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INHERITANCE OF COAT COLOUR IN FERRETS (*MUSTELA PUTORIUS FURO*) BASED ON PEDIGREE ANALYSIS

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Abstract

The study aimed to determine the rules governing the inheritance of coat colour in ferrets, including basic colour, colour concentration patterns, and white markings. To reach this aim, pedigree analysis was applied. It covered the pedigrees of 201 pups born between 2009 and 2017 in two household ferretries. In the analysed population, basic colours black and dark brown dominated over brown, beige, and those with copper reflections. The standard colour concentration pattern dominated the other patterns, the point type being the most recessive. The point pattern is phenotypically similar to the Himalayan mutation, which is also recessive to the wild type. In this study, it was impossible to analyse if the lack of white markings dominated over their presence, due to the small differences in the number of animals with and without white markings. The obtained results refer to a specific animal population and are based only on phenotypic classification.

Introduction

The first recorded coat colour variations in ferrets (*Mustela putorius furo*) were sable (so-called standard) and albino (JEŻEWSKA and MACIEJOWSKI 1989, BEDNARZ and FRINDT 1991, BLASZCZYK et al. 2007). The nomenclature used in 1980s in Polish farm breeding distinguished three types of breeding polecats: grey, lemon, and orange, the colour of undercoat hair being their main difference. There were also brown variations, with the varying intensity of colour, from dark brown to light yellow-brown,

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referred to as fawn (Jeżewska and Maciejowski 1989, Bednarz and Frindt 1991). The Scandinavians described individuals with silver hair on their tails, hind legs, napes, and hips. In addition to the standard and albino colour variations, they also distinguished pastel ferrets, with light brown fur. Ferrets with a dark brown coat, called chocolate, have been reported in Finland, Norway, and the USA (Nes et al. 1988). In 2005, the American Ferret Association distinguished 30 colour variations of ferret coat, 11 of them being basic variations. In addition, the Russians distinguished sable, pearl and goldish variations, differing in undercoat colour. The goldish variation had yellow-orange, pearl had white, and sable had cream-yellow undercoat hair (Lewington 2007). Currently, to correctly characterise the coat colour of a ferret, a three-step analysis should be performed. First, basic colour is determined; then, a concentration pattern is determined; and finally, white markings – if present – are classified (American Ferret Association 2017, Associazione Italiana Furetti 2016). The coat colour of animals depends on the presence of melanin pigments in the hair and skin. In mammals two melanin types responsible for fur colour can be distinguished – namely eumelanin and pheomelanin – they can occur in the hair and skin together or alone. The basic coat colour is determined by the ratio of eumelanin to pheomelanin, which is mainly being controlled by the Agouti signalling protein (*Asip*) and the Melanocortin-1 Receptor (*Mc1r*) genes. The final effects seen in animals can be modified by many other genes, e.g. Tyrosinase-related protein 1 (*Tyrp 1*) can switch the eumelanin colour between black and brown. Some genes may dilute the base colour (e.g. Myosine 5a – *Myo5a*), others may cause white spotting on the fur and skin (e.g. Endothelin receptor type B – *Ednrb*, Dominant white – *Kit*) and the Tyrosinase-related protein gene (*Tyr*) is responsible for the lack of pigment in animals body – albinism (Cieslak et al. 2011, Hoekstra 2006, Ata and Majewski 2016, Rzepka et al. 2016). The topic of genetic basics of coat colour inheritance in ferrets has been briefly described by Grabolus et al. (2016). The authors were also using pedigrees in their analyses but contrary to this study, they concentrated on the genetics of the coat colour.

This study aimed to determine the inheritance scheme – consisting of basic colours, colour concentration patterns, and white markings – of coat colour in ferrets. To meet this aim, a pedigree analysis was conducted.

Material and Methods

Coat colour classification

The classification of colour variations used in this study is based on the Associazione Italiana Furetti (2016) – Furetomania Onulus – Aif (2016) and the American Ferret Association – AFA (2017). The classification includes six basic colours and two types of uniformly white coat colour, five colour concentration patterns, and five variations of white markings. Unlike AIF, AFA uses neither the self pattern nor milk and striped white markings.

The pedigrees

The research included the pedigrees of 201 ferrets born in 2009–2017. The ferrets came from two household ferretries, namely, Ferretta Passion (Poland; 105 ferrets) and Ferret Vendetta (Italy; 96 ferrets). The pedigrees included 354 specimens (178 females and 176 males) for whom it was possible to determine the basic coat colour, concentration pattern, and white markings. Ferrets from both ferretries were related. In addition, breeding lines were carried out and some matings were repeated, allowing for more accurate analysis and the higher reproducibility of the study. The pedigrees originated from private breeders' resources and "Feritage – Ferret Database System", a ferret pedigree database (2017) supervised by Marit Nybakken.

Pedigree analysis

To determine the rules for the inheritance of coat colour in ferrets, the analysis of pedigrees for the litters born between 2009 and 2017 was carried out. The analysis included all the matings found in the pedigrees, which went back three generations (an offspring, parents, grandparents, and great-grandparents). The analysis was carried out separately for each of the three aspects of determining coat colour, that is, basic colour (including the colour uniformly white), a concentration pattern, and white markings.

Because of the colour uniform white for the albino and DEW (Dark Eyed White) coat colours, it is impossible to determine the concentration pattern and the occurrence of white markings for them. In addition, in ferrets with striped white markings, a colour concentration pattern cannot be determined, which is also due to the predominance of the colour white. Therefore, when analysing concentration patterns, mating with uniformly white individuals and striped white markings was considered. To analyse white markings, mating with ferrets with the colours albino and DEW was also considered.

Results and Discussion

Basic colour

Twenty-three out of 37 possible mating combinations for basic colour were detected in the population analysed (Table 1). Coats with mostly black and/or dark brown hair (that is, black, black-sable, and sable) clearly dominated over coats with hair in shades of brown (that is, warm shades), beige, and with copper reflections (that is, chocolate, champagne, and cinnamon).

Table 1

The distribution of the eight basic colours for various matings (27 combinations)

Specification	Black	Black-sable	Sable	Chcoco-late	Cinna-mon	Cham-pagne	DEW	Albinos
Black × black	9	2	8	1	–	–	–	–
Black × black-sable	29	34	3	4	–	–	–	–
Black × sable	9	1	3	4	–	–	–	–
Black × chocolate	12	1	2	6	1	–	–	–
Black × cinnamon	1	–	–	4	–	–	1	–
Black × champagne	–	–	–	–	–	2	–	–
Black × DEW	–	–	1	–	–	–	–	–
Black-sable × black-sable	–	11	2	1	–	–	–	–
Black-sable × sable	–	11	16	5	–	–	–	–
Black-sable × chocolate	6	3	1	3	–	–	–	–
Black-sable × champagne	–	1	–	–	–	–	–	–
Sable × sable	–	–	4	–	1	–	–	–
Sable × chocolate	7	4	14	8	4	5	–	–
Sable × cinnamon	–	1	1	–	–	–	–	–
Sable × champagne	–	–	2	1	–	1	–	–
Sable × DEW	–	–	1	–	–	–	–	–
Sable × albino	–	1	1	–	–	–	–	–
Chocolate × chocolate	–	–	–	2	1	–	–	–
Chocolate × cinnamon	–	–	2	2	–	1	–	–
Chocolate × chapmagne	–	–	–	2	1	–	–	–

cont. Table 1

Cinnamon × cinnamon	–	–	–	–	1	–	–	–
Cinnamon × albino	1	–	–	–	–	–	–	–
Champagne × albino	–	–	–	–	–	–	–	1

Eight base coat colours in ferrets can be distinguished, which results in 37 possible mating combinations. The table presents 23 mating combinations for base coat colours that occurred in the study

It was impossible, however, to determine the dominance series for these three most dominating coat colours, because of their similar distributions of mating combinations and offspring colour. Therefore, it is difficult to determine whether the most dominant colour is black, black-sable, or sable: more detailed analyses that would include the genotypes are needed. The small difference between the number of black and black-sable ferrets may also result from mistakes in coat colour determination, a likely reason being that the breeders prefer black ferrets.

The dominance of dark colours over lighter ones is quite common among mammals. In the majority of species, the wild type (so-called agouti) has most hair of the colour black-brown (BENNET and LAMOREUX 2003, HOEKSTRA 2006, CIESLAK et al. 2011). BEDNARZ and FRINDT (1991) and JEŻEWSKA and MACIEJOWSKI (1989) also claimed that brown ferret variations were recessive to standard variations (so-called polecats). Similarly, in American mink, standard variations (black and dark brown) dominate over various pastel variations (i.e., with coat in shades of brown, beige, and those with copper reflections) (SHACKELFORD 1948, NES et al. 1988, KUŹNIEWICZ and FILISTOWICZ 1999). Also in dogs, cats, and mice, the brown coat colour – also known as chocolate or liver – is recessive to the wild type (RUVINSKY and SAMPSON 2001, SCHMIDT-KÜNTZEL et al. 2005). Uniformly white coats (albino and DEW) are the most recessive to other colours. Like in cats, rabbits, cattle, chickens, sheep, American mink, mice, rats, and humans, albinism in ferrets is inherited autosomal recessively (BENNET and LAMOREUX 2003, BLASZCZYK et al. 2007). Such a small number of white ferrets can also be due to diseases associated with this colour – such as deafness in ferrets of the DEW type – and the resulting reluctance of breeders to reproduce animals of this colour (PIAZZA et al. 2014). The obtained pattern of dominance for the basic coat colour in ferrets does not differ from the commonly existing patterns of coat colour dominance in the above-described mammalian species.

Concentration pattern

Seventeen out of 36 possible mating combinations for concentration patterns were detected in the population studied (Table 2).

Table 2

The distribution of eight concentration patterns for various matings (17 combinations)

Specification	Self	Solid	Standard	Roan	Point*	Striped	DEW	Albinos
Self × self	2	–	–	–	–	–	–	–
Self × standard	3	5	7	–	–	–	–	–
Self × roan	–	5	7	10	1	–	–	–
Self × striped	–	6	8	2	–	–	–	–
Self × DEW	–	–	1	–	–	–	–	–
Solid × solid	1	5	2	–	–	–	–	–
Solid × standard	2	3	9	–	–	–	–	–
Solid × roan	3	9	12	12	1	–	–	–
Standard × standard	–	5	56	5	4	–	–	–
Standard × roan	–	1	22	23	3	1	–	–
Standard × point	–	–	1	–	1	–	–	–
Standard × DEW	–	–	1	1	–	–	–	–
Standard × albinos	–	–	2	–	–	–	–	1
Roan × roan	–	–	5	4	–	–	–	–
Roan × point	–	–	5	–	1	–	–	–
Roan × striped	–	–	–	5	–	–	–	–
Point × striped	–	–	–	–	–	–	1	–

* Point – also Siamese

Eight concentration patterns in ferrets can be distinguished, which results in 36 possible mating combinations. The table presents 17 mating combinations for concentration patterns that occurred in the study. The albino and DEW variations were counted in all three categories because it is impossible to determine the concentration pattern or occurrence of white markings in a uniformly white animal

Of the five patterns, the standard one clearly dominated to the others, closely followed by the roan pattern. The solid pattern was placed third in the dominance series, followed by the self pattern. The point pattern was the most recessive. Situations in which the concentration pattern could not be determined were negligible in the population studied.

The wild type coat colour is dominating to the other colour variations. This was confirmed by the results related to the standard concentration pattern in ferrets, which gives a coat similar to that of a European polecat (JEŻEWSKA and MACIEJOWSKI 1989, BEDNARZ and FRINDT 1991). The roan pattern in ferrets is phenotypically similar to the roan pattern in horses, dogs, and mice. This pattern manifests phenotypically as a mixture of white and coloured hair, in dark-coloured animals giving the salt-and-pepper effect. In addition, like in horses, in ferrets the roan pattern appears for all basic colours, most visible being for dark coat colours (THIRUVENKADAN et al. 2008, WEBB and CULLEN 2010, CIESLAK et al. 2011). The relatively frequent occurrence of the roan pattern – which occurs in neither the wild ferret (polecat) nor polecats bred for fur – may indicate the dominant character of the mutation responsible for the roan pattern. Ferrets in the point (Siamese) pattern are similar in colour to Himalayan mutations in cats (LYONS et al. 2005, SCHMIDT-KÜNTZEL et al. 2005). In mice, rats, guinea pigs, rabbits, and American mink, we can observe a similar phenotype, for which the recessive mutation is responsible (BENKEL et al. 2009, CIESLAK et al. 2011). Due to its recessive nature, the Himalayan mutation is relatively rare if lines of animals of this type are not bred, like in the case of Siamese cats (including Thai, Tonki, and Burmese). In the amateur breeding of ferrets, the point pattern is an unpopular colour variation, additionally decreasing the small number of these animals.

White markings

Twelve out of 35 possible mating combinations of white markings were detected in the population studied (Table 3). The ratio of the number of offspring with no white markings to those having them (two animals with uniformly white coats were classified as having white markings) was 1.5:1.2. In the over half of the mating combinations, at least one of the parents did not have white markings, making it impossible to determine whether in ferrets the presence of white markings is recessive to their lack. In other mammal species, white markings are either recessive (e.g., in mice, rats, and dogs) (WEBB and CULLEN 2010, STRAIN 2011) or – in fewer species – dominant (e.g., in cats and horses) (COOPER et al. 2005, CIESLAK et al. 2011).

Table 3

The distribution of eight white markings for various matings (twelve combinations)

Specification	n.p.*	Milk	Mitt	Blaze	Panda	Striped	DEW	Albinos
N.p. × n.p.	65	2	13	1	–	–	–	–
N.p. × mitt	54	–	64	–	–	–	–	–
N.p. × blaze	1	–	–	–	–	–	–	–
N.p. × panda	2	–	1	1	–	–	–	–
N.p. × striped	13	–	4	–	–	–	1	–
N.p. × DEW	–	–	1	2	–	–	–	–

cont. Table 3

N.p. × albinos	1	–	–	–	–	–	–	1
Mitt × mitt	7	–	22	–	–	–	–	–
Mitt z blaze	1	–	1	–	–	1	–	–
Mitt × panda	–	–	1	1	–	–	–	–
Mitt × striped	–	–	7	–	–	–	–	–
Mitt × albinos	1	–	–	–	–	–	–	–

* N.p. – no pattern (no white markings)
Eight concentration patterns in ferrets can be distinguished, which results in 35 possible mating combinations. The table presents twelve mating combinations for white markings that occurred in the study. The albino and DEW variations were counted in all three categories because it is impossible to determine the concentration pattern or occurrence of white markings in a uniformly white animal

There was a clear dominance of mitts to the other four variations of white markings. The frequencies of ferrets with milk, blaze, panda, and striped white markings were similar, making it impossible to determine which type of white markings followed the mitt variation in the dominance series and which was the most recessive. A low number of ferrets with white markings on their heads (blaze, panda, and striped) is undoubtedly correlated with the large share of deaf ferrets among animals with such white markings. Such a correlation was also found in horses, dogs (for over 90 breeds), cats, pigs, and cattle. In Jack Russell Terriers, this correlation is strong (Webb and Cullen 2010, Cieslak et al. 2011, Strain 2011). Similar results were reported in ferrets. Strong correlation between white markings and congenital deafness was observed in the research carried out on 152 ferrets in 2008–2012 at the Veterinary Hospital and Speciality Center of Frégis and Veterinary Clinic ADVETIA in France, regarding the occurrence of congenital deafness undergoing brain-stem auditory evoked response (Piazza et al. 2014). Therefore, breeders should avoid pairing two ferrets with white markings on their heads as well as two uniformly white ferrets. Despite deafness that uniformly white ferrets and those with white markings are likely to suffer from, some ferretries breed them because of their attractive appearance and the resulting interest of possible buyers. In addition, unlike in dog and cat breeding, a lack of compulsory hearing tests for individuals in the risk group (blaze, panda, Dark Eyed White, and albino variations) additionally decreases the breeding value of such ferrets.

Summarizing results obtained in our study, darker coat colours in ferrets dominate over the lighter ones. It was impossible to determine which of the three most prevalent coat colours is the most dominant one due to their similar distribution in the database. When analysing the concentration pattern the standard one proved to be the most frequent one (138 animals), followed by roan (62 animals). It was impossible to determine whether white markings in ferrets are a dominant or recessive trait due to close ratio of ferrets with and without such markings on their body (1.2:1.5) present in the database.

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