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STUDIES ON THE FEEDING AND NEOPHOBIC BEHAVIOUR IN NORWAY RATS (*Rattus norvegicus* Berkenhout, 1769) FROM FARMS IN GERMANY

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STUDIES ON THE FEEDING AND NEOPHOBIC BEHAVIOUR IN NORWAY RATS (*Rattus norvegicus* Berkenhout, 1769) FROM FARMS IN GERMANY

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SUMMARY

Studies on the feeding and neophobic behaviour in Norway rats (*Rattus norvegicus* Berkenhout, 1769) from farms in Germany

Studies on the feeding and neophobic behaviour of Norway rats (*Rattus norvegicus*) have been done in 1998 – 2000 at the Institute for Nematology and Vertebrate Research, Federal Biological Research Centre for Agriculture and Forestry, Münster. The results of these previous studies showed that there were some differences in the consumption of baits and rodenticides by rats from several farms in the Münsterland. This phenomenon was presumed to be caused by the differences in the feeding and neophobic behaviour of the rats. Therefore, some experiments were conducted in the laboratory, to examine these possible causes using rats from different farms.

Studies on the feeding preference and rodenticides acceptance were done in separate cages. Among cereals, rolled oats was the most palatable feed while intact oats was the least one. There were some differences in the preference of rats from several farms to cereals and to the feed from one farm, except to maize silage. Previous experiences at the particular farm could affect the feeding behaviour in the laboratory. Newly caught rats consumed feed in an equal amounts compared to long adapted rats from the same farm. Comparing all feed offered, rolled oats was the most palatable feed while soybean coarse meal was the least one.

Preference to attractants was studied in a choice test. Rats preferred bait bases with attractants compared to those without attractants. There were some differences in the preference to several attractants between rats from different farms. However, there were no differences in the preference to vanilla-sugar and egg as attractants. Comparing the consumption of rats differing in sex and body weight, it could be shown that female rats consumed more than males, while small rats did more than the bigger ones.

Several rodenticides were tested, with three bait bases and in several batches. There were some differences in the preference of rats to some rodenticides. However, there were no differences in the rodenticides consumption by rats from different farms. Some, but not significant, differences were observed between the results of laboratory and field trials.

Experiments to study the neophobic behaviour were carried out in an experimental room to that the rats had to be adapted. Then, a lamp which was automatically switched on-off and producing a noise as a new object was placed inside

that box where more of the feed was consumed. The rats were afraid of the new object when it was used for the first time. The consumption and time spent inside both boxes were recorded. The experiments were conducted both at groups and individuals level, using the same and different feed (at individuals level). Different sample of rats from two farms were tested in individuals level following the study at groups level.

In the tests on groups and individuals rats, rats from farm no. 4 showed the lowest level of neophobic behaviour, while rats from farms no. 3 and 5 showed the highest one. Rats tested as individuals or in groups showed in most cases identical responses. Comparing different feed it was shown that rats preferred to consume the most palatable feed over the least one, although there was an interference (new object) around the feed. The highest level of neophobic behaviour was found in rats stemming from very quiet locations, without disturbance, and from frequently controlled areas. The lower the level of neophobic behaviour in rats is, the easier the rats accept several kinds of feed and taste.

There was a correlation between the time interval within two trials and the adaptation time on one hand and the neophobic response on the other hand. The shorter the interval and the longer the adaptation time were, the more familiar the rats were with the new object, showing higher feed consumption and longer time spent inside the box with device. Feeding and neophobic behaviour must be taken into consideration in the chemical control of rats. Experiences at the different farms can affect the preferences to the feed and levels of neophobia in rats. There were three factors at the farm that could affect the feeding responses and levels of neophobia, i. e. disturbance, effectiveness of rat control, and feed availability. The differences in the behaviour of rats resulting from these factors are also detectable in laboratory studies and can be decisive for the effectiveness of rodenticides.

ZUSAMMENFASSUNG

Untersuchungen des Fraßverhaltens und des neophoben Verhaltens von Wanderratten (*Rattus norvegicus* Berkenhout, 1769) auf deutschen Landwirtschaftsbetrieben

Untersuchungen über die Futteraufnahme und das neophobe Verhalten der Wanderratte (*Rattus norvegicus*) wurden in den Jahren 1998 – 2000 am Institut für Nematologie und Wirbeltierkunde der BBA in Münster vorgenommen. Die Ergebnisse dieser früheren Felduntersuchungen ergaben, daß Ratten von verschiedenen Landwirtschaftsbetrieben des Münsterlandes Unterschiede bei der Aufnahme von Ködern und Rodentiziden zeigen. Es wird vermutet, daß dieses Phänomen auf Unterschieden im Fraßverhalten und im neophoben Verhalten der Ratten beruht. Daher wurden Laborversuche durchgeführt, um diese Ursachen an Ratten von verschiedenen Betrieben zu überprüfen.

Die Untersuchungen zur Futterpräferenz und Rodentizidakzeptanz wurden in speziellen Käfigen durchgeführt. Unter den Getreidearten wurden Haferflocken am stärksten bevorzugt, während intakter Hafer am schlechtesten gefressen wurde. Zwischen den Ratten von verschiedenen Betrieben bestanden Unterschiede bei der Aufnahme von Getreidearten und Spezialfutter, außer bei Maissilage. Frühere Erfahrungen der Ratten auf bestimmten Betrieben konnten das Fraßverhalten im Labor beeinflussen. Neugefangene Ratten nahmen Futter in gleicher Menge auf wie Ratten des gleichen Betriebes, die länger an Laborbedingungen angepaßt waren. Bei einem Vergleich aller getesteten Futtermittel ergab sich, daß Haferflocken am stärksten bevorzugt und Sojaschrote am wenigsten gefressen wurden.

Die Wirkung von Lockstoffen wurde in Wahlstudien untersucht. Die Ratten bevorzugten Köder mit Lockstoffen gegenüber solchen ohne Zusätze. In der Reaktion auf die Lockstoffe bestanden einige Unterschiede zwischen den Ratten von verschiedenen Betrieben. Diese Unterschiede bestanden aber nicht bei der Präferenzreaktion gegenüber Vanillezucker und Eiern als Lockstoffe. Bei der Bedeutung des Geschlechts und des Körpergewichts für die Futteraufnahme ergab sich, daß weibliche Ratten mehr Futter aufnehmen als männliche Tiere, und kleine Ratten – bezogen auf das Körpergewicht - mehr fressen als große.

Verschieden Rodentizide wurden in Kombination mit drei Köderarten getestet. Bei der Präferenz verschiedener Rodentizide wurden gewisse Unterschiede beobachtet. Es ergaben sich auch Abweichungen zwischen den Labor- und Feldversuchen. Es

konnten aber keine signifikanten Unterschiede bei der Rodentizidaufnahme zwischen Ratten unterschiedlicher Herkunft festgestellt werden.

Die Versuche zum neophoben Verhalten wurden in einem speziellen Versuchsraum durchgeführt, an den die Ratten zunächst gewöhnt wurden. Danach wurde in dem Futterkäfig, in dem bevorzugt Futter aufgenommen wurde, als ein „neues Objekt" eine Lampe installiert, die unter Geräuschentwicklung automatisch an- und abgeschaltet wurde. Die Ratten hatten beim ersten Gebrauch Angst vor dem neuen Objekt. Als Maß für die Neophobie wurden die Futteraufnahme und die Verweilzeit in den Futterkäfigen gemessen. Die Versuche wurden mit Gruppen und Einzeltieren unter Verwendung verschiedener Futtermittel durchgeführt.

In den Gruppen- und Einzeltierversuchen zeigten die Ratten von Betrieb Nr. 4 den geringsten, die Tiere von den Betrieben Nr. 3 und Nr. 5 den höchsten Grad an Neophobie. Die Ergebnisse der Gruppen- und Einzeltierversuche stimmten in allen Fällen überein. Beim Vergleich der Futtermittel zeigte sich, daß unter allen Versuchsbedingungen das am besten schmeckende bevorzugt wurde, auch dann, wenn Störungen durch neue Objekte in der Nähe der Futterquelle vorhanden waren. Der höchste Grad an Neophobie wurde an Ratten beobachtet, die entweder von ruhigen, wenig gestörten Standorten stammten oder von Betrieben, auf denen häufig eine Rattenbekämpfung durchgeführt wurde. Je geringer der Grad ihrer Neophobie war, desto leichter akzeptierten die Ratten verschiedene Futter- und Köderarten.

Es bestand eine Korrelation zwischen den Versuchsintervallen und der Adaptionszeit einerseits und der neophoben Reaktion andererseits. Je kürzer die Intervalle und je länger die Adaptionszeiten waren desto besser hatten sich die Ratten an das neue Objekt gewöhnt und desto größer waren die Futteraufnahme und die Verweildauer in den Futterkäfigen.

Fraßverhalten und neophobe Reaktionen müssen bei der Rattenbekämpfung mit Rodentiziden berücksichtigt werden. Die Erfahrungen auf verschiedenen Landwirtschaftsbetrieben können die Futterpräferenz und die Neophobie der Ratten beeinflussen, was auch in Laborversuchen erkennbar wird. Vor allem drei Faktoren können auf den Betrieben das spätere Verhalten der Ratten beeinflussen: Störungen durch Lärm etc., die Wirksamkeit der Rattenbekämpfung und die Verfügbarkeit von Futter. Die sich aus diesen Einflüssen ergebenden Unterschiede im Verhalten der Ratten von verschiedenen Betrieben sind auch in Laborversuchen nachweisbar und können für die Wirksamkeit von Rodentiziden entscheiden sein.

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LIST OF CONTENT

LIST OF TABLE

TEXT

APPENDICE

LIST OF FIGURE

TEXT

Number **page**

APPENDIX

APPENDICE

Chapter I. GENERAL INTRODUCTION

Agricultural productivity is influenced by many factors including soil fertility, climate and weather, crop varieties, crop management practices as well as pests and diseases. The last mentioned factor can reduce crop yield in the field and cause losses of commodities in the storage as well. Among important pests that can cause losses of agricultural products both in the field and storage are rodents. This group of pests has a special place among other groups of pests in that they have prominent instinctive behaviour. Thus, sound understanding of their bio-ecology and behaviour is essential for the success of their control.

RODENTS

Rodents or gnawing animals represent an order of mammals, which are characterised by the presence of two pairs of incisors, each pair on the upper and lower jaw. These incisors are growing in size continuously throughout the life of the animal. This characteristic distinguishes the incisors of rodents from the incisors of other mammals in general, which stop growing after reaching a certain size (Brooks & Rowe, 1987). Most damage in agriculture, as well as to urban structures, caused by rodents is due to their gnawing activities, and less damage is caused by their feeding activities. A species of mammals other than rodents which often cause problems in agriculture and urban areas, especially in buildings (indoor pest), is the house shrew (*Suncus murinus*, Soricidae : Insectivora), particularly in South East Asia (Kaukeinen, 1994).

In terms of the number of species, rodents represent the largest group of mammals, with a total of 2,015 species or 43.5% of the total number of mammalian species (4,629 species) (Wilson & Reeder, 1993). This large number of species, coupled with their explosive demography, adaptable ecology, and opportunistic behaviour, have made rodents capable of surviving and competing successfully with other mammalian species.

There are some rodent species that have successfully adapted to the human environment, this group of rodents is called “commensal rodents”. These animals could exploit resources in the human environment, which are normally difficult to be utilised by other rodents. Three known species of commensal rodents are : The

Norway rat or brown rat or common rat (*Rattus norvegicus* Berkenhout, 1769), the roof rat or black rat or ship rat (*Rattus rattus* Linnaeus, 1758), and the house mouse (*Mus musculus* Linnaeus, 1758). The success of these rodents is supported by their ability to live in a wide range of habitats, high reproductive capacity, and omnivorous feeding habits.

THE NORWAY RAT

Like the roof rat and house mouse, which have a world-wide distribution, the Norway rat ranks high among rodents that cause conflicts with human interest. Until the year of 1700, the Norway rat is believed to have lived in the desserts and savannahs of mainland Asia, north of the Caspian Sea, the area of the present-day Russian Federation. Factors causing emigration of this species from that area to other parts of the world by far is unclear. It is believed that a favourable breeding season at that time resulted in a huge population of the Norway rat which in turn triggered a massive migration (Lund, 1994; Temme, 1981).

The Norway rat spread to the west of Russia in the early eighteenth century. In stables and barns in agricultural areas of Russia, the Norway rat found abundant resources (feed and nests) so that the population increased dramatically. From there, the Norway rat migrated further than ever before with the help of transportation means, spreading out to almost all parts of the world.

Biology

Since two hundred years, the Norway rat has adapted to the temperate areas as well as to the tropics. The spread of the Norway rat in the tropical areas started at coastal areas of big cities or seaports, then they spread to human settlement areas where they did not find indigenous important competitors. Nowadays, particularly in urban areas, the Norway rat lives in sewer or drainage systems around human settlements, where the temperature is relatively uniform and food is available throughout the year. In addition, the Norway rat also settles in agricultural buildings/structures, basements, warehouses, refuse dumps, and market places. The species prefers to live in areas with a high humidity level. In general, Norway rats cluster in places with abundant resources, i. e. food, water, and shelter. Such places can easily be found in rural and agricultural areas all over the world.

On the average, adult Norway rats consume 20 – 30 gram of cereal per day. This means that hundred rats in an agriculture area would require one ton of food during a year. The mean size and body weight of the adults vary with age. Norway rats at an early reproductive stage, about 2.5 – 3 months old, weigh about 100 – 150 grams. The weight of a Norway rat at the height of its age, 8 – 10 months old, could reach 300 – 400 grams. Norway rats with a body weight of more than 400 grams could hardly be found (Lund, 1994). However, Meehan (1984) noted that an adult of Norway rat could reach up to 550 grams in body weight, 220 mm in head and body length and 170 mm in tail length.

Feeding Behaviour

Feeding behaviour of the Norway rat needs to be well understood since it serves as one of the bases in the development of rat control programmes, especially when poisoned baits are to be used. It is necessary to know about the time of day when the rats are searching for food, competition in food searching, and kinds of food that are needed and preferred.

As a nocturnal animal, most food searching activities by the Norway rat are done at night, under the darkness. The peak food searching activity of the Norway rat occurs at about one to two hours after the sunset and another peak, which is normally less intense, takes place at about one to two hours before the sunrise (Meehan, 1984).

In temperate countries, during summer the time available for searching for food or finding their mates is limited. Under such conditions, if food supply is limited, the rats may explore food during the daytime. Although during the daytime, most rats stay in their nest and only a few rats still roam about outside the nest (Chitty & Shorten, 1946; Barnett & Spencer, 1951).

There were three ways how Norway rats consumed non-powdered cereal baits, i.e. the rats stood on a bait container and consumed cereals directly on that feeding site, rats feed on food spills scattered by other rats, or the rats hoard up the food into their nests before it is consumed (Chitty, 1954; Barnett & Spencer, 1951). Sridhara & Krishnamurty (1978) and Parrack (1969) added that some other rodents species even pile up the food in a higher amount than is needed. The explanation for the hoarding behaviour is that the food stored serves as food reserve in case the food needed is difficult to find outside their nest. Female rats, particularly the lactating ones, hoard up more food than the males. The rats that often suffer interferences from other rats also pile up more food than they normally do. Davis (1979) argued that the hoarding behaviour is learned by the rats from their parents and does not constitute an intrinsic behaviour.

The rats also store various small objects other than food in their nest. The more familiar the object, the more chance the object to be hoarded (Calhoun, 1962). Nevertheless, Miller & Viek (1944) explained that rats preferred to hoard food rather than non-food objects, particularly for rats that have experienced food shortage conditions.

The above hoarding behaviour needs to be soundly considered in the development of Norway rat control programmes using poisoned baits in order to avoid incorrect interpretation of the amount of poisoned bait consumed. In addition, the development of rat control measures using poisoned bait should also consider the preference of rat toward certain baits, bait placement, and bait avoidance or neophobia (Nieder, 1986).

Exploratory Behaviour

Some animals, including the Norway rat, exhibit an exploratory behaviour towards their environment, especially to an area which is strange or new to them. They approach and enter every site that they find. Exploratory behaviour is a kind of movement activity of animals, which is governed by the presence of strange or new objects in their surroundings. This behaviour represents a biological factor that protects the animal from a dangerous situation that could threaten its live. The exploratory behaviour has developed since the rats are still young, but it is doubtful that there is a fixed pattern that underlies its development. It is assumed that this behaviour is shaped by previous experiences (Barnett, 1958b).

A term "new object reaction" could be used to describe a situation that limits the exploratory behaviour. The Norway rat is very sensitive to any change occurring in its environment. The following changes could evoke the new object reaction in the Norway rat: Moving an object from a previously recognised position to a new one, changing an object with a different object which is similar to the previous one, changing the position of a bait container, changing the kind of bait, a minor change in its habitat like sweeping a dirty floor, and changing in illumination (Shorten, 1954).

The Norway rats refused to enter a bait box which was set for the first time, and it took up to 10 days or more for the rats to explore and finally enter it (Elton & Ranson, 1954). Doty (1938) added that in sugarcane plantation in Hawaii, rats initially refused to consume a new bait and it took three days for the suspicion of rats to disappear. Changes in or interference to the environment of rats could decrease the consumption of poisoned baits by rats. All of the above changes could evoke reactions of rats in nature.

Initially it was believed that the suspicious behaviour of rats was caused by human odour, particularly from the control operator that handled baits with bare hands. However, based on the fact that almost all things including poisoned baits never been touched with human hands cause that behaviour, it is hard to accept that human odour constitutes the main factor eliciting the "new object reaction".

Aggressive Behaviour

Male rats compete and fight each other in order to mate with the female. Stronger and more vigorous male rats would have a greater chance to mate with the females (Meehan, 1984).

Male rats tend to defend their nest from male intruders, and to command a territory around the nest, including female rats living within the territory. Dominant males, which are characterised by a larger body size and longer establishment, will occupy a nest in a strategic location. Sub-dominant males will occupy a less strategic area where those rats could establish a local social dominance (FAO, 1982).

PROBLEMS IN RODENT CONTROL

In general, rodent control methods could be divided into two major categories i.e. non-chemical and chemical methods. Non-chemical rat control measures include the use of mechanical traps (single- or multiple-live and dead traps), non-mechanical trap (glue boards), proofing, clubbing, shooting, sanitation, using predator, and repelling (ultrasonic devices, electromagnetic devices, and noise-makers). Chemical control techniques include the use of poisoned baits, poisoned water, contact toxicants, grooming toxicants, fumigants, and chemical repellent (Kaukeinen, 1994). Elton & Ranson (1954) explained that the development of rat control strategies should consider the following factors: Control efficiency, supply of control materials, availability and cost of operators, safety for the operators, as well as effect on non target organisms, and on the environment.

Sound knowledge of the ecological basis of rat management strategies is essential in the development of rat control methods without disturbing the rat demography (Pelz, 1989). Solving problems in rat control often constitutes a specific case and therefore necessitates sound understanding of basic biology, ecology, and behaviour. Such basic knowledge can be generated through a series of laboratory and field experiments and serve as a basis in the development of new rat control strategies (Singleton *et al*., 1999).

Below some problems are listed that are often encountered in rat control practices, either chemical or non-chemical. Such problems, if not overcome, could lead to control failure:

- In the use of mechanical traps, it is necessary to observe the runway of rats. Otherwise, the traps may be placed at the wrong points. Inappropriate types of bait used in the traps could also lead to control failure.
- The use of natural enemies, especially predators, should be based on the biology, ecology, and behaviour of the predators, including the range of preys. Improper release of predators may become a useless effort because the predators may leave the habitat of rats, or they even may prey on non-target animals.
- Rat control using physical means such as proofing, clubbing, shooting, and netting, often fails due to negligence of the following factors: Rat abundance, presence, hiding places, and demography, as well as the capability of human resources as a control operator.
- In chemical control, there are some conditions that need to be observed in order to achieve optimal results. Among them are the type of suitable bait containers (Elton & Ranson, 1954), and the type of bait and poison to be used, since the failure rate in rat control tended to correlate with low consumption of baits by the rats (Quy *et al*., 1992a, b). It is almost impossible to control a house mice in a restaurant area in Birmingham using cereals with high content of starch, therefore fish-base baits were used (Humphries *et al*., 1996). In another report, Cowan *et al*., (1994) showed that in a field trial only 13% of the rat population consumed poisoned bait to the lethal dose.

- Another problem that needs to be observed in implementing chemical control of rats is resistance. There are two kinds of resistance i. e. behavioural and physiological resistance.
- Behavioural resistance occurs when rat reject to consume the poisoned bait offered. In China, only less than 70% of zokor (*Myospalax fontanieri*) population could be suppressed by the use of the best possible baiting technique, i. e. setting baits in their underground tunnels (Zou *et al*., 1998). Improvement of the control method could be achieved by understanding aspects of feeding behaviour (Zhang & Wan, 1997), as well as social behaviour of bait preference (Berdoy, 1994; Galef, 1994). Rejection of baits could occur because the bait offered was not attractive, or another bait was present around the poisoned bait, or the rats showed a neophobic reaction, so that the baits were not tasted at all.
- In physiological resistance, rats do not die after consuming a poison at a dose that would otherwise kill the rats in a normal population. Preventively, a continuous use of a single type of poison for a relatively long period should be avoided, and the chemical control method should be accompanied by non-chemical ones (Greaves, 1994). Singleton *et al*. (1999) stated that substitution of a particular poison with a stronger one could be done. Moreover, they stated that mapping the geographical distribution of rat resistance to certain poisons also needs to be done.

OBJECTIVES OF THE STUDY

In Norway rat control, there is a co-operation between the Federal Biological Research Centre for Agriculture and Forestry (Biologische Bundesanstalt für Land- und Forstwissenschaft) Münster and farmers in the Münsterland to study some aspects related to rat control including monitoring of rat populations at the farms, evaluating chemical control of rat populations at the farms, and testing the level of resistance of rats from several farms to rodenticides. The level of bait consumption by rats is used as an indicator of rat population level. For the control of rat populations at the farms, some rodenticides were evaluated.

In a resistance test, the susceptibility of rats from several farms to the first- and second-generation anticoagulant rodenticides was evaluated in the laboratory. The first-generation anticoagulants tested were warfarin, chlorophacinone, and coumatetralyl, and the second-generation anticoagulants were bromadiolone, difenacoum, brodifacoum, and flocoumafen.

There are three possible causes of failure of chemical control of rats at the farms: Firstly, there is some evidence that rats from certain locations have developed physiological resistance to commonly used rodenticides. Secondly, bait mixes offered might not be attractive to be visited and consumed by the rats, probably because there was plenty of food available around the bait stations. Thirdly, the rats exhibited a behavioural resistance or neophobic reaction to the baits. These three possibilities may explain the differences in response of rats from different farms to the base baits and rodenticides offered.

In order to prove the first possibility, testing the level of resistance to rodenticides of rats from different farms needs to be done. To confirm the latter two possibilities, it is necessary to conduct behavioural tests in the laboratory related to those phenomena.

This work mostly deals with attempts to better understand the latter two phenomena. The results of studies on the acceptance of baits and rodenticides by Norway rats from different farms are presented and discussed in Chapter II, and those on neophobic behaviour of the rats from different farms are presented and discussed in Chapter III. Finally, Chapter IV contains a general discussion summarizing and integrating the results and discussions of the first three chapters.

Chapter II. FEEDING PREFERENCE AND RODENTICIDE ACCEPTANCE

INTRODUCTION

The pattern of feeding and behaviour in rats towards food is among important factors that need to be considered in planning rat control programmes, because the damage by rats to crops, food products, buildings, etc., is mostly the result of feeding activities. In addition, most control methods, particularly in developed countries, involve the use of poisoned baits or rodenticides.

In this study the behaviour of rats towards food was investigated under laboratory conditions. The principal question to be answered was whether striking differences in rodenticide palatability observed from one farm to the next during field trials in the Münsterland area, Nordrhein-Westfalen, (Pelz, 1999) could be mirrored in the laboratory using rats from these farms. Testing in choice and no-choice trials included several kinds of cereals and typical feed available at a farm. Additional tests concerned the effect of texture and of attractants on the feed palatability. Consumption of rats from all farms was broken down into sex and weight of the rats, and the data were analysed for other factors that affect the pattern of feeding behaviour.

Certain ingredients could be mixed together with poisoned baits to mask bad taste of toxicants, and this could increase the consumption of the poisoned baits by target species to the lethal dose. Among ingredients commonly used to enhance bait consumption are sweetening agents and vegetable oils. Some studies using those materials have been conducted by other workers (Fitzwater, 1979, Kühnert, 1981, and Rentokil, 1983). However, experiments on responses of rats to sweetening agents (granulated-, vanilla-, and powder-sugar), vegetable oils (corn-oil), and animal source (egg) are required to give more information on feeding behaviour of rats towards those ingredients. The tendency of individual rats to prefer specific attractants in combination with certain feed has to be examined, since preferences are varying among rats.

OBJECTIVES

The objectives of the experiments described in this chapter were to determine in rats caught at several farms in the Münsterland area the following parameters:

(1) The most palatable feed among a variety of cereals using choice and no-choice tests.

(2) Feeding responses to cereals and typical feed available at a farm in groups of rats originating from different farms, the effect of sex and weight, and the effect of attractants in the feed on consumption.

(3) The effect of texture of feed on its palatability.

(4) The effect of adaptation time in the laboratory on responses of rats to the feed.

(5) The palatability of rodenticides commonly used by the Federal Biological Research Centre for Agriculture and Forestry, Institute for Nematology and Vertebrate Research, Münster, Germany during the period of 1996 – 1998, and the variation in acceptance.

METHODS

General conditions at the farms

The general conditions at each of the farms were recorded to enable relating the results obtained in the laboratory with the situation at the farms.

Bait Acceptance Tests

There is a number of methods that could be used to obtain the most acceptable feed (Chitty, 1954; Kühnert, 1981; Yuet-Ming, 1980).

In the choice test used in this study, rats were kept singly in Macrolon® cages (40 cm length, 25 cm width, and 15 cm height). Two bait containers made of metal containing two kinds of feed were weighed, then they were introduced into each of the cages, at opposing sides, left and right. After 24 hours, the remainder of the feed in both containers was weighed to measure the consumption. The experiment was conducted with several rats, either for one night or four nights continuously, feeder positions were alternated daily to minimize possible side preference bias.

In the no-choice test used in this study, one bait container as above containing a particular kind of feed was weighed, then it was introduced in the rat cage with one rat inside. After 24 hours, the remainder of the feed in the container was weighed to measure the feed consumption for 24 hours. This treatment was carried out with several rats for three continuous nights. On the fourth-night, the feed was replaced with a different kind of feed/bait and the consumption of this feed/bait was also recorded. This treatment was conducted with several rats for one night.

In all experiments, the data were expressed as g of feed consumed/100 g of body weight (Marsh, 1986). Statistical analysis of variance was done using SAS System for Windows v 6.12, followed by paired t-test and Tukey's test at $\alpha = 0.05$ to test the differences in feed consumption among rats from different farms and among feed. The kinds of feed acceptance experiments conducted in this study are shown in Table 1.

In experiment 2, feed consumption by rats from selected farms was compared: Farm no. 3 (10 rats), no. 4 (6 rats), no. 5 (10 rats), no. 9 (10 rats), no. 14 (4 rats), no. 17 (7 rats), and no. 23 (12 rats). Experiments with rats from farm no. 23 were conducted with two different groups of test animals. One group was tested shortly after they had been caught at the farm (= farm no. 23A): five rats for the test with cereals and typical feed from farm (experiment 2 and 4) and four rats for the test with attractants (experiment 5). The other group was kept in the laboratory for at least one year before the rats were used for the study (= farm no. 23, seven rats). Rats from other farms were used after they had been adapted in the laboratory for one year. The choice of these farms was based on the distribution of the locations (Appendix 6).

In experiment 4, methods and rats used were the same as in experiment 2. Typical feed available at farm no. 23 was chosen for this experiment because considerable efforts had been made to control rats at this farm. In addition, the objective of this experiment was to investigate the effect of adaptation time in the laboratory on feeding responses to typical feed from the farm. Since maize silage had a very high moisture content, it was necessary to measure the rate of evaporation of this feed. For this purpose, one additional bait container containing maize silage was placed outside the test cage. Weight losses due to evaporation could be deducted from the actual consumption.

Pig feed at farm no. 23 contained barley, wheat, soybean coarse meal, concentrated feed stuff, and some minerals. Concentrated feed stuff contained wheat, chip pellets, rape coarse meal, maize flour, maize gluten feed, soybean extract coarse meal, molasses, calcium carbonate, sodium, and vitamin-mixture. The nutritional

Table 1. Overview of the feed/bait acceptance experiments conducted in this study

No	Experiment	Method	Feed/Baits compared
1.	Feed preference test	Choice test	a. Rolled oats vs de-husked oats, oats, wheat, rye, barley, maize b. De-husked oats vs oats, wheat c. Oats vs wheat d. Rolled oats, de-husked oats, oats, wheat (four kinds of feed)
		No-choice test	a. Rolled oats vs rolled oats, de-husked oats, oats, wheat, rye, barley, maize b. De-husked oats vs de-husked oats c. Oats vs oats d. Wheat vs wheat
2.	Feeding responses to cereal feed	Choice test	Altromin pellet vs rolled oats, oats, de-husked oats, wheat, rye, barley, maize
3.	Palatability of pelleted versus ground feed	Choice test	Altromin pellet vs ground feed
4.	Feeding responses to typical feed available at a farm	Choice test	Altromin pellet vs barley, pig feed, soybean coarse meal, concentrated feed stuff, maize silage
5.	Feeding responses to attractants	Choice test	a. Altromin meal vs 10 % of granulated-sugar and 8 % of vanilla-sugar in altromin meal b. Rolled oats vs 10 % of egg, 5 % of powder-sugar, 2.5 % of corn-oil, 5 % of powder-sugar + 2.5 % of corn-oil in rolled oats feed
6.	Rodenticide palatability test	Choice and no-choice test	a. Rolled oats vs warfarin batch 1, 2, -wheat; coumatetralyl batch 1, 2, 3; bromadiolone batch 1, 2, 3, –oats; difenacoum batch 1, 2, –wheat; brodifacoum batch 1 b. Oats vs bromadiolone-oats c. De-husked oats vs bromadiolone-oats d. Wheat vs warfarin-, difenacoum-wheat

contents of the concentrated feed stuff were 18.00% raw protein, 2.60% raw fat, 8.30% raw fibre, 6.00% raw ash, 0.70% calcium, 0.50% phosphor, and 0.20% sodium.

In experiment 5, a pre-test was conducted to determine the optimum concentration of attractants in the feed. Four levels of granulated-sugar concentration were tested: 0, 5, 10, and 15%. Two bait containers containing altromin meal with 0 and 5% of granulated-sugar were tested for four nights. Another trial was conducted with different concentration levels of granulated-sugar in the altromin meal (0 - 10 and 0 - 15 %). The same procedures were used in the pre-test using vanilla-sugar (0 - 2; 0 - 4; 0 - 8; and 0 - 10%) in the altromin meal. Another pre-test was conducted to examine the effect of egg as attractant in the rolled oats on the consumption. Two bait containers containing rolled oats with 0 and 10% of egg were tested for four nights. The next pre-test was conducted to examine the effect of water content in the egg on bait palatability. Two bait containers containing rolled oats with 10% of water and 10% of egg were tested for four nights.

In experiment 6, bait preparations were supplied by commercial companies, and in all cases they were divided into several batches. A rodenticide bait preparation made from a liquid concentrate at common field strength of active ingredient with a variety of bait bases (oats, rolled oats, de-husked oats, and wheat) was supplied.

The results of choice tests can be expressed in one of two ways (EPPO, 1982):

$$\textbf{Bait Acceptance} = \frac{\text{Total weight (g) of rodenticide/feed eaten}}{\text{Total weight (g) of control + rodenticide/feed eaten}} \times 100\ \%$$

$$\textbf{Palatability Ratio} = \frac{\text{Total weight (g) of rodenticide/feed eaten}}{\text{Total weight (g) of control eaten}} \times 100\ \%$$

Bait acceptance uses a finite scale of 0 – 100, whereas the palatability ratio is an asymmetric scale ranging from zero to infinity, around the neutral preference level of 100.

RESULTS

The general conditions at each farm where the rats were caught are described in Table 2. Maize silage was available at all farms under study, and other types of feed available at some farms were pig feed and cereals.

Table 2. General conditions at the farms from where rats were taken for laboratory trials

Type of farms	Disturbance	Effectiveness of rat control	Feed available	Farm numbers
I	High	High to moderate	Maize silage, pig feed, and cereal	3, 17, 23
II	Medium	High	Maize silage and cereal	9
III	Medium	Low	Maize silage, pig feed, and cereal	4
			Maize silage	14
IV	Low	Low	Maize silage and pig feed	5

Experiment 1. Feed preference test

(a) Choice test

Rolled oats was the most palatable feed compared with the other feed tested (de-husked oats, oats, wheat, rye, barley, and maize), then followed by de-husked oats, and oats was the least palatable feed (Table 3).

Wheat, rye, and barley were at about the same level of palatability (palatability ratio = 14 – 19 %) compared to rolled oats; and the palatability of maize feed (28 %) lay between de-husked oats (45 %) and the three feed above (wheat, rye, and barley). The Norway rats preferred de-husked oats when paired with oats or wheat, and the rats preferred wheat to oats. Oats was more attractive to the test animals when offered in combination with wheat compared with de-husked oats and rolled oats (palatability ratio = 20.29 % compared to 1.46 % and 1.55 %).

Like in the above choice test, in the test with four choices, the Norway rats preferred rolled oats mostly, then followed by de-husked oats, wheat, and oats, although there were no significant differences between rolled oats and de-husked oats, and between wheat and oats (Table 4).

Table 3. Palatability of Norway rats to some cereals (choice test)

Feed I vs II	Consumption (g) ** x ± SD (n)		Palatability ratio II/I (%)
	Feed I	Feed II	
Rolled oats vs de-husked oats 1	8.39 ± 6.36 (10) a	6.15 ± 4.55 (10) a	73.30
Rolled oats vs de-husked oats 2 *	4.13 ± 1.92 (40) a	1.86 ± 1.66 (40) b	45.04
Rolled oats vs oats 1	16.81 ± 4.61 (10) a	0.26 ± 0.49 (10) b	1.55
Rolled oats vs oats 2 *	5.59 ± 0.81 (40) a	0.10 ± 0.22 (40) b	1.79
Rolled oats vs wheat 1	15.58 ± 7.22 (10) a	3.73 ± 5.44 (10) b	23.94
Rolled oats vs wheat 2 *	5.37 ± 1.32 (40) a	0.83 ± 0.75 (40) b	15.46
Rolled oats vs rye *	5.72 ± 1.21 (40) a	0.83 ± 0.79 (40) b	14.51
Rolled oats vs barley *	6.20 ± 1.58 (40) a	1.16 ± 1.08 (40) b	18.71
Rolled oats vs maize *	5.47 ± 1.28 (40) a	1.55 ± 1.38 (40) b	28.34
De-husked oats vs oats	20.55 ± 4.51 (10) a	0.3 ± 0.66 (10) b	1.46
De-husked oats vs wheat	17.33 ± 7.07 (10) a	3.45 ± 3.59 (10) b	19.91
Wheat vs oats	10.20 ± 7.02 (10) a	2.07 ± 2.39 (10) b	20.29

* Data were expressed as g/100 g of body weight
** Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

Table 4. Palatability of Norway rats to four kinds of cereals (choice test)

Feed	Consumption (g/100 g of body weight) * x ± SD
Rolled oats	7.50 ± 4.12 a
De-husked oats	5.75 ± 5.38 a
Wheat	2.40 ± 2.34 b
Oats	0.35 ± 0.45 b

* N = 20, means in the same column followed by the same letter are not significantly different according to Tukey's test ($\alpha = 0.05$)

(b) No-choice test

In the no-choice tests, in all cases the Norway rats consumed less amounts of feed if they had previously been provided with rolled oats. The least subsequent consumption was recorded with oats, followed by barley, wheat, rye, de-husked oats, maize, and rolled oats (Table 5).

Table 5. Palatability of Norway rats to some cereals (no-choice test)

Feed I vs II	**Consumption (g/100 g of body weight) * x ± SD (n)**		**Palatability ratio II/I (%)**
	Feed I	**Feed II**	
Rolled oats vs de-husked oats	6.60 ± 5.19 (30) a	5.19 ± 1.99 (10) b	78.64
Rolled oats vs oats	6.59 ± 1.38 (30) a	2.72 ± 1.45 (10) b	41.27
Rolled oats vs wheat	7.34 ± 1.37 (30) a	4.59 ± 1.42 (10) b	62.53
Rolled oats vs rye	6.12 ± 0.98 (30) a	3.97 ± 0.98 (10) b	64.87
Rolled oats vs barley	7.09 ± 1.22 (30) a	3.98 ± 1.39 (10) b	56.14
Rolled oats vs maize	6.83 ± 1.15 (30) a	5.92 ± 1.69 (10) a	86.68
Rolled oats vs rolled oats 1 (winter)	7.88 ± 1.58 (30) a	6.48 ± 1.55 (10) b	82.23
Rolled oats vs rolled oats 2 (summer)	7.46 ± 1.43 (30) a	6.63 ± 1.03 (10) a	88.87
De-husked oats vs de-husked oats	7.49 ± 0.91 (30) a	6.98 ± 0.93 (10) a	93.19
Oats vs oats	6.50 ± 2.46 (30) a	6.04 ± 1.73 (10) a	92.92
Wheat vs wheat	5.80 ± 2.74 (30) a	5.76 ± 1.04 (10) a	99.31

* Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

The feed consumption by rats during the last night (fourth-night) was always lower than during the previous three nights (82 – 99 %), although the differences were not significant, except for rolled oats feed in winter time (palatability ratio = 82 %).

There were no significant differences in the consumption of rolled oats and maize feed (palatability ratio = 87 %); while wheat, rye, and barley were at about the same level of palatability (56 – 65 %) compared with rolled oats feed; and oats was the least palatable feed (41 %).

Subsequent consumption of de-husked oats, oats, and wheat did not decrease markedly if the rats had previously been fed with the same feed.

Experiment 2. Feeding responses of rats to cereals

With regard to the origin of the test animals, rats from farm no. 3, 4, and 17 consumed higher amounts of cereals (6.72 g, 6.01 g, and 6.07 g, respectively) (Table 6), because there were cereals at the farm where they came from (Table 2). On the other hand, rats from farm no. 23A and 9 consumed lower amounts of cereals (4.90 g and 5.42 g), although there were cereals at the farm where they had lived before.

Rats from farm no. 5, the farm with the lowest level of disturbance (Table 2), consumed the highest amount of cereals (7.29 g) compared with rats from other farms. In rats from farms no. 3, 17, and 23, where the level of disturbance was high, a relatively lower amount of cereal consumption was found (6.72 g, 6.07 g, and 5.80 g, respectively).

With view to effectiveness of rodent control in the field, there were no significant differences in the cereal consumption between those farms, achieving high effectiveness (farm no. 3 and 9) and those where effectiveness was low (farm no. 4, 5, and 14).

There was relatively large variation in the consumption of seven kinds of feed by the rats from different farms. Rats from farms no. 5, 4, 23, 3, and 17 consumed higher amounts of **rolled oats** compared to those from farm no. 23A and 9. Rats from farms no. 5, 3, and 17 consumed more **oats** compared to those from farms no. 23A and 4. Rats from farm No. 4 consumed a higher quantity of **de-husked oats** compared to those from other farms. Rats from farms no. 23A, 5, 3, and 17 consumed more **wheat** compared to those from farm no. 9. Rats from farm No. 5 consumed the highest quantity of **rye** compared to those from other farms, except from rats from farm no. 4. Rats from farms no. 5, 3, and 23 consumed more **barley** compared to those from farm no. 23A. Rats from farms no. 5, 3, 9, and 17 consumed more **maize** compared to those from farm no. 23A (Table 6).

Table 6. Consumption of cereals by Norway rats from different farms

Farm number	Consumption of indicated feed (g/100 g of body weight) * x ± SD (n)							
	Rolled oats	Wheat	Maize	Barley	De-husked oats	Rye	Oats	Mean
3	8.05 ± 1.29 (40) ab	7.72 ± 1.45 (40) a	7.53 ± 2.09 (40) a	7.12 ± 1.45 (40) ab	5.92 ± 0.91 (60) b	6.10 ± 1.98 (40) b	4.58 ± 3.03 (40) a	**6.72**
4	8.20 ± 1.85 (24) ab	6.76 ± 2.14 (24) ab	4.85 ± 3.47 (24) bc	5.93 ± 2.82 (24) bc	7.96 ± 0.56 (6) a	6.27 ± 2.38 (24) ab	2.09 ± 1.74 (24) C	**6.01**
5	8.56 ± 1.09 (40) a	7.80 ± 3.23 (40) a	7.54 ± 2.38 (40) a	7.78 ± 1.81 (40) a	6.33 ± 1.03 (24) b	8.23 ± 4.24 (40) a	4.79 ± 2.74 (40) a	**7.29**
9	6.44 ± 1.65 (40) c	5.05 ± 2.09 (40) b	6.40 ± 2.77 (40) ab	6.15 ± 1.59 (40) b	5.49 ± 1.65 (31) b	5.55 ± 1.72 (40) b	2.85 ± 2.05 (40) bc	**5.42**
14	7.04 ± 0.78 (16) bc	6.32 ± 1.06 (16) ab	6.06 ± 1.99 (16) abc	5.87 ± 1.07 (16) bc	-	5.05 ± 1.18 (16) b	3.18 ± 2.78 (16) abc	**5.59**
17	7.90 ± 1.44 (28) ab	6.97 ± 2.63 (28) a	6.31 ± 2.61 (28) ab	6.10 ± 2.86 (28) b	5.97 ± 0.88 (19) b	5.08 ± 2.60 (28) b	4.19 ± 2.24 (28) ab	**6.07**
23	8.10 ± 0.93 (28) ab	6.40 ± 2.71 (28) ab	6.14 ± 2.45 (28) abc	6.53 ± 1.73 (28) ab	6.23 ± 1.09 (60) b	4.63 ± 2.85 (28) b	2.59 ± 1.72 (28) bc	**5.80**
23A	6.30 ± 0.69 (16) c	8.58 ± 3.22 (16) a	3.80 ± 1.31 (16) c	4.08 ± 1.11 (16) c	-	5.43 ± 2.98 (20) b	1.23 ± 1.36 (16) c	**4.90**
Mean	**7.67**	**6.92**	**6.58**	**6.45**	**6.06**	**5.96**	**3.45**	

* Means in the same column followed by the same letter are not significantly different according to Tukey's test ($\alpha = 0.05$)

The rats from farm no. 5 showed the highest consumption in six (rolled oats, oats, wheat, rye, barley, maize) out of seven cereals, then followed by rats from farm no. 3, in five cereals (rolled oats, oats, wheat, barley, maize). On the other hand, rats from farm no. 23A showed the lowest consumption in five (rolled oats, oats, rye, barley, maize) out of six cereals, then followed by rats from farm no. 9, in five out of seven cereals (rolled oats, oats, de-husked oats, wheat, and rye).

Rats from farm no. 9 and No. 14 which had a bigger size (318.5 g and 352.0 g of body weight respectively) than those from other farms consumed less feed (5.42 g and 5.59 g respectively). Rats from farm no. 23A showed inconsistency in feed consumption which ranged from 1.23 g (the lowest consumption on oats) to 8.58 g (the highest consumption on wheat). On the other hand, rats from farm no. 5 which had the smallest size among the test rat populations (195.5 g of body weight) consumed more feed (7.29 g) (Table 6).

Experiment 3. Palatability of pelleted versus ground feed

Rats from all farms studied showed much higher preferences to altromin pellets (7.45 g) than to altromin meal (1.04 g). However, there were no differences in altromin meal consumption among rats from different farms (Table 7). The nutritional content of altromin is presented in Appendix 1.

Table 7. Consumption of altromin meal and pellets by Norway rats from different farms

Farm number	**Consumption (g/100 g of body weight) * x ± SD (n)**	
	Altromin meal	**Altromin pellets**
3	1.74 ± 2.47 (40) a	7.12 ± 3.11 (40) b
4	0.49 ± 1.13 (24) a	7.54 ± 2.15 (24) b
5	1.45 ± 2.30 (40) a	7.93 ± 2.84 (40) b
9	1.02 ± 1.79 (40) a	6.49 ± 2.74 (40) b
14	0.62 ± 1.06 (16) a	5.68 ± 1.27 (16) b
17	1.22 ± 2.28 (28) a	7.66 ± 1.74 (28) b
23	0.93 ± 1.77 (28) a	8.49 ± 1.79 (28) b
23A	0.82 ± 1.24 (16) a	8.68 ± 3.15 (16) b
Means	**1.04**	**7.45**

* Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

Experiment 4. Feeding responses of rats to typical feed available at farm

Rats from farms no. 9 and 14, coming from farms where pig feed was unavailable, consumed lower pig feed than those from other farms. Rats from farms with a high level of disturbance (farms no. 3, 17, and 23) consumed lower amounts of typical feed from a farm, than rats from a farm with low disturbance (farm no. 5). These results confirm the observations made in experiment 2.

Rats from farms with a high level of effectiveness in rodent control (farms no. 3 and 9) consumed higher amounts of typical feed from a farm than rats from farms with low levels of effectiveness in rodent control (farms no. 4, 5, and 14).

There was relatively large variation in the consumption of five kinds of typical feed from a farm by the rats from different farms. Rats from farms no. 5, 23A, and 3 consumed more **barley** from a farm compared to those from farm no. 4. Rats from farm no. 3 consumed the highest amount of **pig feed** and differed from the rats from farms no. 14, 4, 9, and 17. Rats from farm no. 17 consumed the highest quantity of **concentrated feed stuff**, and the consumption was different from that by rats from farms no. 4, 9, 14, and 3. Rats from farm no. 23A consumed the highest amount of **soybean coarse meal** compared with those from other farms. There were no significant differences among rats of all farms in the consumption of **maize silage** (Table 8).

The bigger rats from farms no. 14 and 9 (352.0 g and 318.5 g of body weight respectively) consumed less feed (2.27 g and 2.97 g respectively) than those from other farms, while rats from farm no. 4 showed inconsistency in consumption; they consumed very few feed from farm no. 23 (Table 8), but consumed a very high amount of cereal feed (Table 6). On the other hand, the smallest rats from farm no. 5 (195.5 g) consumed more feed (3.73 g) than those from other farms (Table 8).

Rats kept in the laboratory for a long time (no. 23A) consumed the same amount of feed from the farm with those caught at the same farm shortly before testing (no. 23) (Table 8).

Comparison of consumption of feed and altromin pellets

By using the data in Table 6 and 8 along with the data on consumption of altromin pellets, the consumption of several baits was compared with that of altromin pellets (Table 9). Rats from all farms preferred to consume most kinds of feed over altromin pellets, except for oats, soybean coarse meal, concentrated feed stuff, and maize silage (feed per total consumption = 38.08%, 3.89%, 22.93%, and 19.34%, respectively) (Table 9).

Table 8. Consumption of typical feed available at the farm by Norway rats from different farms

Farm number	**Consumption of indicated feed (g/100 g of body weight) * x ± SD (n)**					
	Barley from farm	**Pig feed**	**Concentrated feed stuff**	**Maize silage**	**Soybean coarsemeal**	**Mean**
3	6.31 ± 1.58 (40) a	8.13 ± 2.94 (40) a	1.97 ± 2.03 (40) bc	1.87 ± 1.25 (20) a	0.29 ± 0.29 (40) b	**3.71**
4	4.59 ± 3.38 (24) b	5.07 ± 2.58 (24) bc	1.07 ± 1.13 (24) c	1.23 ± 0.97 (12) a	0.22 ± 0.30 (24) b	**2.44**
5	7.17 ± 2.00 (40) a	6.48 ± 2.69 (40) ab	2.28 ± 2.00 (40) abc	2.32 ± 1.89 (20) a	0.39 ± 0.32 (40) b	**3.73**
9	5.93 ± 1.34 (40) ab	5.17 ± 2.91 (40) b	1.20 ± 1.72 (40) c	2.15 ± 1.80 (20) a	0.42 ± 0.58 (40) b	**2.97**
14	6.14 ± 1.98 (16) ab	2.09 ± 2.21 (16) c	1.51 ± 2.03 (16) bc	1.45 ± 0.96 (8) a	0.15 ± 0.13 (16) b	**2.27**
17	5.96 ± 1.55 (28) ab	5.41 ± 2.93 (28) b	3.54 ± 2.94 (28) a	1.93 ± 1.56 (14) a	0.25 ± 0.31 (28) b	**3.42**
23	6.19 ± 1.51 (28) ab	5.90 ± 3.76 (28) ab	2.36 ± 2.03 (28) abc	1.62 ± 1.17 (14) a	0.24 ± 0.25 (28) b	**3.26**
23A	6.49 ± 2.22 (16) a	6.61 ± 4.55 (16) ab	3.15 ± 2.62 (16) ab	1.69 ± 1.13 (8) a	0.94 ± 1.10 (16) a	**3.78**
Mean	**6.16**	**5.91**	**2.08**	**1.87**	**0.35**	

* Means in the same column followed by the same letter are not significantly different according to Tukey's test (α = 0.05)

Rolled oats and wheat were consumed at higher amounts compared with other cereals. Barley from the market was consumed at about the same quantity as barley from farm. Barley from farm and pig feed were consumed more than other typical feed from farm.

Table 9. Comparison of consumption of different feed and altromin pellets by Norway rats

Types of feed	Consumption (g/100 g of body weight) * x ± SD (n)		Relative consumption of feed (%) **
	Feed (Absolute)	Altromin Pellets	
Rolled oats	7.67 ± 1.53 (232) a	0.55 ± 0.81 (232) b	93.31
Wheat	6.92 ± 2.63 (236) a	1.30 ± 1.99 (236) b	84.18
Maize	6.58 ± 2.67 (216) a	2.02 ± 2.40 (216) b	76.51
Barley from market	6.45 ± 2.11 (232) a	1.71 ± 1.97 (232) b	79.04
Barley from farm	6.16 ± 2.03 (232) a	1.86 ± 1.94 (232) b	76.81
De-husked oats	6.06 ± 1.18 (200) a	0.09 ± 0.19 (200) b	98.54
Rye	6.05 ± 3.10 (196) a	2.43 ± 2.49 (196) b	71.34
Pig-feed	5.91 ± 3.38 (236) a	2.91 ± 2.82 (236) b	67.01
Oats	3.45 ± 2.58 (232) a	5.61 ± 2.75 (232) b	38.08
Concentrated feed stuff	2.08 ± 2.20 (232) a	6.99 ± 2.26 (232) b	22.93
Maize silage	1.87 ± 1.47 (116) a	7.80 ± 1.60 (232) b	19.34
Soybean coarse meal	0.35 ± 0.48 (232) a	8.65 ± 1.72 (232) b	3.89

* Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)
** Percentage of feed consumption per total consumption

In absolute value, rolled oats (7.67 g) was the most palatable feed to rats from all farms compared with other feed, then followed by wheat (6.92 g), maize (6.58 g), barley (6.45 g), barley from farm (6.16 g), and de-husked oats (6.06 g). All feeds were consumed at amounts of > 6 g/100 g of body weight per day. In the same time, rye (5.96 g) and pig feed (5.91 g) were consumed at a medium amounts (5 - 6 g per 100 g of body weight per day). Oats (3.45 g), concentrated feed stuff (2.08 g), maize silage (1.87 g), and soybean coarse meal (0.35 g) were consumed at very low amounts (< 4 g/100 g of body weight per day).

In relative value (percentage of feed consumption per total consumption), de-husked oats (98.54 %) was the most palatable bait, then followed by rolled oats (93.31 %) and wheat (84.18 %). Barley from market, barley from farm, maize, rye, and pig-feed were at about the same level of palatability (67 – 79 %). The others showed less than 40 % of palatability level.

Experiment 5. Feeding responses of rats to attractants

Pre-test

1. Granulated-sugar

Rats preferred to consume altromin meal containing 10% of granulated-sugar, to other concentrations (5% or 15%). The consumption of altromin meal with granulated-sugar as an attractant was always higher than that of altromin meal without attractant (0%) (Appendix 2).

2. Vanilla-sugar

Rats preferred to consume altromin meal containing 8% of vanilla-sugar to other concentrations (2%, 4%, or 10%). Consumption of altromin meal containing vanilla-sugar as an attractant was always higher than that of altromin meal without attractant (0%) (Appendix 3).

3. Egg

Rats preferred to consume rolled oats containing 10% of egg to those with 0% of egg and 10% of water (Appendix 4).

Feeding response test using attractants

In accordance with the results in experiment 2 and 4, results in experiment 5 showed the same tendency in the consumption of feed plus attractants with view to disturbance at the farm where rats came from. Rats from farms with higher levels of disturbance (farms no. 3, 17, and 23) consumed less feed plus attractants (4.97 g, 4.81 g, and 5.24 g) in comparison to farms with lower levels of disturbance (5.33 g in farm no. 5) (Table 10).

There was also a contradiction concerning the effectiveness of rat control and the consumption of feed plus attractants. Rats from farms with high levels of effectiveness (farms no. 3 and 9) consumed lower amounts of feed plus attractants (4.97 g and 5.05 g) compared with rats from farms with low levels (farms no. 4 = 5.93 g and no. 5 = 5.33 g).

Table 10. Consumption of feed with different attractants by Norway rats from different farms

Farm number	Consumption of feed (g/100 g of body weight) * x ± SD (n)						
	Altromin meal with		Rolled oats with				Means
	10% granulated-sugar	8% vanilla-sugar	10% egg	5% powder-sugar (p-s)	2.5% corn-oil (c-o)	5% p-s & 2.5% c-o	
3	6.27 ± 1.45 (40) b	6.41 ± 1.43 (40) a	4.78 ± 2.03 (40) a	3.56 ± 1.60 (44) b	4.46 ± 1.96 (44) ab	4.31 ± 1.92 (44) a	**4.97**
4	6.36 ± 2.67 (16) b	6.68 ± 2.37 (16) a	4.24 ± 2.06 (16) a	6.38 ± 1.49 (4) a	6.19 ± 1.74 (4) a	5.72 ± 2.46 (8) a	**5.93**
5	7.04 ± 1.38 (40) ab	7.37 ± 1.32 (40) a	4.99 ± 1.78 (40) a	4.11 ± 2.06 (20) b	4.20 ± 1.84 (24) ab	4.27 ± 2.21 (32) a	**5.33**
9	6.33 ± 1.81 (40) b	6.41 ± 1.43 (40) a	4.52 ± 1.42 (40) a	3.61 ± 1.27 (20) b	4.20 ± 1.70 (20) ab	5.21 ± 2.14 (20) a	**5.05**
14	5.27 ± 0.71 (4) b	5.90 ± 1.51 (4) a	3.02 ± 1.69 (4) a	-	-	-	**-**
17	6.68 ± 1.25 (24) b	6.32 ± 1.77 (24) a	4.12 ± 1.42 (24) a	3.36 ± 1.22 (12) b	3.49 ± 1.53 (12) b	4.88 ± 3.04 (16) a	**4.81**
23	6.54 ± 1.83 (28) b	6.95 ± 1.72 (28) a	4.32 ± 1.28 (28) a	4.59 ± 1.73 (44) ab	4.78 ± 1.73 (44) ab	4.24 ± 1.56 (32) a	**5.24**
23A	8.35 ± 0.66 (16) a	7.20 ± 2.63 (16) a	3.72 ± 2.36 (16) a	-	-	-	**-**

* Means in the same column followed by the same letter are not significantly different according to Tukey's Test ($\alpha = 0.05$)

Rats from farm no. 23A consumed the highest quantity of altromin meal containing 10% of granulated sugar compared with rats from other farms, except those from farm no. 5. There were no differences among rats from different farms in consuming altromin meal with 8% of vanilla-sugar and rolled oats with 10% of egg.

Rats from farm no. 4 consumed the highest amount of rolled oats containing 5% of powder-sugar compared with rats from other farms, except for rats from farm no. 23. Rolled oats containing 2.5% of corn-oil were also most preferred by rats from farm no. 4 and the consumption was higher than that by rats from farm no. 17. Rolled oats containing those two attractants were also consumed mostly by rats from farm no. 4, but the difference was not significant (Table 10).

Differences in attractants consumption

Using the data in Table 10 added with the consumption on feed without attractants, the preference of rats to the feed with and without attractants could be determined (Table 11).

Table 11. Effect of some attractants on the consumption by Norway rats

Attractants	**Feed Consumption (g/100 g of body weight) * x ± SD (n)**	
	With attractants	**Without attractants**
Granulated-sugar 10 %	6.66 ± 1.70 (208) a	0.61 ± 1.04 (208) b
Vanilla-sugar 8 %	6.73 ± 1.72 (208) a	0.45 ± 0.95 (208) b
Egg 10 %	4.47 ± 1.76 (208) a	2.07 ± 1.52 (208) b
Powder-sugar 5 %	4.02 ± 1.73 (144) a	2.47 ± 1.54 (144) b
Corn-oil 2.5 %	4.45 ± 1.83 (148) a	2.40 ± 1.79 (148) b
Powder-sugar 5 %, corn-oil 2.5 %	4.54 ± 2.13 (152) a	2.26 ± 1.90 (152) b

* Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

Among feed plus attractants tested, altromin meal with 8% of vanilla-sugar and 10% of granulated-sugar were consumed more than rolled oats feed with 10% of egg, 5% of sugar-powder, 2.5% of corn-oil, and combination of the last two attractants.

Effect of sex and weight on feed/bait consumption

The data in Table 6, 8, and 11 were analysed to investigate the effect of sex and weight on feed consumption (Table 12).

Table 12. Consumption of 20 kinds of feed by the Norway rats of different sex and body weight

Feed	Consumption (g/100 g of body weight) * x ± SD (n)			
	Male	Female	Big (> 275 g)	Small (< 275 g)
Rolled oats-1	7.09 ± 1.56 (100) a	8.12 ± 1.35 (132) a	6.77 ± 1.26 (104) b	8.41 ± 1.31 (128) a
Rolled oats-2	5.94 ± 1.11 (72) a	6.17 ± 1.30 (108) a	6.06 ± 1.11 (124) a	6.12 ± 1.47 (56) a
De-husked oats	6.26 ± 1.01 (84) a	5.90 ± 1.27 (114) b	6.00 ± 0.98 (144) a	6.20 ± 1.61 (54) a
Oats	2.87 ± 2.48 (116) a	3.28 ± 2.60 (164) a	2.29 ± 2.08 (132) b	3.84 ± 2.72 (148) a
Wheat	6.17 ± 2.55 (116) b	7.64 ± 2.51 (120) a	5.92 ± 2.15 (108) b	7.76 ± 2.71 (128) a
Rye	5.01 ± 2.27 (112) b	6.82 ± 3.16 (124) a	4.64 ± 1.90 (100) b	6.94 ± 3.15 (136) a
Barley	6.20 ± 1.60 (104) a	6.66 ± 2.43 (128) a	5.56 ± 1.56 (104) b	7.18 ± 2.22 (128) a
Maize	6.17 ± 2.03 (100) a	6.55 ± 3.10 (132) a	5.67 ± 2.26 (104) b	6.97 ± 2.87 (128) a
Barley from farm	5.71 ± 1.40 (100) b	6.50 ± 2.34 (132) a	5.50 ± 1.56 (104) b	6.69 ± 2.21 (128) a
Soybean coarse meal	0.24 ± 0.28 (100) b	0.43 ± 0.57 (132) a	0.26 ± 0.40 (108) b	0.42 ± 0.53 (124) a
Pig feed	5.35 ± 3.11 (104) b	6.35 ± 3.52 (132) a	4.92 ± 3.06 (104) b	6.69 ± 3.42 (132) a
Concentrated feed stuff	1.60 ± 1.77 (100) b	2.45 ± 2.41 (132) a	1.91 ± 2.11 (112) a	2.25 ± 2.27 (120) a
Maize silage	1.70 ± 1.35 (50) a	2.00 ± 1.55 (66) a	1.62 ± 1.12 (54) a	2.08 ± 1.69 (62) a
Altromin meal	1.13 ± 1.95 (100) a	1.14 ± 2.00 (132) a	0.91 ± 1.76 (100) a	1.31 ± 2.11 (132) a
Alt. Meal plus 10% granulated-sugar	6.26 ± 1.46 (100) b	7.03 ± 1.82 (108) a	6.27 ± 1.55 (116) b	7.14 ± 1.76 (92) a
Alt. Meal plus 8 % vanilla-sugar	6.32 ± 1.64 (100) b	7.11 ± 1.71 (108) a	6.08 ± 1.76 (116) b	7.54 ± 1.27 (92) a

Table 12. continued ...

Feed	Consumption (g/100 g of body weight) * x ± SD (n)			
	Male	Female	Big (> 275 g)	Small (< 275 g)
Rolled oats plus 10 % egg	4.26 ± 1.42 (100) a	4.67 ± 2.02 (108) a	4.06 ± 1.58 (116) b	5.00 ± 1.85 (92) a
Rolled oats plus 5 % powder-sugar	3.67 ± 1.84 (64) b	4.30 ± 1.59 (80) a	4.10 ± 1.65 (104) a	3.81 ± 1.94 (40) a
Rolled oats plus 2.5 % corn-oil	4.69 ± 1.83 (64) a	4.26 ± 1.81 (84) a	4.85 ± 1.71 (96) a	3.69 ± 1.81 (52) b
Rolled oats plus 5% powder-sugar 2.5% corn-oil	4.32 ± 2.07 (52) a	4.66 ± 2.16 (100) a	4.49 ± 1.90 (92) a	4.61 ± 2.45 (60) a
Overall mean	**4.62 ± 2.74 (1838) b**	**5.12 ± 3.16 (2328) a**	**4.49 ± 2.57 (2142) b**	**5.35 ± 3.32 (2032) a**

* Means in the same column followed by the same letter are not significantly different according to paired t-test (α = 0.05)

Overall, female rats (5.12 g) consumed more feed and attractants than males (4.62 g) and small rats (5.35 g) consumed more feed and attractants than big rats (4.49 g). Sex differences in bait consumption were found in 10 (50%) out of 20 kinds of feed tested, and body size differences were recorded in 13 (65%) out of 20 kinds of feed.

Experiment 6. Rodenticide palatability test

Results of trials on the palatability of rolled oats rodenticide baits compared with plain rolled oats to the Norway rats are presented in Table 13.

Coumatetralyl showed the highest palatability, either in the choice or no-choice test. It was followed by bromadiolone, brodifacoum, and difenacoum, while warfarin showed the lowest palatability among the rodenticide preparations tested.

In the choice test, coumatetralyl batch 3 was the most palatable rodenticide to the rats (37% palatability ratio) compared with other rodenticides relative to the consumption of rolled oats bait; while bromadiolone batch 1, 2, 3, and difenacoum batch 2 were also palatable enough to the rats (22 - 23%) (Table 14).

Table 13. Rodenticide palatability in Norway rats (choice and no-choice test)

Feed (rolled oats) vs Rodenticide	**Palatability ratio (%)**	
	Choice test	**No-choice test**
Warfarin	2.69	19.63
Coumatetralyl	21.82	67.53
Bromadiolone	18.94	49.30
Difenacoum	11.01	38.89
Brodifacoum	14.01	37.06

Table 14. Rodenticide palatability and acceptance in Norway rats (choice test)

Feed vs rodenticide *	**Consumption (g/100 g of body weight) x ± SD (n) ****		**Palatability ratio (%)**	**Rodenticide acceptance (%)**
	Feed	**Rodenticide**		
Rolled oats vs warfarin batch 1	17.42 ± 6.74 (10) a	0.07 ± 0.11 (10) b	0.40	0.40
Rolled oats vs warfarin batch 2	12.88 ± 5.09 (10) a	0.93 ± 1.59 (10) b	7.22	6.73
Rolled oats vs warfarin wheat	19.94 ± 5.41 (10) a	0.36 ± 0.44 (10) b	1.81	1.77
Rolled oats vs coumatetralyl batch 1	12.68 ± 5.47 (10) a	1.80 ± 3.50 (10) b	14.20	12.43
Rolled oats vs coumatetralyl batch 2	11.90 ± 4.16 (10) a	1.88 ± 3.16 (10) b	15.80	13.64
Rolled oats vs coumatetralyl batch 3	11.29 ± 7.40 (10) a	4.16 ± 5.57 (10) b	36.85	26.93
Rolled oats vs bromadiolone batch 1	12.64 ± 3.00 (10) a	2.93 ± 2.10 (10) b	23.18	18.82
Rolled oats vs bromadiolone batch 2	15.52 ± 6.88 (10) a	3.44 ± 5.78 (10) b	22.16	18.14
Rolled oats vs bromadiolone batch 3	13.91 ± 8.34 (10) a	3.06 ± 3.87 (10) b	22.00	18.03
Rolled oats vs bromadiolone-oats	15.38 ± 6.19 (10) a	1.45 ± 3.05 (10) b	9.43	8.62

Table 14. continued ...

Feed vs rodenticide *	Consumption (g/100 g of body weight) x ± SD (n) **		Palatability ratio (%)	Rodenticide acceptance (%)
	Feed	Rodenticide		
Rolled oats vs difenacoum batch 1	17.23 ± 4.95 (10) a	1.36 ± 3.16 (10) b	7.89	7.32
Rolled oats vs difenacoum batch 2	17.38 ± 8.85 (10) a	4.01 ± 6.49 (10) b	23.07	18.75
Rolled oats vs difenacoum-wheat	20.69 ± 6.12 (10) a	0.72 ± 1.25 (10) b	3.48	3.36
Rolled oats vs brodifacoum batch 1	14.73 ± 6.38 (10) a	2.40 ± 3.04 (10) b	16.29	14.01
Oats vs bromadiolone-oats	0.42 ± 0.76 (10) a	18.13 ± 8.21 (10) b	4,316.67	97.74
De-husked oats vs bromadiolone-oats	13.36 ± 6.47 (10) a	5.02 ± 4.00 (10) b	37.57	27.31
Wheat vs warfarin-wheat	12.30 ± 7.60 (10) a	1.65 ± 4.15 (10) b	13.41	11.83
Wheat vs difenacoum-wheat	17.34 ± 4.62 (10) a	1.89 ± 2.19 (10) b	10.90	9.83

* For batch 1, 2, and 3, the rodenticides were in the rolled oats feed

** Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

In the no-choice test, bromadiolone batch 1 (78%), coumatetralyl batch 1 (72%), and coumatetralyl batch 3 (72%) showed a high palatability ratio, compared with rolled oats. Warfarin batch 1 (3%) was the least palatable rodenticide to the rats. Among all treatments, only bromadiolone-oats (91%) showed no significant difference with oats (Table 15).

In the choice test, among warfarin treatments, warfarin batch 2 (7.22%) showed the highest palatability ratio. Warfarin batch 1 (0.40%) and warfarin-wheat (1.81%) showed the lowest palatability ratio (Table 14). However, in the no-choice test, warfarin-wheat (37%) showed better palatability than the other two warfarin treatments (20 and 3%) (Table 15). Warfarin-wheat showed a better palatability when contrasted with wheat than with rolled oats (13 compared with 2%) (Table 14). The same tendency was also found in the no-choice test (67 compared with 37%) (Table 15).

Table 15. Rodenticide palatability in Norway rats (no-choice test)

Feed vs rodenticide	**Consumption (g/100 g of body weight) x ± SD (n)**		**Palatability ratio (%)**
	Feed	**Rodenticide**	
Rolled oats vs warfarin batch 1	18.33 ± 4.64 (30)	0.51 ± 0.74 (10)	2.78
Rolled oats vs warfarin batch 2	22.32 ± 3.24 (30)	4.54 ± 5.78 (10)	20.34
Rolled oats vs warfarin-wheat	16.66 ± 4.71 (30)	6.21 ± 4.48 (10)	37.27
Rolled oats vs coumatetralyl batch 1	16.49 ± 3.64 (30)	11.80 ± 4.80 (10)	71.56
Rolled oats vs coumatetralyl batch 2	19.45 ± 5.52 (30)	11.75 ±8.15 (10)	60.41
Rolled oats vs coumatetralyl batch 3	17.20 ± 4.38 (30)	12.33 ± 7.54 (10)	71.69
Rolled oats vs bromadiolone batch 1	15.17 ± 3.15 (30)	11.74 ± 5.30 (10)	77.39
Rolled oats vs bromadiolone batch 2	17.38 ± 3.42 (30)	8.87 ± 6.00 (10)	51.04
Rolled oats vs bromadiolone batch 3	19.16 ± 6.20 (30)	2.67 ± 5.02 (10)	13.94
Rolled oats vs bromadiolone-oats	17.25 ± 3.53 (30)	10.71 ± 5.48 (10)	62.09
Rolled oats vs difenacoum batch 1	17.88 ± 3.93 (30)	5.67 ± 6.00 (10)	31.71
Rolled oats vs difenacoum-batch 2	17.91 ± 2.72 (30)	10.04 ± 8.31 (10)	56.06
Rolled oats vs difenacoum-wheat	16.86 ± 2.86 (30)	5.28 ± 5.67 (10)	31.32
Rolled oats vs brodifacoum batch 1	17.08 ± 7.20 (30)	6.33 ± 7.25 (10)	37.06
Oats vs bromadiolone-oats	14.07 ± 4.06 (30)	12.81 ± 5.20 (10)	91.04
De-husked oats vs bromadiolone-oats	16.36 ± 3.62 (30)	11.14 ± 5.41 (10)	68.09
Wheat vs warfarin-wheat	16.65 ± 2.86 (30)	11.13 ± 7.61 (10)	66.85
Wheat vs difenacoum-wheat	14.41 ± 2.82 (30)	8.11 ± 6.52 (10)	56.28

* For batch 1, 2, and 3, the rodenticides were in the rolled oats feed
** Means in the same row followed by the same letter are not significantly different according to paired t-test ($\alpha = 0.05$)

Among coumatetralyl rodenticides, coumatetralyl batch 3 (37% of palatability ratio) showed the best rodenticide acceptance (Table 14). However, in the no-choice test, coumatetralyl batch 3 and 1 were at about the same level of palatability (72% of palatability ratio), and batch 2 was the lowest (60%) (Table 15).

In the choice test, among bromadiolone treatments, the acceptance of bromadiolone-oats (9%) was lower than bromadiolone batch 1, 2, and 3 (22 - 23%). In the no-choice test, however, the acceptance of bromadiolone-oats (62%) was better than batch 2 (51%) and batch 3 (14%) (Table 14 - 15). Bromadiolone-oats showed a very high palatability ratio (4,317%) compared with oats only.

Among difenacoum rodenticides, difenacoum batch 2 (23 and 56%) showed the highest acceptance, followed by batch 1 (8 and 32%) and -wheat (3.5 % and 31 %). These results were consistent both in the choice and no-choice test (Table 14 - 15). Difenacoum-wheat showed a better palatability when contrasted with wheat than with rolled oats (11 compared with 3.5%) (Table 14). The same tendency was also found in the no-choice test (56 compared with 31%) (Table 15).

Effect of the area of rat's origin

There were no differences in rodenticide consumption by rats from different farms, neither in the choice nor in the no-choice tests (Table 16).

Table 16. Rodenticide consumption by Norway rats from different farms

Farm number	Consumption (g/100 g of body weight) x ± SD (n) *	
	Choice test	No-choice test
3	3.83 ± 4.78 (12) a	7.10 ± 7.76 (11) a
4	0.76 ± 1.58 (8) a	7.52 ± 7.02 (15) a
5	3.17 ± 5.32 (37) a	11.01 ± 4.60 (30) a
9	2.41 ± 3.13 (12) a	11.04 ± 8.73 (10) a
14	2.11 ± 2.89 (12) a	8.89 ± 5.63 (8) a
17	0.35 ± 0.51 (4) a	9.62 ± 3.35 (11) a
23	4.59 ± 8.17 (12) a	8.98 ± 6.21 (20) a

* Means in the same column followed by the same letter are not significantly different according to Tukey's test ($\alpha = 0.05$)

Comparison of laboratory and field results

Comparison of laboratory (in no-choice test) and field (day-1 and day-max) results, is presented in Table 17.

Table 17. Rodenticide palatability by Norway rats in the laboratory and in the field

Rodenticide	Palatability ratio (%)		
	In the laboratory (no-choice test)	in the field *	
		(day-1)	(day-max)
Warfarin batch 1	2.78 **	31.2	55.0
Warfarin batch 2	20.34	41.3	56.1
Warfarin-wheat	37.27	57.4	64.9
Coumatetralyl batch 1	71.56	69.7	71.6
Coumatetralyl batch 2	60.41	67.8	67.8
Coumatetralyl batch 3	71.69	78.2	78.2
Bromadiolone batch 3	13.94 **	79.1	97.9
Difenacoum batch 1	31.71	55.6	56.5
Difenacoum batch 2	56.06	42.7	58.0
Difenacoum-wheat	31.32	6.4 ***	28.1 ***
Brodifacoum batch 1	37.06	43.5	44.7

* Source : Pelz (1999)
** Much lower than in the field
*** Much lower than in the laboratory

Warfarin batch 1 tested in the laboratory showed much lower palatability ratio (3%), than the results obtained from the field test (31 – 55%). The same tendency is true for bromadiolone batch 3 (laboratory palatability 14 % and field palatability 79 – 98%). On the other hand, palatability of difenacoum-wheat in the field (6 – 28%) was lower than that in the laboratory (31%). Among the rodenticides tested, coumatetralyl batch 1, 2, 3, difenacoum batch 2, and difenacoum-wheat showed the same palatability in the laboratory as in the field (Table 17).

DISCUSSION

The Norway rat is an omnivorous animal that can consume almost all kinds of food. Nevertheless, like in other rat species, cereal is the most palatable feed. This study showed that rolled oats was the most palatable feed compared with other cereal feed tested. It was followed by de-husked oats, while oats was the least palatable feed, because the husk still present on the grains.

Results of tests of the preference in rats to cereals showed that feed palatability is influenced by ease to consume that feed. This is in line with result of trials by Corbitt and Stellar (1964). The Norway rat preferred to consume cereal without husk (including wheat, rye, barley, and maize) compared to those with husk (oats), that need exertion to remove its peel before it can be consumed. The same was found by Kaufman and Collier (1981). Furthermore, if rats remove the hull, most of the added rodenticide sticking on the surface will be lost (Kühnert, 1981; Marsh, 1986).

Kühnert (1981) found that the sequence of preference in the Norway rats on cereals was rice, wheat, barley, and maize at a farm house and millet, rice, barley, and maize at a poultry house, while Nieder (1986) stated that feed preference in the Norway rats was wheat, rice, maize, barley, and oats.

Among four kinds of cereals used in the choice tests, significant differences in consumption were recorded between rolled oats and de-husked oats to wheat and oats. These results are in accordance with other trials, either in the choice or no-choice test. Based on these results, it can be concluded that rolled oats is the best choice among cereals tested to be used as a bait base for rodenticides. Among several cereals, rolled oats is the first choice (Buckle, 1994). Kühnert (1981) added that rolled oats can be used as a bait for monitoring rat populations in the field, because most of the rats prefer to consume it and even rolled oats can be applied in the warehouses in the European countries where plenty of food stuff is stored. On the other hand, in our experiments oats was the least consumed feed. Thus, based on our results, unshelled grains or oats can not be recommended for rat control and for monitoring the population in the fields.

The Norway rats which were offered cereals still recognized the feed well. They consumed the feed at larger amounts than altromin pellets. In this case, the higher content of carbohydrates in cereals could have stimulated their high consumption. Carbohydrates are needed by rats to maintain their health (Meehan, 1984). Several studies, either in the laboratory or in the field, emphasize the advantages of cereals as a bait base: High preference to the target animal, availability in the ready to use form, acceptable cost, and suitability for formulating with active ingredients (Macdonald *et al*., 1999; Meehan, 1984). Moreover, Buckle (1994) explained that cereal grains either whole, broken, rolled or ground are widely used as a bait base both by large manufacturers and small-scale formulators.

The results of the choice tests concerning feed preference suggest that de-husked oats are an acceptable feed for rats. The result of the no-choice test suggested that maize could also be used as a substitute for rolled oats in the monitoring and control of rats in the fields. Rolled oats and maize could be mixed together as a palatable feed for rat control programmes, because these cereals were consumed mostly by the test animals. Mixing of two kinds of cereals could be done to improve its palatability, however, for such blending not more than four kinds of cereals are suggested, because otherwise rodents might be faced with problems to recognize their feed (Marsh, 1986).

Wheat, rye, and barley were at about the same level of palatability compared with rolled oats feed, and the palatability of maize lay in between de-husked oats and those three feeds above. Oats were more attractive to the test animals when offered with wheat compared with de-husked oats and rolled oats, showing that wheat was less palatable than de-husked oats and rolled oats.

The decrease in rolled oats feed consumption on the fourth-night was lower than that in the other feed like de-husked oats, oats, and wheat. Palatability ratio in rolled oats was 82 to 88 %, compared with 92 to 99 % in the other feed. This was probably due to the large amount of consumption of rolled oats feed in the first three nights, particularly on the first-night, after a long time these rats had been fed on standard diets only. But then the consumption decreases appropriately with the calorific value required being reached. Rats tend to consume feed of a calorific value which maintains their metabolism, indicated by a constant or slightly increasing weight (Hausman, 1932; Galef, 1986).

With regard to texture of the feed, rats preferred to consume pellets (altromin pellets) over ground feed (altromin meal). Rats prefer materials in shape of particles, rather than from flour-like nature. Texture of feed played an important role in the preference of rats. Besides, when cereal blends were reduced to a meal form it often resulted in less consumption by rats (Barnett & Spencer, 1953; Kühnert, 1981; Marsh, 1986).

With regard to the origin of the test animals, rats from farms where there were cereals at the farm, consumed both the highest and the lowest amounts of cereals. Results to typical feed available at the farm showed that the consumption on the first day was relatively high for cereals, but it was relatively low for typical feed from the farm. These were because cereals as a bait base were very common for rats since they lived at the farms, and the typical feed from the farm was available only at the particular farm and only recognized by rats from that farm. Rats coming from farms where pig feed was unavailable consumed lower pig feed than those from other farms.

Rats from farms with a lower level of disturbance consumed higher amounts of cereals, typical feed from the farm, and feed plus attractants. Rats from farms where the level of disturbance was high consumed relatively lower amounts of cereals. These facts were in the contrary with expected results. Disturbance at the farm (noise) could affect the feeding behaviour in rats, although they have been kept singly caged for more than one year in the laboratory.

In connection with effectiveness of rat control at the farm, there were no significant differences in the cereal consumption between the higher and the lower level of effectiveness, because cereals were commonly found at the farm, thus rats became familiar to the feed. With view to typical feed from the farm, rats from farms with a high level of effectiveness in rat control consumed higher amounts than rats from farms with low levels. This phenomenon explained the alertness theory in the Norway rats. The lower the level of effectiveness in rat control at the farm, the higher the caution of rats to the novelty feed, the lower consumption amounts on it. However, there was a contradiction with regard to the consumption of feed plus attractants. Rats from farms with high levels of effectiveness of rat control consumed lower amounts than rats from farms with low levels. The expected results were the other way. The higher the level of effectiveness in rat control, the lower the level of alertness in rats, the higher the amount of consumption. The difference in response of the rats from different farms might be triggered and caused by the experience of infant rats living together with adult rats.

The consumption levels by rats from each farm fluctuated even for an individual rat for several nights. This variation resulted in high standard deviations of some data.

This condition agreed with the statement of Wang (1923) and Slonaker (1924) about the daily fluctuation in the consumption of rats, either in the laboratory or in the field. Wang (1925) added that feed consumption was related to the activity of rats, which differed each night.

The rats from farm no. 5 showed the highest consumption in six out of seven cereals, then followed by rats from farm no. 3 (in five cereals). On the other hand, rats from farm no. 23A showed the lowest consumption in five out of six cereals, then followed by rats from farm no. 9 (in five out of seven cereals). The differences in the consumption among cereals tested were probably caused by differences in food intake and inconsistency in the feeding responses of rats. This is in compliance with Ward (1943) who stated that feed preference in rats is very heterogeneous so that a list of feed in order or sequence of preference to rats is difficult to be used.

The rats from farm no. 5 showed a higher consumption of barley from farm than those from other farms. Rats from farm no. 3 preferred pig feed, those from farm no. 17 preferred concentrated feed stuff, and those from farm no. 23A preferred soybean coarse meal. It is difficult to obtain consistent results in such experiments because feeding preferences may change from colony to colony and during the year even in the same colony for Norway rats (Takahashi & Lore, 1980; Taylor & Quy, 1978).

The low consumption of rolled oats by rats from farm no. 9 was presumably caused by the intensive chemical control using rodenticide with rolled oats as a bait base which was applied at that farm for 27 weeks (Appendix 6). This might have caused bait-shyness in the rats when the same bait, even without toxicant, was offered in the laboratory. Once, rats could learn to recognize kinds of poisoned baits, they always remembered in a long period of time to avoid it (Howard, 1982; Meehan, 1984). Rzoska (1953) explained that the Norway rats tend to take a small sample of novelty feed rather than taking a large meal at once. Thus, it could reduce the consumption on poisoned baits which are harmful to rats. While Rozin & Kalat (1971) added that rats having experience with poison baits in the familiar feed would be phobic to the novelty feed.

Rats kept in the laboratory for a long time consumed equal amounts of feed from the farm as those caught at the same farm shortly before testing, suggesting that the rats recognized the taste of the feed that they consumed before. The rats from farm no. 23A (newly caught rats) consumed cereals and typical feed available at the farm with no statistically difference to those from farm no. 23 (adapted rats in the laboratory using commercial standard diet). This indicated that there was the same basic behaviour of feeding response in rats.

The rats from farm no. 23A consumed a higher amount of feed than those from other farms (rank 1 or 2), except for maize silage (rank 5), because maize silage was available at every farm and thus they recognized it and did not hesitate to consume it. There were no significant differences among rats of all farms to consume maize silage, and maize silage was low in palatability, probably because of the taste, smell, and texture. Besides, a high level of water content in maize silage could also have decreased its palatability, because rats were used to consume feed with a low water content (cereals). Water content in maize silage feed in this study was very high (> 75%).

The rats from farm no. 23A and 23 consumed higher amounts of barley than rats from farm no. 4, probably because there was some barley available at farm no. 23. The same tendency is true for pig feed at farm no. 3 versus farm no. 14 and 9, and soybean coarse meal at farm no. 23A versus other farms. The availability of food at the farms influenced the feeding response of the rats. The differences in the consumption on typical feed from farm by rats from other farms was probably due to the experience of rats at the farm, who learned from their mother and other adult rats (Galef, 1982; Posadas-Andrews & Roper, 1983; Strupp & Levitsky, 1984).

Pig feed at the farm contained at least two cereals, barley and wheat, plus minerals, which made this feed more palatable to rats. Soybean coarse meal and concentrated feed stuff were in the flour form, therefore their palatability was very low as exemplified in Experiment 3. Soybean coarse meal, a special livestock feed at the farm, was the least palatable feed to the rats from all farms. In India, the poultry feed ranked seventh in comparison to cereals and pulses, moreover cereals were consumed five times as much as poultry feed in Punjab (Parshad *et al*., 1987, 1991). These results contradicted with Bhardwaj (1983) who stated that poultry feed could be used as a bait for rats at poultry farms.

Attractants which are mixed with feed can enhance the consumption of rats from the bait offered. Two kinds of sugar (granulated and powder) were used in this study, although the type of sugar used as an attractant does not significantly influence the palatability (Rentokil, 1983). According to several authors, concentration of sugar mixed with the feed is the most important factor to influence the level of its palatability. Collier and Bolles (1968) found that 32% of liquid sucrose was preferred by rats over 4, 8, and 16%, whereas, Richter & Campbell (1940) stated that 11% of sugar was the optimum concentration. According to Howard *et al*. (1972), Rentokil (1983), and Kühnert (1981) 5 and 6.4% of sugar is the best concentration as an attractant, and concentration higher than 10% will lower the bait acceptance. This study showed that 10% of granulated-sugar in the altromin meal bait base was the optimum concentration.

Egg that was used in this study can increase the consumption of bait. Compared to those without egg, 10% of egg in the rolled oats feed can increase 116% of its consumption ($T = 14.72$, $p < 0.0001$, Table 11). However, the response of rats from different farms did not differ from each other. This fact explained that the taste of egg was not a novelty for rats from all farms studied. Rochman (1993) reported that the egg powder was the most preferred bait flavour among 16 kinds of bait flavours and Cott (1952) added that rats in poultry houses consumed eggs of hen and wild birds.

Corn-oil was used as an attractant in this study. Cornwell & Bull (1967) stated that groundnut oil mixed in the bait base could increase the consumption of the bait. Moreover, Fitzwater (1979), Kühnert (1981), and Rentokil (1983) added that other vegetable oil like coconut, palm, rape, and peanut, were also preferred by the Norway rats.

The rats from farm no. 4 consumed the highest quantity of feed containing powder-sugar, corn-oil, and their combination as an attractant, and this fact was relevant in the tests for neophobia (Chapter III), i. e. the rats from this farm showed the lowest level of neophobic behaviour. A phenomenon of low level of neophobic behaviour could also be seen in their ready acceptance of all kinds of baits that were offered.

Among feed plus attractants tested, altromin meal with 8% of vanilla-sugar and 10% of granulated-sugar were consumed more than rolled oats feed with 10% of egg, 5% of sugar-powder, 2.5% of corn-oil, and combination of the last two attractants. This condition was evoked by the consumption amount of another feed offered together in the same cage at the opposite site i. e. altromin meal and rolled oats without attractants. Altromin meal without attractants was consumed at a very low amount, while rolled oats without attractants were consumed at higher amount. It could be concluded that rats preferred to consume rolled oats as a bait base of attractants to altromin meal. This is in line with Experiment 1 and 2 (rolled oats as a feed for bait base of rodenticide).

The use of two attractants (powder-sugar and corn-oil) simultaneously in a bait base only increased the bait consumption slightly (4.54 g compared with 4.02 g and 4.45 g). This coincides with Kühnert (1981) who stated that two bait enhancers might not double the effect, but might actually lower acceptance, because it is difficult for rats to recognize the taste of that mixture. However, experiments by Quy *et al*. (1996) showed that the acceptance of a mixture of corn-oil and caster-sugar in pinhead oatmeal was better over pinhead oatmeal without caster sugar.

Results concerning the effect of sex and weight on the consumption showed that female rats consumed more feed than males and small rats consumed more feed than the big ones. The following consumption of wheat feed was observed: 7.76 g in small and 5.92 g in big rats ($T = 5.70$, $p < 0.0001$), 7.64 g in female and 6.17 g in male rats ($T = 2.59$, $p = 0.01$). These results agreed with those reported by Leslie & Ranson (1954) in which consumption of wheat by small rats was 10.49 ± 3.02 (23) g/100 g of bodyweight; by big rats 7.00 ± 0.63 (7) g/100 g of bodyweight; by female rats 10.00 ± 3.21 (17) g/100 g of bodyweight; and by male rats 9.25 ± 2.88 (13) g/100 g of bodyweight. Corbitt & Stellar (1964) also stated that food intake was directly related to the palatability of the diet and inversely related to the body weight of animals.

Differences in the feed consumption between female and male rats were recorded in 50% of the total number of feed components tested (de-husked oats, wheat, rye, barley from farm, soybean coarse meal, pig feed, concentrated feed stuff, 10% granulated sugar, 8% vanilla sugar, and 5% powder sugar). Those between small and big rats occurred in 65% of the feed (rolled oats1, oats, wheat, rye, barley, maize, barley from farm, soybean coarse meal, pig feed, 10% granulated sugar, 8% vanilla sugar, 10% egg, and 2.5% corn-oil). The differences are stable in 35% of feed tested (wheat, rye, barley from farm, soybean coarse meal, pig feed, 10% granulated sugar, and 8% vanilla sugar). Exploratory behaviour which happened in both sexes and at all ages of the test animals played an important role and was a significant component in the feeding behaviour of rats (Barnett, 1956). Krebs (1999) added that diet of rats changes seasonally.

A field study by Klemann (personal communication) showed that the order of feed preference by rats at farm no. 23 was rolled oats, wheat, pig feed, and rye. The same results were obtained in the laboratory trial with the same rat population (farms no. 23 and 23A). The rats adapted in the laboratory for a long period (no. 23) showed no difference in feeding response from those adapted for a short period or newly caught (no. 23A). It could be concluded that the basic behaviour of feeding response is still persisting after rats have been adapted for a long period (one year) at the different environment.

The behaviour in the Norway rats to feed or bait preference is stable in its characteristics. They showed a basic of feeding response when choices of cereal and laboratory diet were offered. Cereal, particularly rolled oats, was still the first choice compared to the other feed. Such feeding response is maintained for along time, even, it can be stated that the basic behaviour lasted until the end of their life. Such behaviour has been taught from their mother since the beginning they recognized a solid diet, and it was continually in taught by another adult rats in their surrounding (Galef, 1982). Further research is needed to test the persistent of this basic behaviour.

With view to the attractants, studies in the field conducted by Klemann showed that the order of preference by rats at farm no. 23 was rolled oats containing 5% powder-sugar and 2.5% corn-oil combination, followed by wheat containing 5% powder-sugar and 2.5% corn-oil combination, and rolled oats containing 5% powder-sugar. The results differed from those obtained in the laboratory. The rats from farm No. 23 preferred to consume rolled oats plus corn-oil 2.5%, followed by 5% powder-sugar, and powder-sugar 5% and corn-oil 2.5% combination, although the differences in the consumption of feed containing those three attractants were not significant. Conditions at the laboratory and in the field are very different, thus results obtained in the laboratory could give different results when re-tested in the field. Buckle & Kaukeinen (1988) supported this statement.

Results of the rodenticide palatability test with the Norway rats showed that coumatetralyl was the most palatable rodenticide both in the choice and no-choice tests. It was followed by bromadiolone, brodifacoum, and difenacoum. Warfarin was the least palatable rodenticide. Lund (1972) explained that the anticoagulant coumatetralyl has improved the palatability of bait and Schmutterer (1981) added that coumatetralyl does not induce bait-shyness to the rats. Quy *et al*. (1996) stated that the acceptance of each bromadiolone bait was greater than its equivalent difenacoum bait.

There were no differences in rodenticide consumption in the rats from each farm, either in the choice or in the no-choice tests, because there was a great variation in the rodenticide consumption by individual rats from different farms. The rats from farm No. 23 consumed 0 – 20 g of different kinds of rodenticides in the choice test and those from farm No. 9 consumed 0 – 29 g in the no-choice test. Such wide range of rodenticide consumption was due to large variation in individual rat behaviour and preference, resulting in standard deviations that were always greater than the means, particularly in the choice test. In the no-choice test, although the standard deviations were always smaller than means, the variations of the means were not large enough to yield significant differences among treatments (rats from each farm).

In the laboratory, warfarin batch 1 and bromadiolone batch 3 were much less accepted compared with the result of the field test. The low rodenticide consumption in the laboratory was probably due to the previous experience of rats with the poisoned baits. On the other hand, the acceptance of difenacoum-wheat tested in the field was much lower compared with the result in the laboratory test. Among the rodenticides tested, the acceptance of coumatetralyl batch 1, 2, 3, and difenacoum batch 2 in the laboratory was the same as that in the field. The reluctance of rats to consume poisoned bait was directly related with the concentration level of toxicants in the poisoned baits (Marsh, 1986; Berdoy and Smith, 1993), although in this study there were no trials with regard to this factor and the use of the poisoned baits at the farm.

When there are bait uptake problems in a farm-rat population, it would be one of the best ways to take a sample of rats into the laboratory, then to check them for their acceptance and preference to the feed and rodenticide. The advantage of this measure is that this method is efficient and simple in the implementation, because there is minor external factors which could influence the response. Besides, individual behaviour could be monitored and the result of consumption level on each rat could be detected. However, such activity in the laboratory would face problems if the effect of external factors to the feeding response was significant.

The main expectation of the study in the laboratory was to observe the feeding response of Norway rats towards several feed and rodenticides. Results in the laboratory trials showed that some of the feeding responses in the Norway rats were in accordance with the assumption concerning the consumption of cereals, typical feed from farm, attractants, and rodenticides. However, regarding the adaptation time in the laboratory, the result was different, that means adaptation process in the laboratory for more than one year would not result in the different response with newly caught.

Experimental design, which was set up in this study, was adequate to obtain some important findings. However, the differences in the replication could probably affect the analyses of variance. Feeding response tests with of rats using the same number of replicates needs to be conducted. Moreover, there was some unavailable treatment at the farm which were conducted in the laboratory. It is necessary to conduct all feed and rodenticides tests at the farm as well as in the laboratory.

Potency of a rodenticide and its palatability in the presence of competing alterna-tive food are of a critical importance. Striking differences in rodenticide palatability observed from several farms during field trials in the Münsterland area could be mirrored in the laboratory using rats from these farms.

The main findings in this chapter can be summarized as follows:

- Rolled oats is the best choice to be used as a rodenticide bait base and a feed for monitoring rat populations in the field. De-husked oats could also be used as relatively good baits, but oats can not be recommended.
- Wheat, rye, and barley were at about the same level of palatability and the palatability of maize bait lies in between de-husked oats and wheat, rye, barley.
- The difference in the adaptation time in the laboratory, between farm no. 23 and 23A, would not result in a different feeding responses.
- Rats preferred to consume altromin pellets over ground feed (altromin meal), and there were no differences in altromin meal consumption by rats from all farms.
- Among all typical feed from farm tested, barley was the most palatable bait, followed by pig feed, while soybean coarse meal was the least palatable bait.
- Granulated-, vanilla-, and powder-sugar, corn-oil, and egg were the materials which could enhance the consumption of feed.
- Rats from farm no. 4 consumed the highest quantity of feed containing powder-sugar, corn-oil, and their combination. This fact relates to the neophobic behaviour of rats.

- Female rats consumed more feed than males and small rats consumed more than the larger ones.
- Coumatetralyl was the most palatable rodenticide, while warfarin was the least palatable rodenticide.
- Rodenticides with bait bases other than rolled oats showed a better acceptance only when compared with the plain bait base itself.

Chapter III. NEOPHOBIC BEHAVIOUR

INTRODUCTION

There are three possible causes of failure in rat control. Firstly, there is some evidence that rats from certain locations have developed physiological resistance to the poisons used. Secondly, the bait offered may not be attractive to the rats because there are many food choices available around the bait stations. Thirdly, the rats may show behavioural resistance or neophobic reactions.

The rats from the farms in the Münsterland showed different response to the feed and rodenticides offered. To investigate the first possibility, a study to determine the level of physiological resistance in the rats has been conducted by the Federal Biological Research Centre for Agriculture and Forestry, Institute for Nematology and Vertebrate Research, Münster. To check the second and third possibilities, it is necessary to conduct some relevant experiments in the laboratory.

Some experiments have been conducted to study the neophobic behaviour in Norway rats (Brigham and Sibly, 1999). Various types of changes in their surroundings disturbed the behaviour of rats. Factors which disturb the behaviour of rats will lower the efficiency of control measures. Changes in illumination may affect the behaviour of rats and change from total dark to light suddenly makes them run away from the feeding point. The Norway rats have a great suspicion and alertness towards unfamiliar factors at its surroundings, and it is very likely that rats could be disturbed by noise (Shorten, 1954). Based on this knowledge, a study to observe the behaviour of the Norway rats towards a new object using a combination of light and noise treatments was conducted.

Neophobic behaviour trials in groups or individuals of Norway rats from several farms towards a new object (device) was investigated under laboratory conditions. The main question to be answered was whether the differences in the behaviour of rats observed at the farms during field trials in the Münsterland area, Nordrhein-Westfalen (Pelz, 1999) would be reflected in the laboratory using rats from these farms. Additional tests concerned the effect of the time interval between two trials and the adaptation time in the laboratory on the response of rats to the new object.

The response of rats to the new object (device) was observed using a video camera (automatic recording) equipped with an infra red censor, because direct observation of responses of the rats will give the most complete information compared with other methods. The following variables were analysed in this study: Total daily intake of feed offered and time spent in the box, either using the same (rolled oats) or different (rolled oats and oats) feed. Observation of activity of the rats can be used to record their response before and after a change in the environment (Advani & Idris, 1982).

OBJECTIVES

Experiments were conducted to study:

(1) Differences in the neophobic behaviour of rats from several farms in the Münster-land, either in groups or individually using the same (rolled oats) and different (rolled oats and oats) feed. Moreover, test was conducted with individuals newly caught from two special farms (no. 3 and 4)

(2) The effect of time interval between two trials and adaptation time on the consumption of feed and time spent in the box

METHODS

Experiment 1. Neophobic behaviour test in groups of rats

1.1. Pre-test

Three female rats from farm no. 3 were placed inside the test room with 5 meter (length) x 3 meter (width) x 2.5 meter (height) in dimension. Before the test, all rats were anaesthetized to mark them by clipping hair at the back. The experimental room was provided with two feed containers - on the left and right position - and a water container in the middle, three wooden boxes with dry grass inside as shelter, and soil on the ground to absorb urine and faeces (Figure 1).

Rats were adapted inside this room by offering rolled oats feed in both bait containers for three to seven days, until they showed a constant pattern of feeding behaviour. After that, a big blue ball, as a new object (device), was introduced near the preferred feed container, and the reactions or responses of the rats were observed.

1.2. Actual test

This test was prepared in the same way as in the pre-test, however both feed and water containers were placed inside a black box to cover them. The lamp which was

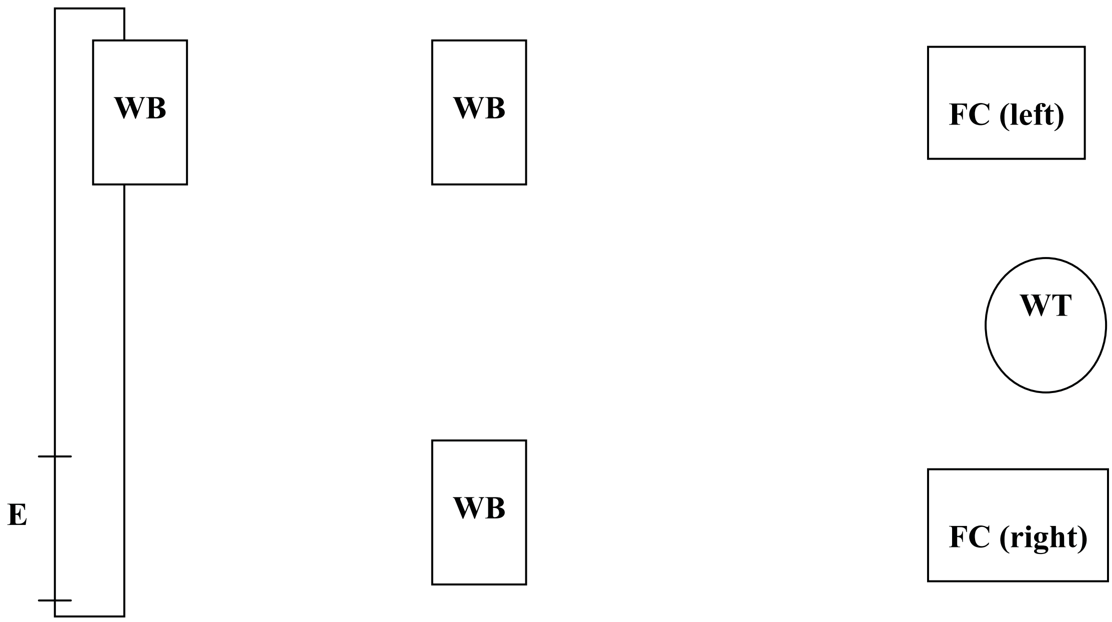

Figure 1. Lay out of the experimental room (WB = wooden box, FC = box with feed container inside, WT = water container, E = entrance)

automatically switched on - off and produced a noise, as a new object (device), was placed inside the black box that had been preferred by the rats. The feed consumption by and responses of the rats in both black boxes were recorded. The trial was stopped if the consumption by the rats levelled to the normal quantity, i. e. the total consumption in the treatment was equal to that before the device was put inside the box. If the consumption in the box containing the device was still very low, then the device was transferred to the other box, and the observation was continued. If the consumption was still low, rolled oats feed was removed from the box without the device, to force the rats to visit and consume only from the box with the device.

Duration of time spent of rats in each box was recorded with a video camera. The same method was used in the test using rats from other farms (no. 4, 5, 9, 17, and 23). The rats from farm no. 23A were the same as those used in the feeding behaviour test (Chapter II), while rats from farm no. 23B came from the same farm but were used shortly after they had been caught without adaptation in the laboratory.

Experiment 2. Neophobic behaviour test in individual rats

2A. Individual test using the same feed (rolled oats)

The neophobic behaviour of individual rats was conducted using the same rats and method as in Experiment 1. In this test, only one rat was used in every single trial, either female or male. Using only one rat in each experimental room, there was no chance for the rat to learn the preferred location of the feed from the demonstrator as it was explained by Galef & Heiber (1976); Posadas-Andrews & Roper (1983); Strupp & Levitsky (1984).

2B. Individual test using different feed (rolled oats and oats)

This test was basically the same as Experiment 2.A, except that two different kinds of feed were used, rolled oats and oats. The procedures and rats used were the same as those in Experiment 2A.

2C. Comparison of response of rats from farm no. 3 and 4

From the results of neophobic tests with groups of rats (Table 18 - 20), it could be concluded that the rats from farm no. 3 showed the highest level of neophobic behaviour, while those from farm no. 4 showed the lowest. Given such results, it was important to conduct a further experiment with newly caught rats from both farms to derive a more accurate conclusion. Ten newly caught rats each from farm no. 3 and 4 were tested using the same method as described above (experiment 2A).

The conditions at the farms

The conditions at each farm were recorded to determine the relationship between the results obtained in the above experiments and the background or experience of rats at the farms. The general conditions at each farm where the rats were caught are described in Table 2.

RESULTS

Experiment 1. Neophobic behaviour test in groups of rats

Pre-test

The results the pre-test showed that the rats were not afraid of the big blue ball (a new object). They approached the ball and consumed the feed in the container near it without any sign of interference.

Actual test

The rats from farm no. 4 showed the lowest level of neophobic behaviour, both in terms of feed consumption (3.69 g) (Table 18) and in the total time spent in the box (97.19 minutes) (Table 19). However, in terms of mean time spent in the box, the rats from farm no. 23A showed the longest time spent in the box with device (3.87 minutes), although the duration was not significantly different from that of rats from other farms (Table 20).

Table 18. Consumption of feed and percentage of consumption by groups of rats in the neophobic test

Farm number (no. of rats)	Consumption of feed in the box (g/100 g of body weight) * [x ± SD (n)]		Percentage of consumption, with relative to without device (%) * [x ± SD (n)]
	With device	Without device	
3 (4)	0.05 ± 0.08 (5) c	5.60 ± 0.63 (5) ab	0.95 ± 1.75 (5) c
4 (3)	3.69 ± 0.07 (2) a	3.02 ± 0.78 (2) de	126.75 ± 35.17 (2) a
5 (6)	0.57 ± 0.36 (6) c	5.03 ± 1.06 (6) abc	11.48 ± 7.61 (6) c
9 (3)	0.34 ± 0.67 (5) c	4.81 ± 0.81 (5) bcd	9.12 ± 18.79 (5) c
17 (3)	0.28 ± 0.28 (3) c	3.31 ± 0.99 (3) cde	9.65 ± 9.85 (3) c
23A (3)	1.50 ± 0.45 (5) b	2.92 ± 0.22 (5) e	48.40 ± 17.65(5) b
23B (4)	0.84 ± 0.38 (6) bc	6.71 ± 0.48 (6) a	12.85 ± 6.24 (6) c

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

Table 19. Total and percentage of time spent in the box by groups of rats in the neophobic test

Farm number (no. of rats)	**Total time spent in the box (minutes) * [x ± SD (n)]**		**Percentage of time spent in the box, with relative to without device (%) * [x ± SD (n)]**
	With device	**Without device**	
3 (4)	1.11 ± 0.83 (4) b	101.83 ± 69.37(2) a	1.00 ± 1.16 (2) c
4 (3)	97.19 ± 9.56 (2) a	97.85 ± 1.83 (2) a	99.44 ± 11.63 (2) a
5 (6)	20.45 ± 18.30 (6) b	104.32 ± 19.41(6) a	18.11 ± 15.56 (6) bc
9 (3)	14.70 ± 20.39 (5) b	114.96 ± 23.53(5) a	16.36 ± 25.89 (5) bc
17 (3)	12.57 ± 7.81 (3) b	131.78 ± 42.54 (5) a	14.50 ± 6.55 (3) bc
23A (3)	93.46 ± 48.57 (5) a	82.72 ± 13.21 (3) a	78.57 ± 49.81 (5) ab
23B (4)	33.55 ± 16.40 (6) b	137.42 ± 17.19 (6) a	25.82 ± 15.94 (6) bc

* Means in the same column followed by the same letter were not significantly different according to Tukey's test (α = 0.05)

Table 20. Mean time spent in the box and adaptation time by groups of rats in the neophobic test

Farm number (no. of rats)	**Mean time spent in the box (minutes) * [x ± SD (n)]**		**Adaptation time (minutes) * [x ± SD (n)]**
	With device	**Without device**	
3 (4)	0.26 ± 0.18 (4) b	0.81 ± 0.52 (2) b	444.13 ± 432.44 (8) a
4 (3)	1.94 ± 0.08 (2) ab	2.78 ± 0.34 (2) ab	8 ± 6 (3) b
5 (6)	0.61 ± 0.16 (6) b	1.37 ± 0.74 (6) ab	190.38 ± 230.14 (8) ab
9 (3)	0.50 ± 0.17 (5) b	1.76 ± 0.95 (5) ab	111.83 ± 128.32 (6) b
17 (3)	2.45 ± 1.45 (3) ab	3.85 ± 0.56 (3) ab	69 ± 111.20 (4) b
23A (3)	3.87 ± 4.38 (5) a	4.57 ± 0.38 (5) a	115 ± 110.82 (5) b
23B (4)	1.77 ± 0.68 (6) ab	0.86 ± 0.21 (6) ab	28.25 ± 39.49 (8) b

* Means in the same column followed by the same letter were not significantly different according to Tukey's test (α = 0.05)

Rats from farm no. 3 showed the highest level of neophobic behaviour, either in terms of feed consumption (0.05 g) (Table 18); or in the total time spent in the box (1.11 minutes) (Table 19); or in the mean time spent in the box (0.26 minutes) (Table 20). The mean time spent in the box was not significantly different from that of rats from other farms. In the box without device the mean time spent in the box of rats from farm no. 3 was also the shortest (0.81 minutes) (Table 20).

The rats from farm no. 4 consumed more feed in the box with device than in that without device (relative consumption 126.75%) (Table 18). Thus, the device (lamp and noise-maker) did not exert any interference to the rats. Such lack of interference is also reflected by the relative total time spent in the box which reached almost 100% (Table 19).

The relative consumption by rats from farm no. 3 in the box with device was very low (0.95%), although the consumption was not significantly different from that by rats from farm no. 9 (9.12%), no. 17 (9.65%), no. 5 (11.48%), and no. 23B (12.85%) (Table 20). The relative total time spent in the box of rats from farm no. 3 was also very low (1%) and it was significantly different from that of rats from farm no. 23A (78.57%) and no. 4 (99.44%) (Table 19).

With regard to the adaptation time (the interval between the first time the rats observed the device and the time they entered the box with device) the rat from farm no. 3 took the longest time (444.13 minutes). The mean adaptation time was significantly different from that of rats from other farms, except from farm no. 5 (190.38 minutes). On the other hand, the rats from farm no. 4 showed the shortest adaptation time (8 minutes) (Table 20).

Experiment 2. Neophobic behaviour test in individual rats

2A. Individual test using the same feed (rolled oats)

Like in the test with groups of rats, in this test the rats from farm no. 4 also showed the lowest level of neophobic behaviour. This could be seen both in the feed consumption (2.31 g) (Table 21), in the total time spent in the box (59.92 minutes) (Table 22), and in the mean time spent in the box (10.74 minutes) (Table 23).

The highest level of neophobic behaviour in the experiment with individual rats was shown by rats from farms no. 5 and 3. In terms of feed consumption the highest level was shown by rats from farm no. 5 (0.38 g), although the consumption was not significantly different from that by rats from other farms (Table 21). In terms of the total time spent in the box and adaptation time, the highest level was also shown by rats from farm no. 5 (1.68 and 719.91 minutes), although it was not significantly different from that of rats from other farms, except farm no. 4 (59.92 and 1.4 minutes) (Table 22 and 23). However, in terms of the mean time spent in the box, rats from farm no. 3 (0.51 minutes) showed the highest level (Table 23).

Table 21. Consumption of feed and percentage of consumption by individual rat using the same feed (rolled oats) in the neophobic test

Farm number (no. of rats)	**Consumption of feed in the box (g/100 g of body weight) * [x ± SD (n)]**		**Percentage of consumption, with relative to without device (%) * [x ± SD (n)]**
	With device	**Without device**	
3 (3)	0.57 ± 1.18 (11) a	4.54 ± 1.28 (11) a	23.33 ± 52.73 (11) a
4 (3)	2.31 ± 1.43 (5) a	2.90 ± 1.99 (5) abc	455.78 ± 865.29 (5) a
5 (3)	0.38 ± 0.72 (11) a	3.97 ± 1.19 (11) ab	15.01 ± 34.45 (11) a
9 (4)	2.08 ± 1.74 (13) a	1.81 ± 1.67 (13) c	553.06 ± 1035.91 (10) a
17 (3)	2.07 ± 1.88 (12) a	2.32 ± 1.86 (12) bc	283.66 ± 464.98 (11) a
23B (3)	1.22 ± 1.44 (8) a	3.49 ± 1.11 (8) abc	53.87 ± 74.06 (8) a

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

Table 22. Total and percentage time spent in the box by individual rats using the same feed (rolled oats) in the neophobic test

Farm number (no. of rats)	**Total time spent in the box (minutes) * [x ± SD (n)]**		**Percentage of time spent in the box, with relative to without device (%) * [x ± SD (n)]**
	With device	**Without device**	
3 (3)	11.23 ± 15.19 (7) b	36.72 ± 9.75 (7) ab	43.08 ± 68.14 (7) a
4 (3)	59.92 ± 41.14 (5) a	41.91 ± 32.77 (5) ab	21,640 ± 47931 (5) a
5 (3)	1.68 ± 3.43 (10) b	48.87 ± 11.67 (10) a	3.65 ± 7.77 (10) a
9 (4)	34.55 ± 26.08 (10) ab	28.60 ± 30.40 (10) b	1,066.78 ± 1731.11 (9) a
17 (3)	38.69 ± 40.07 (12) ab	39.72 ± 30.08 (12) ab	2,904 ± 6374 (12) a
23B (3)	15.41 ± 19.04 (8) b	24.47 ± 5.01 (8) ab	66.18 ± 90.65 (5) a

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

Table 23. Mean time spent in the box and adaptation time by individual rats using the same feed (rolled oats) in the neophobic test

Farm number (no. of rats)	Mean time spent in the box (minutes) * [x ± SD (n)]		Adaptation time (minutes) * [x ± SD (n)]
	With device	Without device	
3 (3)	0.51 ± 0.80 (19) d	4.61 ± 2.17 (19) bcd	403.26 ± 580.79 (19) ab
4 (3)	10.74 ± 10.19 (5) ab	6.61 ± 5.55 (5) abcd	1.4 ± 1.67 (5) b
5 (3)	1.31 ± 3.50 (10) cd	11.32 ± 6.95 (10) a	719.91 ± 708.78 (11) a
9 (4)	5.52 ± 3.56 (10) abcd	5.66 ± 5.54 (10) abcd	293.8 ± 604.34 (10) ab
17 (3)	6.90 ± 5.63 (12) abc	7.33 ± 5.36 (12) abc	149.15 ± 398.68 (13) ab
23B (3)	1.22 ± 1.70 (16) cd	4.06 ± 1.33 (16) cd	540.13 ± 719.90 (16) ab

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

With regard to relative consumption, rats from three out of six farms (no. 9 = 553.06%, no. 4 = 455.78%, and no. 17 = 283.66%), consumed feed in the box with device more than 100% relative to that without device (Table 22). The relative total time spent in the box also showed the same tendency as the relative consumption. Rats from three farms (no. 4 = 21,640%, no. 17 = 2,904%, and no. 9 = 1,066.78%) showed a relative total time spent in the box greater than 100% (Table 22).

2B. Individual test using different feed (rolled oats and oats)

Rats from different farms showed different responses to the device when different feed was used (rolled oats and oats) compared with those using the same feed (rolled oats). Almost all the rats consumed more feed in the box with device (2.67 - 5.82 g) than without device (0.09 - 1.05 g), except for rats from farm no. 9 (1.60 g with and 3.18 g without device). Thus, the rats preferred to consume the more palatable feed (rolled oats) to the least palatable one (oats), although there was a disturbance around the bait (device = new object). The rats from all farms showed a relative consumption of more than 100% (Table 24).

Table 24. Consumption of feed and percentage of consumption by individual rats using different feed (rolled oats and oats) in the neophobic test

Farm number (no. of rats)	Consumption of feed in the box (g/100 g of body weight) * [x ± SD (n)]		Percentage of consumption, with relative to without device (%) * [x ± SD (n)]
	With device	Without device	
3 (4)	4.54 ± 0.58 (3) a	0.41 ± 0.61 (3) a	2,346.29 ± 2798.33 (2) a
4 (2)	5.23 ± 1.29 (2) a	0.31 ± 0.18 (2) a	2,196.47 ± 1717.77 (2) a
5 (6)	2.67 ± 2.84 (5) a	1.05 ± 1.73 (5) a	476.64 ± 554.3 (3) a
9 (4)	1.60 ± 2.38 (3) a	3.18 ± 5.18 (3) a	1,094.55 ± 1739.18 (3) a
17 (3)	4.30 ± 2.93 (2) a	0.09 ± 0.02 (2) a	4,777.86 ± 2251.63 (2) a
23B (4)	5.82 ± 0.35 (2) a	0.18 ± 0.16 (2) a	5,288.92 ± 4763.39 (2) a

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

The same tendency was recorded with regard to the total time spent in the box. The total time spent of rats in the box with device (32.88 - 113.65 minutes) was longer than that without device (0.44 - 22.20 minutes), except for rats from farm no. 5 and 9 where the reverse was true (Table 25). With regard to percentage time spent in the box, only rats from farm no. 9 showed the relative length of activity of less than 100% (31.50%).

Table 25. Total and percentage time spent in the box by individual rats using different feed (rolled oats and oats) in the neophobic test

Farm number (no. of rats)	Total time spent in the box (minutes) * [x ± SD (n)]		Percentage of time spent in the box, with relative to without device (%) * [x ± SD (n)]
	With device	Without device	
3 (4)	32.88 ± 68 (3) b	10.20 ± 11.52 (3) a	768.69 ± 614.24 (3) a
4 (2)	94.54 ± 15.86 (2) ab	22.20 ± 29.05 (2) a	3,282.72 ± 4366.76 (2) a
5 (6)	27.65 ± 26.34 (5) b	36.49 ± 60.53 (5) a	174.60 ± 166.44 (3) a
9 (4)	25.06 ± 21.62 (3) b	27.32 ± 31.77 (3) a	31.50 ± 3.01 (2) a
17 (3)	113.65 ± 48.54 (2) a	5.48 ± 7.74 (2) a	1,351.32 ± - (1) a
23B (4)	42.61 ± 21.20 (2) ab	0.44 ± 0.16 (2) a	11,510.91 ± 9176.96 (2) a

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

There were no significant differences in the mean time spent in the box with and without device (Table 26), because there was a large variation in the response of rats from the same farm. Only rats from farm no. 3 spent the shortest time in the box with device, indicating that the rats from this farm exhibited the highest neophobic behaviour (Table 26).

Table 26. Mean time spent in the box and adaptation time by individual rats using different feed (rolled oats and oats) in the neophobic test

Farm number (no. of rats)	Mean time spent in the box (minutes) * [x ± SD (n)]		Adaptation time (minutes) * [x ± SD (n)]
	With device	Without device	
3 (4)	1.50 ± 1.08 (4) a	2.78 ± 3.67 (4) a	170.75 ± 135.33 (4) a
4 (2)	12.45 ± 11.85 (2) a	10.81 ± 14.94 (2) a	0 ± 0 (2) a
5 (6)	7.77 ± 6.96 (6) a	9.85 ± 15.05 (6) a	567.67 ± 677.31 (6) a
9 (4)	7.82 ± 8.96 (4) a	0.80 ± 1.05 (4) a	41.5 ± 75.21 (4) a
17 (3)	7.52 ± 2.86 (3) a	1.15 ± 1.01 (3) a	59.67 ± 103.35 (3) a
23B (4)	3.23 ± 3.09 (3) a	1.58 ± 1.99 (3) a	46.67 ± 80.83 (3) a

* Means in the same column followed by the same letter are not significantly different according to Tukey's test ($\alpha = 0.05$)

Although the total time spent in the box of rats from farm no. 17 (113.65 minutes) was the highest, their mean time spent in the box (7.52 minutes) was less than that of rats from farm no. 4 (12.45 minutes).

There were no significant differences in the adaptation time of rats from all farms, although there was a huge difference in that between rats from farm no. 5 (567.67 minutes) and no. 4 (0 minutes).

2C. Comparison of response of rats from farm no. 3 and 4

The newly caught rats from farm no. 4 still showed a lower level of neophobic behaviour compared with rats from farm no. 3. These differences were recorded with respect to the consumption (0.92 to 0.06 g) (Table 27), the total time spent in the box (5.49 to 0.43 minutes) (Table 28), and the mean time spent in the box (0.38 to 0.07

minutes) (Table 29). The rats from farm no. 3 preferred to consume rolled oats and spent much time in the box without device.

In terms of the percentage, there were large differences in consumption and total time spent in the box, i. e. more than 100% (480.70 and 258.15%) in rats from farm no. 4, and only 1% (0.95 and 1.03%) in rats from farm no. 3 (Table 27 - 28). The same tendency of response was also recorded with regard to the adaptation time. The rats from farm no. 4 (884.08 minutes) needed a shorter period to become familiar with the device than did rats from farm no. 3 (951.47 minutes), although the difference was not significant (Table 29).

Table 27. Consumption of feed and percentage of consumption by individual rat from farm no. 3 and 4 in the neophobic test

Farm number (no. of rats)	**Consumption of feed in the box (g/100 g of body weight) * [x ± SD (n)]**		**Percentage of consumption, with relative to without device (%) * [x ± SD (n)]**
	With device	**Without device**	
3 (10)	0.06 ± 0.11 (40) b	6.99 ± 1.88 (40) b	0.95 ± 1.87 (40) a
4 (10)	0.92 ± 2.30 (39) a	4.11 ± 2.72 (39) a	480.70 ± 1,878.46 (35) a

* Means in the same column followed by the same letter were not significantly different according to paired t-test ($\alpha = 0.05$)

Table 28. Total and percentage time spent in the box by individual rat from farm no. 3 and 4 in the neophobic test

Farm number (no. of rats)	**Total time spent in the box (minutes) * [x ± SD (n)]**		**Percentage of time spent in the box, with relative to without device (%) * [x ± SD (n)]**
	With device	**Without device**	
3 (10)	0.43 ± 0.69 (40) b	44.85 ± 14.10 (40) b	1.03 ± 1.64 (40) a
4 (10)	5.49 ± 12.86 (39) a	30.91 ± 22.23 (39) a	258.15 ± 814.23 (36) a

* Means in the same column followed by the same letter were not significantly different according to paired t-test ($\alpha = 0.05$)

Table 29. Mean time spent in the box and adaptation time by individual rat from farm no. 3 and 4 in the neophobic test

Farm number (no. of rats)	Mean time spent in the box (minutes) * [x ± SD (n)]		Adaptation time (minutes) * [x ± SD (n)]
	With device	Without device	
3 (10)	0.07 ± 0.10 (40) b	4.25 ± 2.98 (40) b	951.47 ± 662.73 (40) a
4 (10)	0.38 ± 0.95 (36) a	3.12 ± 2.65 (36) a	884.08 ± 668.88 (36) a

* Means in the same column followed by the same letter were not significantly different according to paired t-test ($\alpha = 0.05$)

Among rats from farm no. 4, only two out of ten rats (20%) showed no strong avoidance of the device in this test, but all the rats from farm no. 3 showed strong avoidance. The two rats from farm no. 4 tended to feed only at one feeding site (Table 30).

Table 30. Responses of two rats from farm no. 4 (lower level of neophobic behaviour)

Rat number	Consumption (g/100 g of body weight)		Time spent in the box (minutes)	
	Left Box	Right Box	Left Box	Right Box
4822	5.11 ☼	2.45	15.38 ☼	13.78
	7.36 ☼	0.07	36.98 ☼	0.88
	8.59 ☼	0.34	41.32 ☼	2.65
	7.77 ☼	0.00	40.73 ☼	2.03
4831	2.76 ☼	1.12	23.42 ☼	11.32
	3.32 ☼	0.10	43.32 ☼	3.62
	4.30	0.10 ☼	67.30	1.13 ☼
	4.68	0.00 ☼	72.80	0.42 ☼

☼ Box with device inside

Rank of neophobic behaviour

The general conditions on each farm are presented in Table 2 and the ranks in neophobic behaviour of rats from all farms based on the data in Table 18 - 23 (neophobic behaviour in groups and individual rats using the same feed) are presented in Table 31.

Table 31. Results of neophobic behaviour tests and ranks of neophobia of rats from each farm

Variable of neophobic test	Farm number					
	3	5	9	23	17	4
Consumption (g)	0.31	0.48	1.21	1.03	1.18	3.00
Total time spent in the box (minutes)	6.17	11.07	24.63	24.48	25.63	78.56
Mean time spent in the box (minutes)	0.34	0.96	3.06	1.50	4.68	6.34
Adaptation time (minutes)	423.69	455.15	202.82	284.19	109.08	4.7
Rank of neophobia	I	II	III	IV	V	VI

Effect of the time interval between two trials on the feed consumption and time spent in the box

Using the result in Table 18 – 26, the effect of time interval between two trials on the feed consumption and time spent in the box could be calculated. There was a correlation between the time interval in the two trials and the percentage of consumption and time spent in the box: The shorter the interval (< = 1 month), the higher the relative consumption (2,145.89%) and the longer the relative time spent in the box (12,122.52%) although it is not statistically different (Table 32).

Among rats from several farms, the rats from farm no. 17 showed the highest relative consumption (108.88%) and it was significantly different from that by rats from farm no. 5 (3.94%). The rats from farm no. 4 showed the longest the relative time spent in the box (124.59%) which was significantly different from rats from farms no. 5 (5.19%), no. 23 (27.17%), and no. 3 (31.21%) (Table 33).

Table 32. Effect of time interval between the two tests on the relative consumption and time spent in the box

Time interval between two trials (no. of rats)	Relative in the box with device (%) * [x ± SD (n)]	
	Consumption	Time spent in the box
< = 1 month (4)	2,145.89 ± 2,588.06 (10) a	12,122.52 ± 28,832.06 (10) a
2 – 3 months (3)	71.05 ± 48.60 (9) b	81.23 ± 87.81 (9) a
> 4 months (5)	56.14 ± 77.28 (18) b	34.55 ± 31.35 (18) a
Statistics	F = 8.93 Pr = 0.0008	F = 2.42 Pr = 0.1044

* Means in the same column followed by the same letter were not significantly different according to Tukey's test (α = 0.05)

Table 33. Effect of the time interval between two tests on relative consumption and time spent in the box of rats from different farms

Farm number (no. of rats)	Relative in the box with device (%) * [x ± SD (n)]	
	Consumption	Time spent in the box
3 (2)	17.54 ± 26.88 (7) ab	31.21 ± 41.30 (7) b
4 (2)	87.16 ± 49.64 (5) ab	124.59 ± 103.32 (5) a
5 (2)	3.94 ± 6.02 (6) b	5.19 ± 10.75 (6) b
9 (2)	56.38 ± 43.68 (6) ab	44.90 ± 35.57 (6) ab
17 (2)	108.88 ± 90.01 (8) a	46.75 ± 20.43 (8) ab
23 (2)	20.26 ± 23.75 (8) ab	27.17 ± 32.69 (8) b

* Means in the same column followed by the same letter were not significantly different according to Tukey's test (α = 0.05)

Effect of adaptation time on the feed consumption and time spent in the box

Using the results in Tables 21 – 26, the effect of adaptation time on the feed consumption and time spent in the box could be calculated. There was an indication that the adaptation time in the laboratory (time interval between the date of catch and trial) did not change essentially the neophobic behaviour. The longer the adaptation time (> 2 years) was, the more familiar the rats were with the new object. This was shown by the higher consumption and longer time spent inside the box with device after increasing the adaptation time.

Table 34. Effect of adaptation time on the consumption and time spent in the box

Time interval between the date of catch and trial (no. of rats)	**In box with device * [x ± SD (n)]**	
	Consumption (g/100 g of body weight)	**Time spent in the box (minutes)**
< 1 year (4)	2.14 ± 2.32 (10) a	20.85 ± 21.53 (10) a
1 – 2 years (24)	1.65 ± 2.10 (47) a	21.14 ± 31.77 (46) a
> 2 years (6)	2.79 ± 1.39 (17) a	57.37 ± 33.65 (17) b

* Means in the same column followed by the same letter were not significantly different according to Tukey's test ($\alpha = 0.05$)

DISCUSSION

Soon after all rats had been put into the experimental room, they moved directly into the wooden boxes to find shelter. A couple of minutes later, however, they moved out from the boxes and explored the new habitat. This behaviour was observed with rats from all farms. Such behaviour could be compared with that in mazes as described by Cowan (1977), when put into mazes for the first time rats responded with an extensive investigati-on of their new environment.

The use of a big blue ball in the pre-test of this study seemed not to be effective as a new object (novel thing) to frighten the rats. This is in contradiction with the statement of Barnett (1958b) and Meehan (1984) that placing a box in the path or at a usual feeding point or placing a feed in a different container could effectively prevent the rats using that path and reduce the consumption. Moreover, Chance & Mead (1955) completed that the addition of a new object has a greater effect than the deletion. However, this statement could not be used to clarify the behaviour of rats towards the big blue ball, since all rats did not hesitate to approach the ball and consumed the feed without any obvious interference.

It can be concluded that the big blue ball as a new object did not frighten the test animals. The use of a lamp that automatically switched on – off and made a noise, as a new object (novel thing), was expected to elicit an obvious response in the rats tested.

Visual and acoustic devices have been used for scaring animals. Unfamiliar noises could cause rats to remain in their nest or to flee if they are outside (Baker & Macdonald, 1999; Barnett, 1958a). Howard (1982) explained that there were some reports on limited success in using lights to reduce damage by field rodents, but they were useful enough in controlling commensal rats.

The effect of scaring devices, however, tended to be short-term, both noise and visual deterrents being prone to habituation for the target species (Draulans, 1987; EIFAC, 1988; Inglis, 1980; Wade, 1978). Köhler *et al*. (1990) suggested that combining acoustic and visual stimuli can enhance effectiveness, while varying the techniques used and the placement of frightening devices can delay the habituation.

The use of feed consumption as the only index for measuring new object reaction, can lead to misinterpretation (Campbell & Sheffield, 1953; Hebb, 1949). Therefore, two other variables, time spent in the box and adaptation time, were also used to measure the levels of neophobia.

In describing new object reactions, Barnett (1958a) introduced the term neophobia, literally meaning fear for the new, but Barnett (1958b) defined it operationally as avoiding an unfamiliar object, including strange odors, tastes, sounds, and food containers, in familiar surroundings. Brigham & Sibly (1999) defined neophobia as the initial avoidance of novel objects including feed in a familiar environment.

Neophobia is the pattern of feeding behaviour that represents a conflict between avoidance and exploration. Neophobia has been selected in some species because it protects them against human control exertion (Barnett & Cowan, 1976; Beck *et al*., 1988; Brunton *et al*., 1993; Cowan, 1977; Miller & Holzman, 1981; Mitchell, 1976; Oliver *et al*., 1982).

Neophobia differs between rodent species (mice are reported to be neophilic, Meehan, 1984), between Rattus species (Cowan, 1977), between wild and laboratory strains, and even between populations and individuals (Cowan, 1977; Mitchell, 1976). Corey (1978) and Schleidt (1961) stated that a variety of animals respond differently to a novelty stimulus.

The development of neophobic behaviour in commensal rodents is due to selection for many generations during the acquisition and maintenance of commensal habits (Brooks, 1973; Richter, 1954). Failures in rodenticide application in the field, which not belongs to physiological resistance, are behavioural resistance (neophobia) and conditioned or unconditioned aversion to the rodenticide. Such behaviour can help rats to avoid consuming a lethal dose of rodenticide (Brunton *et al*., 1993; Parshad & Kochar, 1995; Quy *et al*., 1992b; Rzoska, 1953).

Three rats were used in the trial with groups of rats showing social interaction in rats, but they were caged singly during their adaptation in the laboratory, before being used in the experiment. Archer (1970) and Gentsch *et al*. (1981) explained that rats reared in groups could be more neophobic (consumed less) than in insulation, and this social facilitation was due to competition. Only female rats were used in the study with groups of rats, because hostility between female individuals was rarely seen. When males and females are mixed together, males usually show hostility to each other, either in exploring the resources (food) even between males and females, or in competing for a female.

In the experiment with groups of rats, it was often observed that the behaviour of one rat influenced the others and the discrimination between dominant and sub-dominant rats in exploiting the resources. Social rank of animals in a group might also affect the selection of neophobic individuals (Buckle *et al*., 1987; Robertson, 1982; Shepherd & Inglis, 1987). Moreover, Nieder (1986) and Galef & Wigmore (1983) explained the strategy through which a rat may acquire information from conspecifics. Barnett (1958b) and Archer (1970) defined the term social behaviour as any activity which directly influences the behaviour of other individuals of the same species.

In the neophobic behaviour test in groups and individuals (using the same feed) of rats, the rats from farm no. 4 showed the lowest level of neophobia as reflected by the highest amount of feed consumption, the longest total and mean time spent in the box, and the shortest adaptation time to the device (8 minutes). The relative consumption by rats from farm no. 4 in the box with device was greater than 100%, relative to that without device. The newly caught rats from farm no. 4 still showed a lower level of neophobic behaviour, as reflected by high relative values of neophobic variables, i. e. more than 100%.

The conditions at the farm no. 4 seemed normal with no significant disturbance. The second and third lowest level of neophobia was recorded in the rats from farm No. 17 and 23 (Table 31), where there was a train railway and cereal shedder and huller around the farm (Appendix 5). Presumably these objects did not affect the behaviour of the rats. Rats were not much disturbed by the noise of a train passing immediately and noises which maintain an accustomed tempo, however noises which occurred at irregular intervals produced the power to disturb the rats (Shorten, 1954).

Among the newly caught rats from farm no. 4 only two out of ten rats showed no avoidance towards the new object. In those two rats, there was a tendency to consume only at one feeding site. For the rat number 4822, the position of the device remained constant at one station until the end of the trial, but for the rat number 4831, the position of the device was changed from one station to another, after two nights of the trial. Under both conditions, the rats preferred to explore the source (feed) only at one station, whether with or without device. Although rats explore freely, they do seem to prefer to feed at certain locations (Mellgren, 1982). Moreover, Klopfer (1965, 1967) added that rats might not explore all possible foraging sites.

In the study with individual rats using the same feed, the shortest and longest adaptation time to the device showed the same tendency as the other variables, although there was a large variation in the adaptation time of rats from different farms. Cowan (1975) argued that commensal *R. norvegicus* individuals vary markedly in the duration of their new object reaction or identification. The relative consumption and time spent in the box with device compared with those without device showed greater than 100% in rats from three out of six farms. It seems that the rats used in the individual tests have already been familiar with the new object, compared with rats used in the group tests.

The rats from farm no. 3 showed the highest level of neophobia in groups of rats as reflected by the lowest amount of feed consumption, the shortest total and mean time spent in the box, and the longest adaptation time to the device (444 minutes). The relative consumption and total time spent in the box with device compared with those without device was only about 1%. The lowest mean time spent in the box was recorded, not only in the box with device, but also in the box without device. This may suggest that the neophobic behaviour in the “dangerous” box was transferred to the “save” box. Barnett (1958a) stated that new object reaction can be displayed even in a small cage, and that it consists of avoiding an unfamiliar object in familiar surroundings and also a considerable area around it.

Farm no. 3 was characterised by considerable disturbances and noises, and the high level of effectiveness in rat control at that farm (Table 2). However, this condition has a reversed effect on the high level of neophobia. The lower the neophobia, the rats did not hesitate to consume the bait offered at the farm, and the consequence is the high the level of effectiveness in rat control. The high level of neophobia in the group tests was presumably caused by social behaviour in groups of rats. Four rats used to test rats from this farm showed a higher degree of neophobia than groups of three rats from other farms. The same case was obtained between rats from farm no. 23B (4 rats) and no. 23A (3 rats) (Table 18, 19, 20).

However, the highest level of neophobia in the individual test was observed not only in the rats from farm no. 3 but also from no. 5. The farm no. 5 was very quiet and dark (Appendix 5). It seemed that the rats living at that farm had to be careful and were quite suspicious to exploit resources found around their environment. This fact was supported by the low level of effectiveness in rat control at that farm (Table 2). The higher the level of neophobia, the higher the suspiciousness of the rats to the bait offered. The phobic behaviour of rats from farm no. 5 could explain the difficulties in controlling the rats at that farm in which the use of warfarin, difenacoum, and brodifacoum did not result in a good control (Appendix 5).

At farms no. 3 and 5, there were only two kinds of feed (maize silage and pig feed) compared with at least three kinds of feed at farms no. 4 and 23 (Appendix 5). This might be responsible for the higher neophobia in rats from farms no. 3 and 5. The more kinds of feed at the farms, the more familiar the rats were with the situation, the lower the level of neophobic behaviour was. However, there were more kinds of feed at the farm no. 9. Macdonald *et al*., (1999) explained the contrary, the abundant supply of alternative feed and the stable environment were more likely explanations of the reluctance of rats to consume feed and the higher level of neophobia. Thus, supply of feed at the farm is not the only one factor which affected the level of neophobia. The combination of the variability of the feed supply and environmental changes may be important in the determination of neophobia in animals. Rats have been found to be easily trapped on land-fill refuse areas, where the frequently changing environment makes a neophobic strategy impossible (Boice & Boice, 1968; Boice, 1971).

There were three possible ways how the rats entered and consumed the feed in the box with device. In the first way, one rat entered the box and consumed the feed inside for some time without any interference. This represented a normal behaviour indicating that the rat was not afraid of the device. In the second way, one rat entered the box, but it suddenly came out of the box after only a very short time (1 - 2 seconds), carrying cereals in its mouth and consuming the feed outside the box. This suggested that the rat was afraid of the device, but it still searched for the feed inside the box with device. In the third way, one rat only observed the device through the "door", even from a certain distance (10 - 100 cm) and never entered. However, those three patterns of behaviour did not occur consistently in rats from each farm studied, therefore it is difficult to draw a relationship between the neophobic levels to the kinds of activity.

It can be concluded from this study that the differences in the conditions at the farm, where the rats lived before they were used in the trials, could affect the response of the rats to the device (new object) in the laboratory. Such neophobic behaviour may explain why some rat control operations have failed, not because of physiological resistance but due to the behavioural resistance i. e. avoidance of baits (Quy *et al.*, 1992b).

Reaction of individual rats from each farm to the new object using different feed differed from that using the same feed. Almost all of the test rats consumed more feed in the box with device than without device, except for rats from farm no. 9. The high neophobia in rats from farm no. 9 was reflected by the difficult control situation at that farm where it took 27 weeks to control the rats with poisoned bait, while only 2 – 14 weeks at other farms were needed (Appendix 5). Rats in frequently controlled areas generally showed a higher level of neophobia (Mitchell *et al.*, 1977). Moreover, Mitchell (1976) added that any population of wild rats is not behaviourally static but changing over time, and particular environ-ments select for particular behavioural characteristics.

Thus, rats preferred to consume the most palatable feed, although it was difficult to obtain or there was a disturbance around the feed (rolled oats in the box with device in this study) to the least palatable one, although it was easier to obtain (oats in the box without device in this study) (Mitchell *et al.*, 1973). Moreover, Mitchell *et al.* (1973) and Shepherd & Inglis (1987) explained that neophobia towards a palatable new feed, even containing poison, is likely to be transient compared to the neophobia towards a new object such as a feed container.

In the total time spent in the box of individual rats using different feed, the time spent by rats in the box with device was longer than that in the box without device, depending on the presence of the most palatable feed. Although the total time spent in the box of rats from farm no. 17 (113.65 minutes) was the highest, their mean time spent in the box (7.52 minutes) was less than that of rats from farm no. 4 (12.45 minutes). This discrepancy was caused by the frequent movement into and out of the box in rats from farm no. 17 indicating that those rats had a higher level of neophobia than rats from farm no. 4.

In the test using different feed, there were no significant differences in the mean time spent in the box and the adaptation time to the device among rats from different farms. The rats from farm no. 4 immediately entered the box with device (0 minute in adaptation time), whereas those from farm no. 5 did enter the box not until after 567 minutes. This condition was caused by a great variation in the behaviour of individual rats, even between rats from the same farm, as could be seen in the large value of standard deviation of their adaptation time (Table 26).

In the present work, all trials were conducted in the laboratory, where it is easier to determine the level of neophobia in rats coming from different farms. It is difficult to quantify neophobia of rats in the field, because of a large number of potentially confounding variables (Macdonald *et al*., 1999). The differences in the behaviour of rats observed at the farms during field trials in the Münsterland area is found to be reflected in the laboratory using rats from these farms.

There was a good correlation between the time interval between the two trials and the relative feed consumption and time spent in the box: The shorter the interval, the higher the relative values of those two variables. Thus, the rats still recognised the device used in the previous trials.

Although the difference in the time spent in the box between the shortest and the longest time interval was fairly large, the difference was not statistically significant, because of the large standard deviation (28,832.06). The strongest neophobic responses were triggered by the last treatment and the weakest responses by the fist treatment (Inglis, *et al*., 1996).

Comparing responses of rats from farms to the effect of the time interval between two trials on the relative feed consumption and time spent in the box, the rats from farm no. 17 showed the highest relative consumption, while those from farm no. 4 showed the longest time spent in the box. There was inconsistency on the relative consumption in which it should be shown by rats from farm no. 4.

There was a relatively good correlation between adaptation time at the laboratory and the level of neophobia. Rats which had been adapted in the laboratory for several months showed responses that were slightly different from the newly caught rats when faced with the new object. In the other word the adaptation time in the laboratory could affect slightly to the neophobic behaviour in the Norway rats.

The main findings in this chapter can be summarized as follows:

- The feed consumption, time spent in the box, and adaptation time to the device were used as a parameters in the neophobic behaviour test.
- Neophobic behaviour occurred both at the group and individual level. In experiments with individuals, rats were more familiar with the new object than in groups.
- The rats from farm no. 4 showed the lowest level of neophobia both in groups and individual trials. While the highest level of neophobia was shown by rats from farms no. 3 and 5.
- The conditions at the farm, where rats previously lived, affected markedly the neophobic behaviour of the rats to a new object, although the rats had been adapted to the laboratory conditions for more than one year.
- The rats preferred to consume the more palatable feed (rolled oats) to the less palatable feed (oats), although there was a disturbance (device) around the feed.
- The neophobic behaviour was shown by the rats with both long adaptation in the laboratory and the newly caught rats.
- There was a good correlation between the time interval between two trials and the adaptation time to relative consumption and time spent in the box.
- The shorter the interval and the longer the adaptation time were, the more familiar the rats were with the new object, showing higher feed consumption and longer time spent inside the box with device.

Chapter IV. GENERAL DISCUSSION

The aim of this general discussion is to summarise and integrate all main findings described in this thesis, and to put forward some suggestions for future research.

To confirm that the bait mixtures offered might not be attractive to be visited and consumed by the rats and the rats exhibited a behavioural resistance or neophobic reaction to the baits, it is necessary to conduct behavioural tests in the laboratory related to those phenomena. In this study the behaviour of rats towards food (included several kinds of cereals, typical feed available at a farm, and attractants) and neophobic behaviour trials both in groups and individuals of Norway rats from several farms towards a new object (device) was investigated under laboratory conditions.

The acceptance of several cereals in both choice and no-choice tests; typical feed obtained from one special farm; results of experiments on the usefulness of consumption enhancers such as sweetening agents (granulated-, vanilla-, and powder-sugar), vegetable oils (corn-oil), and animal source (egg); the effect of feed texture; the effect of sex and weight of rats on bait consumption; results of studies on rodenticide acceptance by rats, particularly from several farms in the Münsterland, Nordrhein Westfalen, using both choice and no-choice tests were used to evaluate feeding responses of the rats and were discussed in Chapter II.

Neophobic behaviour, either in groups or individual rats, and additional tests concerned the effect of the time interval between two trials and the adaptation time in the laboratory on the response of rats to the new object were discussed in Chapter III.

The principal findings were striking differences in rodenticide palatability and in the behaviour of rats observed from one farm to the next during field trials in the Münsterland area, Nordrhein-Westfalen, (Pelz, 1999) that could be mirrored in the laboratory using rats from these farms.

The higher the level of neophobia, the higher the suspiciousness of the rats to the bait offered. The high level of neophobia in rats from farm no. 9 was reflected by the difficult control situation at that farm where it took 27 weeks of poisoned bait for sufficient control, while only less than 14 weeks were needed at other farms. This fact answered the low consumption of rolled oats by rats from farm no. 9. The phobic behaviour of rats from farm no. 5 could explain the difficulties in controlling the rats at that farm in which the use of warfarin, difenacoum, and brodifacoum did not result in a good control.

The rats from farm no. 4 showed the lowest level of neophobia. The rats consumed the highest quantity of feed containing powder-sugar, corn-oil, and their combination. A phenomenon of low level of neophobic behaviour could also be seen in their ready acceptance of all kinds of baits that were offered, included brodifacoum application for 3 weeks.

Coumatetralyl showed the highest palatability, both in the choice and no-choice test, while warfarin showed the lowest palatability among the rodenticide preparations tested. Results at the farms proved that coumatetralyl showed a good results at 2 farms and bad results at 2 farms, while warfarin only good at 1 farm and bad at 5 farms.

Testing methods

In the experiments to evaluate feeding preference and rodenticide acceptance by the test animals, two commonly used methods were applied, i. e. the choice and no-choice tests. The advantages and disadvantages of each method have been well recognised by pertinent researchers. Which method will be used much depends on the goal that shall be achieved. The choice test is more suitable if the experiment conducted is aimed at simulating the field conditions, because there is various feed other than baits available in the field which could affect the bait acceptance. The no-choice test is more suitable to be conducted when someone wants to test consequences of the intake of certain feed or rodenticides by the target species.

In the no-choice feeding test, the un-poisoned bait-base was given for three days continuously, and on the fourth day it was replaced by the toxic bait (Yuet-Ming, 1980; Kühnert, 1981). A primary objective of the evaluation therefore is to determine the free-feeding toxicity of rodenticide bait preparations and also to evaluate bio-availability of the active ingredient in the proposed formulation. Besides, different kinds of methods should be considered either in the length of the treatments or in the different methods of the treatment itself.

In the trial to the Norway rats, using two different rats will affect a significant responses, not only on the influence to the treatment, but also to control, as exemplified in experiment 2 of Chapter II. Rats coming from the same farm could give a different feeding response as could be seen in the large standard deviation.

Feed and rodenticide acceptance

Rolled oats was the most palatable feed to the Norway rats in all tests, whereas oats was the least palatable feed. The use of special feed as an attractant for rats in the field (pre-baiting) and also as a bait base for rodenticides is worthwhile to be considered for the success of rat control programmes. It is therefore necessary to carry out a study on the preference of rats to several cereals, because the selection of grain or other food items that make up the bait base is critical to good rodent control (Meehan, 1984; Marsh, 1986).

In addition to bait base, other factors that may affect the success of rat control programmes include: The type of bait container, bait placement in the field, and the conditions or disturbances in the control area. The consequence of this application is the problem that has been faced in searching for a baiting mix which is the most palatable to the rats, compared with other feed stuff in the field. The rats are expected to come and consume the palatable bait (Meehan, 1984).

The nutritive value or food quality is an important factor in the feed preference. Besides, other factors could affect the feed preference, i. e. water content in the food, particle size, digestive physiology of animals, experience, ecological aspects, location of the bait at the farm, species, and social behaviour (Bond, 1984; FAO, 1982; Galef, 1983, 1989). Among those, only six factors were relevant for the results of the trials:

1. Nutritive value (typical feed from farm with rich versus poor in carbohydrate content)
2. Water content in the food (maize silage)
3. Particle size (altromin in pellet versus in meal form)
4. Experience at the farm (presence of certain feed at the farm)
5. Ecological aspect (disturbance at the farm)
6. Social behaviour (intensive chemical control using rodenticide with rolled oats bait base).

With view to the effect of attractants, all attractants tested in this study (sugar, vegetable oil, and egg) gave a positive effect, in that they could increase the bait consumption by the rats, either with rolled oats or altromin meal bait base, compared with consumption of the bait base without attractants. Nevertheless, further studies which involve a long-term treatment need to be conducted to find out whether the rats will continue consuming the bait or the consumption will decrease with time.

In addition to attractants tested, many other attractants, which could be obtained from the market or extracted from nature, like plant or animal tissues, could be tested in the laboratory or in the field. Besides those dry cereal grains offered to the test animal, rats also need a diet coming from animal materials. Norway rats are omnivorous and need food with slight addition of carnivorous materials. Other feed stuff like fish, meat, shrimp, or pellets factory produced as animal food, peanuts, and beans are recommended, but those baits are refused by rodents which are not familiar with them (Kühnert, 1981).

The difference in localities or habitat or farm could result in the different preferences of rats to the feed. The feeding behaviour of wild rats varies with the individuals and environment (Berdoy & Smith, 1993). The result is a great adaptability to a number of situations and marked specialisation.

The different results between laboratory and field trials, either in the feed or rodenticide acceptance, indicate that laboratory and field conditions were very different, and it can be caused by the following factors:

1. Another food source available at the farm where poison baits have always to compete with existing non-poisonous food (Barnett & Spencer, 1951; Calhoun, 1949).
2. Laying the bait down at the feeding point whether in a container or applied directly into rat burrows (Quy *et al*., 1992a).
3. Social communication among rats (Galef, 1986).
4. The interference by other animals, i. e. the competition between males (Barnett, 1955), and interference by other things at the farm.
5. The condition of feed and rodenticides tested, time of storage before and after grinding, and the variety of grains used (Kühnert, 1981).

Tests on rodenticide acceptance or palatability to the target animals are very important to be conducted either in the laboratory or in the field. The palatability of rodenticide baits is usually assessed in the laboratory where test procedures are easily standardized and within the normal limits of experimental error, reproducible results could be obtained. Standard protocols for such tests have been published both in Europe (EPPO, 1982) and in the USA (ASTM, 1977). The results obtained could be evaluated, and the effectiveness of each rodenticide to suppress the rat population at the farm could be analysed. The low acceptance of rodenticides by rats would pose a great problem in rat control. This phenomenon could be caused by inappropriate bait base, or bad taste of active ingredients, or the negative effect of additives compound. All these factors should be considered when rodenticides are to be used for combating rat problem in the fields.

Neophobic behaviour

The use of a big blue ball in the pre-test seems not to be effective to frighten the Norway rats, however, a light-producing object which was on – off automatically with a constant rhythm of noise, could frighten the rats. In general, the neophobic response is governed by the material of which a new object is made and the distance from the normal path of the rat. Thompson (1948) demonstrated neophobia in wild rats in response to both new feed and lighting used to observe its experimental site. Another possible new object which could give an effect on rat behaviour is light producing device which also produces a little noise (noise-maker).

Changes in illumination at a site normally used for food had less effect on the behaviour of the rat than the placing of a new object. In many other cases in the experimental colonies, the switching on - off of the lights did not cause cessation of feeding, or any noticeable reaction amongst the rats. The disturbing effect of noise remains operative in any case, but then, the rats recover more quickly (Shorten, 1954). Both readiness to eat and drink vary significantly, but only slightly and somewhat inconsistently with illumination and noise level (Bolles & Rapp, 1965). Results of this study were different from the above results.

The neophobic behaviour test was conducted in a series of experiments. It started with the testing of groups of rats, using three or four female rats from each farm to evaluate the differences in their response to the new object. The next step of the trial was the testing with individual rats from particular farms. In the individual tests, responses of rats from all farms to the new object were tested, either using the same feed (rolled oats) or the different feed (rolled oats and oats) in the different containers. Using all methods, it could be compared between groups and individuals, and between the same and different level of feed palatability.

Norway rats are known to be exceptionally wary of unfamiliar feed (Marsh, 1983; Prakash, 1988). Neophobia is a response of a rat population to the presence of a new feed source and at the same time it may be considered as a strategy developed in the commensal rodent colonies to protect rats from poisons and traps (Cowan, 1977; Mitchell, 1976; Nieder *et al*., 1977).

Three factors that may govern the phenomena of neophobia are genetically enhanced neophobia, experience, and the stability of the environment (Macdonald *et al*., 1999). The differences in the levels of neophobia in rats in this study were very likely caused by the experience of the test animals and the stability of the environment at the farms. However, it is important to conduct further studies to prove the occurrence of genetically enhanced neophobia in Norway rats.

Factors influencing neophobic behaviour in Norway rats

Based on results of this study supported by information from the relevant literature, it can be concluded that the following factors could affect the neophobic levels in rats:

1. Social factor

Rats are believed to be highly social and co-operative animals. Group-housed rats consumed less food than isolated ones. This absence of social facilitation was attributed to the *ad libitum* feeding schedule compared with the daily feeding employed in social facilitation experiments. The effect of the behaviour of one rat on the others could often be observed. Many authors have shown the dependence of neophobia on social factors (Nieder, 1986).

2. The natural variability of the food supply

Particular environments select for particular behavioural characteristics. The availability and the diversity of feed at the farms influenced the feeding behaviour of the rats. The farms in Hampshire tended to be large and surrounded by fields of cereals, this provides an abundant and relatively predictable alternative feed supply. Rats living in this environment can therefore afford to be neophobic. By contrast, in Mid Wales, where rat control by poisoning is widely held to be successful, farms tend to be smaller with more livestock and less stored grain. In these less predictable environments, rats would need to be more opportunistic (Macdonald *et al*., 1999).

3. Interaction with human

The fluctuations in the levels of neophobia may be due to the interactions between rats and humans in both rural and urban environments (Chitty & Shorten, 1946; Mitchell, 1976). While Barnett & Cowan (1976) added that the feed avoidance after a poisoning period has been considered as a learned response.

4. Variation in individual rats

A large individual variation among the test animals of the same strain in the responses to new feed and its containers placed in the home range is evident (Inglis *et al*., 1996; Mitchell, 1976; Brunton, 1995). Moreover Mitchell (1976) explained that variation in neophobia is, at least partly, heritable as evidence by the consistent differences in time to first consumption by different strains of rats.

5. Control activities

Norway rats are subject to intensive control and eradication regimes through poisoning and trapping over several years, and it might be expected to select more neophobic individuals (Barnett & Cowan, 1976; Berdoy & Smith, 1993; Quy *et al*., 1992b), and are amongst the most neophobic mammals known (Meehan 1984). Barnet *et al*. (1975); Brunton *et al*. (1993) added that the strong avoidance of novel stimuli in the Norway rat is thought to be a significant impairment to the efficacy of eradication programmes.

There is a general consensus that neophobia has been selected for in some species, because it protects them against human control measures (Barnett, 1975; Barnett & Cowan, 1976; Brunton *et al*., 1993; Mitchell, 1976; Oliver *et al*., 1982). Moreover, Mitchell (1976) added that the use of a single rodenticide can have such a profound effect on the physiological characteristics of the victim population and the intensive use of a broad spectrum of rodenticides can also have an effect on the behavioural characteristics.

6. Pathogens

Wild Norway rats with *Toxoplasma* infections were significantly less neophobic than uninfected rats, although this factor was not examined in this study. These findings were consistent with the results of laboratory studies using mice (Hutchison *et al*., 1980a, b, c; Hay *et al*., 1983a, b), despite the contrasting feeding behaviour of the two species (rats are neophobic and mice neophilic). *Toxoplasma* is yet one of the suite of factors that might affect the behavioural resistance at some farms to poison and contribute to the individual differences in neophobia (Brunton *et al*., 1993).

Diminished neophobia to novel food may be a side effect of the parasite, the relevance of which to rat host survival will have only recently become important as comprehensive vermin control programmes have been developed.

CONCLUSIONS

1. Experience at the different farms could affect the preferences and response of rats to the feed and levels of neophobia in rats in the laboratory
2. There were three factors at the farms that could affect the feeding responses of rats and levels of neophobia in rats in the laboratory, i. e. disturbance, effectiveness in rat control, and feed availability
3. The lower the level of the neophobic behaviour in rats was, the easier the rats accepted several kinds of feed and taste
4. The rats with a high level of neophobia came from very quiet locations, without disturbance, and from frequently controlled areas
5. The normal condition to many disturbances at the locations of origin and the more kinds of feed and change at the farm, resulted in the low level of neophobia
6. The differences in the behaviour of rats observed at the farms during field trials were reflected in the laboratory using rats from these farms.

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Appendice

Appendix 1. Nutritional content of altromin pellet as a standard diet for rats and mice

Components	%	Supplementary materials	Content per kg
Raw protein	19.0	Vitamin A	15.000 IU
Raw fat	4.0	Vitamin D3	600 IU
Crude fibre	6.0	Vitamin E	75 mg
Raw ashes	7.0	Copper	5 mg
Calcium	0.9		
Phosphor	0.7		

Source : Trade Label

Appendix 2. Consumption of altromin meal amended with granulated-sugar as attractant by Norway rats (pre-test, choice method)

Attractant concentration (%)	Consumption of feed (g/100 g of body weight) * x ± SD (n)	
	Without attractant	With attractant
5	2.05 ± 1.96 (98) a	4.29 ± 2.68 (98) b
10	1.00 ± 1.81 (98) a	6.28 ± 2.43 (98) b
15	1.05 ± 1.19 (25) a	5.26 ± 2.65 (25) b

* Consumption in the same row followed by the same letter are not significantly different according to t-test ($\alpha = 0.05$)

Appendix 3. Consumption of altromin meal amended with vanilla-sugar as attractant by Norway rats (pre-test, choice method)

Attractant concentration (%)	Consumption of feed (g/100 g of body weight) * x ± SD (n)	
	Without attractant	With attractant
2	1.47 ± 1.68 (63) a	4.38 ± 2.35 (63) b
4	1.21 ± 1.16 (64) a	5.07 ± 1.94 (64) b
8	0.70 ± 1.25 (64) a	6.29 ± 1.77 (64) b
10	0.93 ± 1.33 (40) a	4.95 ± 2.28 (40) b

* Consumption in the same row followed by the same letter are not significantly different according to t-test ($\alpha = 0.05$)

Appendix 4. Consumption of rolled oats amended with egg (10 %) as attractant by Norway rats (pre-test, choice method)

Type of control	**Consumption of feed (g/100 g of body weight) * x ± SD (n)**	
	Without attractant	**With attractant**
Rolled oats only	1.20 ± 1.37 (46) a	5.42 ± 2.13 (46) b
Rolled oats with 10 % water	2.33 ± 1.31 (52) a	4.60 ± 1.55 (52) b

* Consumption in the same row followed by the same letter are not significantly different according to t-test ($\alpha = 0.05$)

Appendix 5. General conditions at the farms from where rats were taken for laboratory trials

Farm no.	**Rodenticides, application time (weeks), and result**	**Livestock feed**	**Conditions**
3	Warfarin, 3, good Difenacoum, 4, good Warfarin, 2, bad Coumatetralyl, 2, bad Difenacoum, 3, good	Maize silage, pig feed	Many disturbance and very unquiet
4	Warfarin, 4, bad Difenacoum, 4, bad Brodifacoum, 3, good	Wheat, maize silage, pig feed	Normal
5	Warfarin, 4, bad Coumatetralyl, 3, good Difenacoum, 3, bad Brodifacoum, 3, bad	Maize silage pig feed	Silent and dark
9	Warfarin, 3, bad Difenacoum, 11, good Brodifacoum, 13, good	Barley, wheat, maize silage, triticale, CCM	Normal
14	Warfarin, 2, bad Bromadiolone, 2, bad Difenacoum, 3, bad Difenacoum, 2, good	Maize silage	Normal
17	Coumatetralyl, 2, bad	Maize silage, pig feed	Train railway
23	Warfarin, 2, bad Coumatetralyl, 2, good Bromadiolone, 3, bad	Wheat, barley, maize silage, pig feed, soybean coarse meal, mineral material, cow corn, milk powder	Cereal shedder and huller

Appendix 6. The distribution of rats samples at the farm in Münsterland

CURRICULUM VITAE

Name : Swastiko Priyambodo

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Management experiences :
Member of Research Commission, Dept. of Plant Pests and Diseases, Bogor Agric. Univ. (1991 – 1994)
Member of Education Commission, Dept. of Plant Pests and Diseases, Bogor Agric. Univ. (1994 – 1996)
Secretary of the Dept. of Plant Pests and Diseases, Bogor Agric. Univ. (1996 – 1997)

Marital Status : Married

Wife : Sulistijorini Soetrisno, born in Malang, 20 September 1963
(Graduated from Post-graduated Program, Bogor Agric. Univ.) 1995

Children :
1. Andrini Aditya Wardhani (daughter), born in Bogor, 5 July 1989
2. Muhammad Aji Wibisono (son), born in Bogor, 17 December 1992
3. Muhammad Abi Wicaksono (son), born in Bogor, 21 April 1995

Göttingen, 14 May 2002
Swastiko Priyambodo