described in a 14 week old calf with a history, for two weeks of weight loss, lethargy and anorexia (Collins et al, 1988). E. stiedae is of historical importance in coccidiology and protozoology, being the first unicellular animal to be observed by Loewenhock in 1674 (Pellerdy, 1974).

The main host of E. stiedae is the European wild rabbit (Oryctolagus cuniculus), and less frequently the wild hare (Lepus americanus), and cottontail "rabbits" including Sylvilagus floridanus mallurus, Sylvilagus floridanus mearnsi, and Sylvilagus nuttali grangeri (Pellerdy, 1974).

Hepatic coccidiosis is caused by the ingestion of large numbers of sporulated oocysts of E. stiedae. The oocysts of the parasite are ovoid or ellipsoidal in shape and yellowish-orange in colour, measuring 36.9 x 18.9 µm with a bare flattened micropyle approx. 6.4 x 10 µm. The oocysts have no otocystic residual body, but each of the four sporocysts contains a large granular residual body, 8.0 µm x 6.0 µm (Davies et al, 1963).

Sporulation of the oocysts occurs in 2-3 days. Durr et al (1972) were able to distinguish seven successive stages of sporulation as follows:

1. spheroid transformation of the sporont,
2. first pyramid stage,
3. first four globe stage,
4. second pyramid stage,
5. second four globe stage,
6. sprorozoite differentiation stage and
7. sporozoite maturation stage.

The respiratory rate of the oocysts is high at the beginning of sporulation, falls during the spindle stage and rises again by the end of sporulation (Pellerdy, 1974). The spindle stage can

be seen during sporogony and is associated with the reorganization of the chromatin of the nucleus after fertilization. The occurance of this stage may be species characteristic and it is prominent in E. tenella and short-lived or absent in E. stiedae (Wagenbach and Burns, 1969).

After the sporulated oocysts have been ingested, the sporozoites are liberated in the duodenum, mainly by the action of pancreatic enzymes. Other factors affecting excystation of the oocysts are the pH, temperature and time, and intrinsic factors of the oocysts themselves. After excystation, the liberated sporozoites penetrate the mucosa of the intestine. Pellerdy (1974) reports that in experimental infections after sporozoites have penetrated the intestinal wall they appear in the mesenteric lymphnodes 24 hours later and in the liver within one to five days. Horton (1967) concludes that sporozoites reach the lymphnodes via the lymph vessels. The same author observed sporozoites within macrophages in the lamina propria of the duodenum, and similar observations are reported by Rose (1958) in her studies on the pathogenesis of the disease.

Pellerdy and Durr (1969) believe that at least some sporozoites migrate from the lymphnodes to liver via the blood stream, although they did not detect any free sporozoites in the blood, even after massive infection. Horton (1967) observed that sporozoites migrate from the lymphnodes to the liver both within monocysts and free in the blood.

After the sporozoites have reached the liver, they migrate from the blood stream towards the bile ducts and lie at the base of the epithelial cells, parallel to the longitudinal axis of the duct. Two days later, the schizonts arise from the sporozoites. By the fifth day the second schizonic generation develops. Both stages of shizonts invade the biliary duct epithelial cells along the luminal side. Another three generations of schizonts develop up to the 11th day after infection. The sexual stages develop 12 days after infection and differentiate later. The biliary duct epithelium becomes packed with sexual stages and the epithelium

proliferates. Gametogony is completed 16 days after infection when oocysts are passed in the faeces 15 days after infection and by the 23rd day there are up to 15 or 16 million oocysts per gram of faeces (Pellerdy, 1974). The numbers then start decreasing rapidly until the 37th day when very few can be found in the faeces (Davies et al, 1963).

From the fourth day after infection the biliary duct epithelium starts proliferating and in two days the proliferating cells may entirely fill the lumen of the distended biliary capillaries. Eight to ten days after experimental infection the liver becomes enlarged and morphologically resembles that of naturally infected livers (Pellerdy, 1974)

Almost all the epithelial cells of the bile ducts are packed with parasites and the pus like material in the liver nodules consists almost entirely of oocysts . The bile ducts are surrounded by cellular infiltration of varying intensity, mainly of lymphocytes, plasma cells, eosinophils and sometimes neutrophilic leucocytes. Peripherally, fibrous tissue develops from one periportal field to another. The whole liver shows gross enlargement often weighing 20% of the total carcass weight (normally only about 3.7% of body weight). Apart from the multiple hepatic lesions, containing yelow pus-like material, the kidneys may show subcapsular petechial haemmorrhages and the peritoneal and pleural cavities are filled with a yellowish serous exudate. The gall bladder is enlarged and thickened and the carcass sometimes is jaundiced and oedematous. At a later stage the liver becomes cirrhotic but without systemic evidence of jaundice (Davies et al, 1963).

According to Pellerdy and Temesi (1950), 21 days after infection rabbits develop a strong immunity against further infection. The same authors succeeded in establishing complete protection by infecting the rabbits at intervals of 30 days. Rose (1959) estimates the duration of immunity to be up to two years.

Lightly infected animals show few, if any, clinical signs. In heavy infections, anorexia, loss of weight , fever and meteorism (bloat), are relatively constant signs (Flynn, 1966). Diarrhoea and icterus are common signs often associated with subsequent death, especially in young rabbits (Flynn, 1966). Liver enlargement may be palpable and even the coccidial nodules on its surface may be grossly visible through the skin in direct sunlight (Pellerdy, 1974).

The typical clinical signs of hepatic coccidiosis together with the demonstrated oocysts of E. stiedae in faeces are relatively conclusive diagnostic features. The absence of oocysts of E. stiedae in the faeces cannot be considered as lack of evidence of infection, as often severe signs of disease occur before oocysts are shed. A definite diagnosis can be made only if at necropsy the liver shows the typical lesions in which coccidial parasites can be demonstrated (Flynn, 1966).

Various forms of treatment of hepatic coccidiosis are recommended. These include Sulfadimidine or Sulfamerazine at a dose of 100mg/kg liveweight for three consecutive days, folowed by a week without treatment and repetition of the cycle twice (Spanoghe et al, 1972). Simultaneous treatment with 0.01% Sulfaquinoxaline and 0.025% Pyrimethamine is very effective against E. stiedae (Durr and Schrecke 1970). However, Davies et al, (1963), suggest that under practical conditions a sulfonamide is best given, as soon as the disease is diagnosed, for 7-10 days, to all rabbits of the colony and the treatment repeated after a week's interval without treatment.

In a study of liver coccidiosis in rabbits, brief reference to intestinal coccidiosis of these animals is necessary for several reasons. First, the similarity of the signs of disease associated with both liver and intestinal coccidiosis. Secondly, coccidiosis in rabbits is usually associated with infection of two or more species of Eimeria. Thirdly, for an accurate identification of the oocysts of E. stiedae in rabbit faeces, a

knowledge of the specific characteristics of other oocysts is necessary (Pellerdy, 1974).

In practice it is difficult to determine which species of Eimeria play the main role in the expression of the disease. Investigations by Rutherford (1943), indicated that E. irresidua and E. magna were the primary agents. Pellerdy and Babos (1953) believe that E. media and E. irresidua are more important than E. magna, because they develop subepithelially. E. piriformis is considered distinctly pathogenic (Pellerdy, 1974).

In terms of the pathogenesis of intestinal coccidiosis, the extent of the inflammatory changes depends on the resistance of the rabbit, the pathogenicity of the parasite and the number of oocysts ingested. In cases where very large numbers of oocysts are ingested, even if of potentially low pathogenicity, severe digestive troubles and denudation of the intestinal epithelium can occur (Pellerdy, 1974).

Intestinal coccidiosis is not always regarded as an independent disease but to be associated with conditions arising from other causes. Durr (1971) states that there is possibility of synergism between certain species of fungi and enteric coccidia in producing enteric disease in rabbits. Whitney and Arch (1957) suggest that viral agents may also play a role.

Some species of Eimeria associated with intestinal coccidiosis in rabbits are described in the following text, as the morphological features of the oocysts are important in relation to differentiating them from those of E. stiedae.

E. irresidua: This is one of the more pathogenic species that develops in the epithelium of the villi of the small intestine, from the duodenum to the lower ileum. The lifecycle is completed in eight days. The oocysts are yellow in colour, with a mean size of 38.3µm x 25.6µm, ovoid in shape with a

prominent micropyle. Sporulation occurs in 50-64 hours and the sporulated oocyst has a sporocystic residual body (Davies et al, 1963).

E. magna: Is found mainly in the mid jejunum and ileum and never in the upper small intestine. The life cycle is completed in seven days. This is one of the more pathogenic species. The oocysts are broad, ovoid and yellow to yellow-brown in colour. They measure 35.5µm x 24.4µm. They have a prominent micropyle and large otocystic residual body. Sporulation occurs in 48 hours (Davies et al, 1963).

E. media: This species develops throughout the length of the small intestine. The duration of the life cycle is six days. The parasite is regarded as non pathogenic. The oocysts are ellipsoidal in shape, size 31.2µm x 18.5µm, have well developed oocystic residual body and they are orange-pink in colour. They have also a prominent micropyle (Davies et al, 1963).

E. perforans: This species is found in the gut from the lower duodenum to the lower ileum. The life cycle is completed in five days. This species is considered to be of low pathogenicity. The oocysts, which are faintly pink in colour and ellipsoidal in shape, measure 22.7µm x 14.2µm. The micropyle is not easily distinguishable. The minimum sporulation time is 30 hours. They contain an oocystic residual body, which readily differentiates this oocyst from that of E. stiedae (Davies, et al, 1963).

It is generally believed that although liver coccidiosis of rabbits is a disease of young animals, rabbits up to approx. the

15th day of life are resistant to infection by the oocysts of E. stiedae. However, experimental work carried out by Pellerdy (1969), Schrecke (1969) and Schrecke and Durr (1970), has shown that the disease can be induced in young rabbits during the first two weeks of life, by giving them massive doses of oocysts of E. stiedae. Under natural conditions, after the age of 15 days, young rabbits become susceptible to the infection until about four months of age. After the fourth month, it has been shown experimentally that, resistance to infection develops (Kotlan and Pellerdy, 1936).

An extensive study of the rabbit population in New Zealand (Bull, 1958) showed that hepatic coccidiosis affects rabbits of mainly 6 - 11 weeks of age although younger or older rabbits may be less frequently affected.

Either in the wild or in rabbitries, long breeding seasons normally result in high population densities which is a hazard for the young rabbits. In these circumstances the environment may become very heavily contaminated and generations of young rabbits,born later in the season, are exposed to massive doses of sporulated oocysts and subsequently develop severe hepatic coccidiosis (Bull,1958). Such young rabbits are invariably concurrently infected with coccidia causing enteric coccidiosis. It is thought that such dual infection exacerbates the adverse effects of E. stiedae infection (Bull,1958).

Some investigators believe that coprophagia, a phenomenon specific for rabbits, contributes to the occurrence of the disease. They believe that the "soft" faeces, ingested during coprophagia, could contain active sporozoites or schizonts, which may serve to reinfect the rabbits (Fitzgerald, 1972). Other authors disagree with this theory and suggest that coprophagia should have no effect on the pathogenesis of liver coccidiosis because the "soft" faeces do not contain sporulated oocysts (cited by Anon (1986)). Unfortunately not enough information is

available to clarify the significance of coprophagia in relation to the life cycle of hepatic coccidiosis.

It has been found in Europe (Boughton, 1932) that during years of high rainfall, the prevalence of hepatic coccidiosis in hares, was higher than during years with normal rainfall. It is unclear if this is due to the effect of the moisture prolonging the survival of oocysts in the environment.

The introduction to the rabbitry of subclinically infected young breeding stock, can initiate a severe outbreak of hepatic coccidiosis, especially if management faults coexist on the farm (personal observation).

Husbandry is a major factor in successful commercial rabbit production. Housing rabbits on the floor, in limited space, potentially exposes young rabbits to infection with massive doses of oocysts. For rabbits reared in cages, both the construction of cages and methods of clearing and disinfection can affect the incidence and severity of hepatic coccidiosis. Other factors, including the number of animals per cage, the water supply and the quality of the food, can also affect the incidence and severity of the disease.

From the work reported in Chapter Eight, it would appear that rabbits submitted for slaughter, come from either farms endemically infected with E. stiedae, or from farms where infection is absent. Closer scrutiny of the total rabbit populations on different farms, would help to test this hypothesis. It must be appreciated that the histological changes, thought to be associated with previous infections with E.stiedae, are not necessarily pathognomonic, and that demonstration of the parasite is the only absolute criterion, on which a definite diagnosis can be based. It was therefore decided to visit both, a farm thought to be free of infection and others thought to be endemically infected, and to examine the faeces of rabbits of different ages and material from the environment, for the

presence of oocysts of E. stiedae. Thus the coccidial status of the farms could be more definitively assessed.

MATERIALS AND METHODS

Farms Studied

Three rabbitries were studied. Two farms (1 and 4) had supplied animals for slaughter which had gross and histological lesions of hepatic coccidiosis. One farm (7) had submitted animals for slaughter, none of which had either gross or histological lesions.

Farm 1

The rabbitry is situated in the Taihape area, is a small unit with ten, Angora wool producing does, and the same number of New Zealand White does. The animals are housed in an open ended hay barn with an earth floor. The does are caged in individual wire cages and the young rabbits in groups of up to approx. ten per cage. The cages are in five lines, about half a meter from the floor. The water supply to the animals is by nipples in each cage from a central supply and pellets are presented in conventional individual hoppers. Hay and green feed is also given to the animals every day. Breeding is carried out approx. four times per doe per year.

At our visit, the standards of hygiene and "house keeping", both within the rabbit house and on the farm, were generally poor. Surface water was present in many places and excessive amounts of manure mixed with mud was present both within the shed and its immediate environment. According to the owner, the shed is cleaned out twice a year.

The major health problems affecting the rabbits, as perceived by the owner, are snuffles and coccidiosis (hepatic and

intestinal). The only drugs used for the treatment of rabbits are penicillin and streptomycin.

Usually the farm sends rabbits between 10 and 11 weeks of age for slaughter, every three to four weeks. According to the owner it is not a profitable business, because of the expenses involved in sending animals to the abattoir, such a long distance away from the farm.

Five samples of faeces were collected on a paper on the night before the visit. These consisted of one sample from a cage of four young rabbits of four and a half weeks of age, one from another cage of six rabbits of the same age, one from one rabbit twelve weeks old and one from a 14 week old rabbit. Five mixed faecal samples were collected from the inside of the shed at least 0.7 of a meter from the cages containing rabbits (see table 9.1, page 158).

Farm 4

This farm is at Waitotara approx. 20 km from Wanganui. It is a large Angora breeding rabbitry of approx. 300 does, mainly for wool production. Old cull does are sent to the abattoir.

This farm is relatively new, consisting of several sheds situated in two areas approx. 200 meters apart. The relatively new buildings are about 80 meters in length and three to four meters in width, with open sides, containing two rows of wire cages on either side of a central passage. The pellets are presented in feeders and the water is supplied automatically. The general standards of hygiene are reasonable and the animals appear healthy. During the visit music was played as a background calming influence on the animals. Further information on the farm and management systems, was not available because no-one was present at the time of the visit. Thirty four faecal samples were collected from both a breeding and a growing shed on the farm, from faecal material which had accumulated under the cages. One

sample was collected from animals of three weeks of age, ten from animals of four to five weeks of age, five from animals six to eight weeks of age, seven from animals nine weeks of age, one from a group 11 weeks of age, two samples from young adults (around 20 weeks of age) and eight from individual adult rabbits.

Farm 7

This is a small rabbitry (of 10 - 15 New Zealand White does and a few bucks), situated in the Himatangi area near Palmerston North and owned by the "inspector" at the Masterton abattoir. Animals are housed in two adjoining open fronted sheds with wire screens to prevent the entry of birds. The equipment of the rabbitry is quite old and the cages are very close to each other. The rabbitry is cleaned every two-three months. The cages are always cleaned and flamed with a hand operated flame gun and left outside for a couple of weeks before being used for a new batch of rabbits. The animals are fed pellets and hay and water supplied by a conventional nipple system. Does are bred three to four times a year. The major source of income from this unit is the sale of pedigree breeding stock. Sub-standard animals are submitted for slaughter at the abattoir at Masterton.

During the first visit, ten faecal samples were collected from the material accumulated under the cages of growing rabbits, choosing recently void faecal pellets. Efforts made to collect faecal material directly from the rectum failed. One sample was taken from under the cage of three week old animals, four samples from five week old animals, two from ten week old animals, two from eleven week old and one from rabbits of 14 - 16 weeks of age.

Two weeks after the first visit, the owner was asked by phone to put the 11 rabbits in the cage from which E.stiedae oocysts were recovered, into individual cages and to send their individual faecal samples to the laboratory for examination.

After these samples had been processed, it was decided to purchase two of these eleven rabbits for further investigations, because they showed intestinal oocysts in their faeces, whereas the remaining nine individual faecal samples were found free from any oocysts. These two rabbits were slaughtered and processed immediately after purchase and were examined. Examination consisted of a standard autopsy, including histological examination of the nine sites in the liver described in Chapter Eight, the gall bladder, the duodenum, proximal and distal parts of the ileum, caecum, colon and rectum. Contents of the GIT from these six sites were also examined for the presence of coccidial oocysts.

Examination of the Faecal Material

Samples taken on the farm were collected in clean plastic containers and if necessary stored overnight at 4°C. The faecal material collected from the three farms, as well as the twelve samples taken from the GIT of the two rabbits, were all examined by the simple flotation technique. A concentration technique was carried out on those samples from which oocysts had been demonstrated by the flotation technique.

(a) Flotation Technique

An approx. 2 g sample of faecal pallets was homogenized with saturated salt solution (NaCl specific gravity (s/g) 1.2) and subsequently strained, using a 1mm sieve. The solution was then poured into 15 ml tubes filled to the top and covered with a coverslip. After at least 15 minutes the coverslip was removed, placed on a glass slide and examined microscopically for the presence of oocysts.

The investigation of the content of the gallbladder was carried out by washing out the content of this organ with a saturated salt solution (1.2 s/g). The solution (salt and bile)

was poured in a 15 ml tube filled to the top and treated and examined as already described.

(b) Concentration Method

Approx. 4 g of faecal material from each sample was homogenized in approx. 50 ml of tap water and subsequently strained first through 1 mm and then through a 50 μm sieve.

The faecal suspension was centrifuged for six minutes at 1500 g, the supernatant removed, the material resuspended and the process repeated until the supernatant was clear.

The material was suspended in saturated salt solution, left for 15 minutes, and centrifuged at 500 g. The top 4 ml of the suspension was removed the remaining material suspended in water and recentrifuged at 500 g. This procedure was repeated five times.

The supernatant was then removed leaving two to three ml in the bottom of the tube. This was then well shaken and transferred to a smaller centrifuge tube (15 ml) and centrifuged at 150 g. The upper part of the supernatant was discarded by suction and the remaining 2-3 mls shaken into suspension and poured into petri dishes of 6 cm diameter. Two to three ml of 2.5% potassium dichromate was added, and the samples were incubated at 27°C for four days to sporulate.

Following incubation, the solution, if clear, was poured into 15 ml tubes, filled up to the top with sucrose solution (1.2 s/g) covered with a coverslip, which after 15 minutes, was examined under the microscope. If the solution was cloudy, it was centrifuged for five minutes at 150 g, resuspended in a sucrose solution and the process repeated until the supernatant solution was clear. The slide was then examined microscopically.

Identification of the Oocysts

Two criteria were used for the identification of the sporulated oocysts. First, specific morphological features which for oocysts of E.stiedae are a flattened micropyle, a thin wall of the oocyst, an ovoidal or ellipsoidal shape, an orange yellowish colour and the absence of a residual body. Secondly, the size of the oocyst, which for E. stiedae is 36.9µm x 19.9µm (Davies et al, 1963).

Both criteria were observed and measured, using differential interference contrast microscopy at a magnification of 500x. The oocysts were measured using an electronic eyepiece micrometer (Olympus Optical Company L.M.D. Model O.S.M.D.C.).

Histological Examination of Samples from the GIT

The 12 sections taken from the wall of the GIT of the two rabbits as well as the 18 blocks from the two livers were fixed in 10% formalin, embedded in wax and stained by Hematoxylin-Eosin.

RESULTS

The results from the examination of all faecal samples are presented in tables 9.1 and 9.2.

Farm 1

Two out of five faecal samples from under the cages were found to contain oocysts. One of these was from a cage of four rabbits four and a half weeks of age, and the other from a cage of three rabbits, eight weeks of age. E. stiedae was identified from the former sample only. Oocysts were demonstrated in four out of five environmental samples but in only one E. stiedae oocysts were identified.

Farm 4

Of the 34 samples examined, four originating from rabbits four to five weeks of age, one sample from a cage with three week old rabbits and two from nine week old rabbits, revealed Eimeria spp. oocysts. One out of the four samples (from 4 week old) revealed E. stiedae oocysts, while the remaining six were oocysts of intestinal coccidia.

Farm 7

Faecal samples: Two out of the ten samples revealed E. stiedae oocysts. Two weeks later, individual samples from 11 rabbits from the two cages from which E. stiedae was demonstrated, were examined. At this time no oocysts of E. stiedae were found but oocysts of intestinal coccidia were demonstrated in two samples.

Content from the GIT: Out of 12 samples (six from each rabbit) taken from different parts of the GIT of the two rabbits, only one (from the large intestine) revealed an oocyst which could not however be identified.

Gall Bladder: No oocysts were found in the content of the gall- bladder taken from the two rabbits.

Sections taken from the wall of the GIT: No oocysts, developing stages of the Eimeria spp., or microscopical changes were found from the sections taken from different places of the GIT of the two rabbits.

Liver Sections: Seventeen out of eighteen sections of the two livers showed fibrosis and biliary proliferation, while the remaining section showed eosinophils and lymphocytes (see table 9.2. page 159).

Table 9.1

Detection of oocysts in faeces

	Age (weeks)	No. of rabbits examined	No. of samples	No. with oocysts	No. with *E. stiedae* oocysts
Farm No.1	4.5	10	2	1	1
	8	3	1	1	-
	12	1	-	-	-
	14	1	-	-	-
	Environ-mental	-	5	4	1
Farm No.4	3	6	1	1	-
	4-5	26	10	4	1
	6-8	3	5	-	-
	9	12	7	2	-
	11	4	1	-	-
	Young adults	4	2	-	-
	Adults	8*	8	-	-
Farm No.7	3	6	1	-	-
	5	4	4	-	-
	10	3	2	1	-
	11	2	2	-	-
	14-16	11	1	1	1
	16-18	11	11	2	-

* = Individual faecal samples

Table 9.2

Results of microscopical examination of two livers from rabbits from a hepatic coccidiosis free farm

Sampling Site*	Eos.	Lymp.	Other Inflam. Cells**	Fibr.	Biliary Prol.	Oocysts or Developing stages
1	-	-	-	-	+	-
2	+	+	+	-	-	-
3	-	-	-	+	+	-
4	-	-	-	+	+	-
5	-	-	-	+	+	-
6	-	-	-	+	+	-
7	-	-	-	+	+	-
8	-	-	-	+	+	-
9	-	-	-	+	+	-
1	-	-	-	+	+	-
2	-	-	-	+	+	-
3	-	-	-	+	+	-
4	-	-	-	+	+	-
5	-	-	-	+	+	-
6	-	-	-	+	+	-
7	-	-	-	+	+	-
8	-	-	-	+	+	-
9	-	-	-	+	+	-

* = See Fig. 8.1 (page 128)
** = Plasma cells, neutrophils

Abbreviations:

Eos. = Eosinophils
Lymp. = Lymphocytes
Inflam. = Inflammatory
Fibr. = Fibrosis
Prol. = proliferation

Discussion

The aims of the study described in this chapter were to investigate the validity of the hypothesis, that the histological changes already described are pathognomonic for hepatic coccidiosis, and to investigate some aspects of the epidemiology of this disease in rabbits in New Zealand.

No rabbits submitted for slaughter from farm 7 had histological hepatic lesions . However, liver samples from two rabbits from which a cage of 11 rabbits on farm 7 from which faecal material contained oocysts of both E. stiedae and intestinal species of Eimeria, had histological changes typical of those associated with hepatic coccidiosis. The faeces of the other nine rabbits from this cage contained no oocysts. Given the co-existence of enteric and hepatic coccidiosis, it was concluded that both types of infection occurred simultaneously. Presumably the other nine rabbits were either infected at an earlier period of their life but had ceased excreting oocysts, or they were never infected. Unfortunately it was not possible to purchase these other nine animals and carry out histological examination, as funds were unavailable.

It is interesting to speculate why these two rabbits did not have oocysts of E. stiedae in their faeces two weeks after they were first examined. The duration of excretion of the oocysts in the faeces is around three weeks (Davies et al, 1963). However, if it is assumed that the two rabbits, when first examined were close to the end of their excretory period, they would be likely to have no oocysts in their faeces, two weeks later.

It would therefore appear that on farm No. 7, infection with E.stiedae is not endemic and is limited to individual cages of rabbits. Only one cage was found to contain infected rabbits, and these had microscopic hepatic lesions. The rabbits in cages which contained animals slaughtered at the abattoir, were apparently

not infected. As recorded in Chapter Eight, none of the animals had histological lesions.

Oocysts of E.stiedae were identified in samples from both farm 1 and farm 4, and the rabbits from these farms when slaughtered had typical microscopical hepatic lesions.

It would therefore appear that the hepatic lesions, described in chapter eight, are pathognomonic for detecting rabbits which have been inffected with hepatic coccidiosis.

In terms of the second aim of this study, results from faecal examinations from farms 1 and 4, indicate that the pattern of E. stiedae in New Zealand is similar to that recorded in other countries. Most of the infected rabbits were young, between six and eleven weeks of age, as recorded by Bull (1958). This author believes that cases occurring after the 11th week of age, are associated with low levels of environmental contamination with oocysts of E. stiedae. In the present study the two infected rabbits on farm 7 were 14 to 16 weeks of age and were from a farm with high standards of cage hygiene. According to the owner of this rabbitry, all cages on the farm were flamed with a hand-operated flame gun and left unused for at least two weeks, before being reused. This low degree of environmental contamination with oocysts of E. stiedae, resulting from the strict hygiene measures employed on the farm, was probably responsible for the lack of evidence of infection in the group of 31 rabbits, which were examined at the abattoir. The presence of microscopical lesions of the paraside found in the liver of the two rabbits of 16-18 weeks of age originating from the same farm, indicates that in farms with low degree of environmental contamination with the oocysts, contamination occurs after the age of 8-10 weeks, when these are usually slaughtered and before the 16th week when increasing innate resistance to the parasite occurs (Bull, 1958). This indicates also that even in the cleanest farms, the presence of the pathological agent cannot be excluded.

In cases where the contamination of the environment of the rabbits is low, as is believed to be the case in relation to the small animal unit and farm 8, which was free from gross lesions for 12 months (see table 8.3, page 137), the prevalence of histological hepatic lesions was less and degree of change less marked, than in rabbits from most other properties, and gross lesions were absent. Conversely if contamination of the environment is high,early infection usually occurs and by the age of eight to ten weeks, when rabbits are normally slaughtered, excretion of the oocysts in the faeces will have ceased. This presumably was the reason why occysts where demonstrated in the liver of only one rabbit, from the infected farms sending animals for slaughter at the abattoir. This was also the likely reason why only ooccysts were demonstrated in faeces from four to four and half week old rabbits on farms 1 and 4. This early infection of young rabbits on endemically infected farms is in agreement with previous findings (Bull 1958, Davies et al, 1963).

This presumed early infection of rabbits, on heavily contaminated farms, is substantiated by the chronic inflammatory hepatic lesions (fibrosis and biliary proliferation) seen in rabbits and described in the previous chapter. If the lesions were associated with only active infection they would be more acute. In such circumstances one would expect to see greater numbers of lymphocytes and other inflammatory cells than those observed, as well as oocysts and developing stages of the parasite.

The results presented in this chapter, tend to validate the histological criteria used as a benchmark in the investigation of the accuracy of meat inspection procedures, to detect hepatic coccidiosis. The more general epidemiological investigations tend to indicate that the pattern of hepatic coccidiosis in New Zealand is similar to that described elsewhere in the world.

CHAPTER TEN

GENERAL DISCUSSION

The work presented in this thesis has indicated two major problems associated with the production of rabbit meat, namely the problem of humane slaughter of rabbits and the hygienic production of rabbit meat.

Animal welfare in general, and the humane slaughter of stock in particular, are areas of great concern in modern society. In New Zealand the slaughter of stock, game and poultry regulations, 1969, amendment No. 1.1977/266 (Anon, 1977), specify the approved methods of stunning and slaughter. However, the indicators of a so-called humane method of stunning are not always completely reliable . In some cases, animals, although fully sensible, do not react to painful stimuli during exsanguination and vise-versa. Animals, although insensible as a result of the stunning method, may exhibit violent body movements or vocalization, giving the subjective false impression of sensibility to pain (cited in Blackmore and Delany 1988). In the present study, attempts were made to determine if dislocation of the neck induced immediate insensibility in rabbits. After careful observation of various reflexes exhibited by the stunned animals, especially pupillary dilatation, it was concluded that the humaneness of the method was questionable. However dislocation of the neck, as it was carried out at the abattoir by an experienced person, effectively induced immobilization, although not necessarily insensibility of the animals. In the opinion of the author, dislocation of the neck is an acceptable procedure for the stunning of rabbits, for two reasons: first, it gives the observer the impression that the rabbit is insensible and secondly, it facilitates the handling of the animals during

slaughtering. However, it is emphasized that further investigation is necessary in order to fully clarify the humaneness of the method. Compared to neck dislocation, stunning by a penetrative percussive method, judging from the magnitude of the brain damage inflicted, undoubtedly renders the animal insensible. However, rabbits react with violent spontaneous body movements, giving the subjective impression of sensibility. Considering the severe brain damage these violent movements are believed to be purely of spinal origin.

In relation to the hygienic production of rabbit meat, the results of the studies on the washing of rabbit carcasses by immersion are comparable with studies of washing of lamb carcasses (Turner, 1987). Washing of carcasses must, from a hygienic point of view, be considered contraindicated because it can result in a redistribution of microorganisms, and not necessarily in a reduction in actual numbers. The addition of large amounts of hypochlorite or organic acids to the washing water assures a reduction in the surface flora (Skelley et al, 1985). In the opinion of the author the bacterial counts could be improved by increasing the rate of water replacement in the washing bath, by moving the carcasses contrary to the water flow in the bath or by using a combination of these. Associated with differences in the ratio of weight to surface area it appears that the handling of small rabbit carcasses is a factor of greater concern with regards to the bacterial load as compared to carcasses of the large meat animals.

According to the WHO (World Health Organization) expert committee on hygienic meat production, there is little epidemiological evidence that the present systems of meat inspection can control the high incidence of food born diseases in humans in developed countries. Bearing in mind that nowadays wholesalers, as well as local consumer organizations, ask for more than the traditional "hygienic slaughter standards" (Stolle, 1988), the committee recommended the establishment of the HACCP (Hazard Analysis Critical Control Point) system with three main

considerations. In the case of meat: to assess the hazards associated with the production of animals and the processing of meat,to determine the critical control points required to control any identifiable hazard, and to establish suitable procedures to monitor the critical control points.

As previously discussed, the traditional post mortem inspection of meat carcasses, including those of rabbits, is of limited value in terms of detecting meat which might be a risk to public health. Visual control, even by skilled personnel, e.g. veterinarians, are not sufficient to guarantee hygienic meat processing (Stolle, 1988). The same also applies to certain aesthetic defects like non-zoonotic parasitic lesions. Post mortem inspection in its present form, can be useful for the detection of gross lesions, such as cirrhotic livers,pleurisy, bruising, abnormal pigmentation etc, which are only aesthetically unacceptable. The detection of non-zoonotic aesthetic defects should be the responsibility of the meat processing company and be subjected to a quality assurance programme laid down and monitored by the regulatory authority.

The contamination of the carcasses during processing with enteric pathogens, is of considerable public health significance. It is necessary, however, that emphasis should be paid to standards of hygiene within the processing plant, although carcass contamination can probably never be completely avoided. The establishment of critical control points following a hazard analysis, should however result in a risk reduction. Factors which could affect the level of contamination of the carcasses during processing have already been described elsewhere in this Thesis.

Bearing in mind that which has already been discussed, and considering suggestions already made for a new approach to inspection procedures for poultry, as well as for other meat producing animals, it could be said that similar procedures could also be adapted to the inspection of rabbits. The limited scale

of rabbit farming, compared with other meat animals, is an extra reason for paying a greater emphasis on the health status of the rabbits submitted for slaughter, than to individual post mortem inspection of carcasses. In a country like New Zealand, with a small, intensive rabbit industry, it would be relatively easy to introduce requirements for a certificate showing the health status of flocks of rabbits, issued at regular intervals by the veterinary services. Such certificates, accompanying rabbits submitted for slaughter, could provide a useful guide to determine a suitable procedure to be employed at post mortem inspection.

The system already suggested for the production of wholesome rabbit meat, could be included in a general package of changes for the manufacture of wholesome products from all meat animals. Countries like New Zealand, being an important exporter of beef and lamb, could be leading the world in this field. Such changes are very important because of the implementation of stringent hygiene requirements by some countries, and the protection of the exports of meat and meat products, to countries with a developed public health system. An alternative solution, which could be employed until the "health certificate" system is implemented, is the systematic post mortem inspection of individual rabbit carcasses carried out by a well trained company employee. In such circumstances, the regulatory authorities should visit the rabbit slaughter houses to investigate and to assure that processing is carried in a hygienic manner and the environment of the slaughter-house is maintained to an acceptable standard of hygiene. It would also be advisable for the regulatory authorities, during their visits to take samples from carcasses, machinery and instruments used during processing, the processing environment and of water for bacteriological examination. This would allow an appraisal of the status of the overall hygiene of meat production.

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