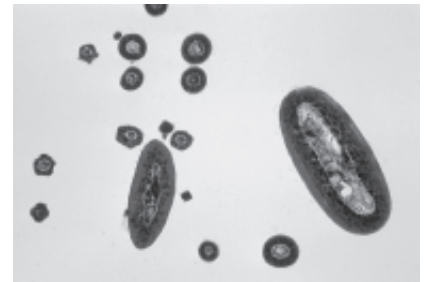
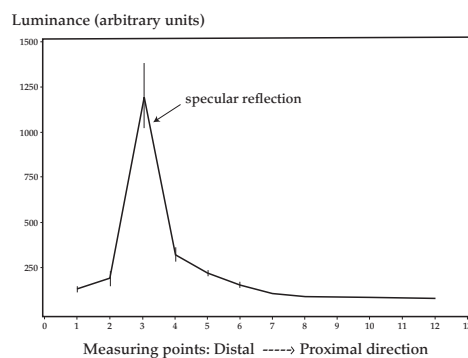


September 2001

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No. 35 • Animal Husbandry



Palle Vistisen Rasmussen

Morphological and optical fur properties in mink (*Mustela vison*)

– A study on raw, dried mink pelts with reference
to product quality

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Preface

This publication is mainly based on a reversed version of a survey article included in my Ph.D. thesis dated April 1998 and entitled “Morphological and Optical Fur Properties in Mink (*Mustela vison*). A study on dried mink pelts, with special reference to product quality” from Faculty of Science, University of Copenhagen.

During my master study in zoology at the University of Copenhagen, I got involved in the research on feather morphology and feather colours in peregrine falcons. The aim was to obtain expressions for colour differences between two almost uniform (brown versus dark-brown), stuffed, subspecies of the falcon. By using microscope spectrophotometry, transmission and scanning electron microscopy, it was possible to discriminate between the two subspecies. In spite of the speciality of this zoological study, it turned out to be the entrance door to histomorphological research on hair, skin and pelt in farm-raised fur animals at the former National Institute of Animal Science in Denmark, now the Danish Institute of Agricultural Sciences (DIAS).

In the establishing phase of the research field dealing with fur, focus was put on different fur defects and fur abnormalities in mink and foxes. Furthermore, the normal variation in hair fibre morphometry and hair fibre quantity between different strains of dark farm-raised mink was examined. It is possible to provide objective information about fur development, composition and quality. The idea was to find a basis of certain quality criteria improving the breeding work and prediction of quality, supplying the interpretations of feeding trials, bearing in mind that the concept of fur quality is difficult to specify. The main reason is that fur quality depends on several sub-traits, which demonstrate interdependence.

Foulum, September 2001
Palle Vistisen Rasmussen

Summary

The product quality of farm-produced mink pelts can be controlled and influenced towards demands especially made by buyers and designers. By selection of breeding animals the individual fur breeder can modify important product properties concerning quantitative traits, such as size, hair type and the colour shade of hair fibres in the colour type concerned.

In practice the grading of fur quality of live animals and dried pelts done by the fur breeders (primary producers) and the grading of dried pelts done by the sales organisations are mainly based on subjective, sensory i. e., visual and/or tactile, methods. However, fur quality is composed of a large number of sub-traits i. e., morphological hair fibre characteristics such as fibre diameter, fibre length, fibre density, relations between guard hairs and underhairs, the orientation of the guard hairs, the colour shade of the underfur. A large variation in these parameters is observed. The multitude of the sub-traits makes judgment or grading of fur quality difficult. In order to improve grading, selection and breeding, an important purpose of research on fur product quality is to find particular objective quality parameters, which correlate significantly with subjective assessments of different sub-traits of the fur.

The present work is a study on dried mink pelts. Based on references and personal investigations, the work deals with fur structure and hair morphology in fur animals in general and dark mink in particular, with hair type variation, and how it can be determined numerically and pointed out by using morphometric, microscopic and photometric methods. It also deals with important fur properties related to fur quality and defects. The quality is divided into a) guard hair quality, b) underfur quality, and c) associated fur properties.

It is concluded that development, adaptation and use of objective methods is advantageous for production of particular information about descriptive and causal relations in respect to several traits and their variation in the mink pelt and fur. The methods and investigations discussed in this summarising report have produced results, which help to explain and thus provide a background for the sensory judgment and grading of fur. Relationships between objective variables and subjective judgments are to a certain degree determined by the accuracy of sensory judgments. It is obvious that in combination the methods and results may contribute to rationalize some concepts of grading and selection of pelts, serving as a kind of fur formulation devices and thus improving fur quality and its control.

Introduction

The product quality of farm-produced mink pelts can be controlled and influenced towards demands especially made by buyers and designers. By selection of breeding animals the individual fur breeder can modify important product properties concerning quantitative traits as size, hair type and colour shade of hair fibres in the colour type concerned (Berg, 1993). At the moment pelt size is the economically most important property, because the buyers are paying very well for long pelts. However, talking about product development, the most visionary potential does probably not include size.

In practice gradings of fur quality on live animals and dried pelts done by the fur breeders (primary producers) and gradings of dried pelts done by e.g. Danish Fur Sales are usually based on subjective, sensory (i.e., visual and/or tactile) methods. Fur quality depends on a large number of sub-traits, i.e., morphological hair fibre characteristics such as fibre diameter, fibre length, fibre number (density), relations between guard hairs and underhairs, orientation of and parallelism of guard hairs, and colour shade of the underfur. A large variation in these parameters is observed (Blomstedt, 1979; Lohi and Rasmussen, 1991; Reiten, 1978; Skårman, 1945; Wentz and Hunt, 1951). The multitude of sub-traits complicates judgment or grading of the fur quality. In order to improve grading, selection and breeding, an important purpose of research on fur product quality is to provide objective quality parameters, which correlate significantly with and explain subjective judgments of different sub-traits of the fur.

In 1951, Wentz and Hunt suggestively wrote that “quantitative measures of each component of quality will be necessary in genetic research” and “standard fur measurement should also be useful in determining the economic value of certain feeding and management practices.” Correspondingly, the author believes that quantitative means for measuring fur quality could form the basis for criteria of product quality improving the genetic control of the quality.

The present work is a metrological study on dried mink pelts. Based on references and personal investigations, it deals with fur structure and hair morphology in fur animals in general and dark mink in particular, with hair type variation and how it can be measured numerically and pointed out by use of morphometric, microscopical, and photometrical methods. It also deals with important fur properties connected with fur quality and defects. The quality is divided into a) guard hair quality, b) underfur quality, and c) associated fur properties.

In the literature, measurement of optical properties of the plumage of birds and the pelage of certain mammals (i.e., mice, rabbits) have been reported. However, very few includes mink. In the present work, investigations dealing with silkiness and colour shade focus on the brown type of farmed mink. As it can be imagined, a certain surface or colour character often means ten different surface or colour shade impressions to ten different persons. Therefore, the purpose of that work has been to develop or to adapt objective methods for obtaining detailed (descriptive) optical data and use these in the attempt to explain the subjective grading of optical impressions of silkiness and of colour shades.

Hair Morphology and Fur Structure

Introduction

During the last 100 years, systematic and detailed investigations and descriptions of hair fibres and fur or pelage structure of wild mammals have been carried out. Human hair fibres have been included, too. These studies were based on both macroscopical and microscopical methods. Some important works should be mentioned.

Toldt (1935) wrote a book not only aimed at zoologists and anatomists but also at fur breeders, furriers and tanners. It has two chapters: The first is called "Aufbau (Haarformenbestand) des Haarkleides der Wildsäugetiere" and deals especially with the so-called "hair fibre constellation" and its importance for the fur character. The second chapter deals with fur colour and is called "Über die natürliche Färbung des Felles in seinen verschiedenen Tiefen (Tiefen- oder Profilfärbung)." This work includes 80 pages with very detailed and illustrative colour drawings of fur samples and single hair fibres. Lochte (1938) made an "Atlas der menschlichen und tierischen Haare" applied to human, veterinarian and forensic medicine, zoology, animal breeding, furriers and the cosmetic industry. Dathe and Schöps (1986) edited a "Pelztieratlas" with special reference to the zoological point of view. They write: "Die zoologische Systematik lief gewissermassen der ausübenden Praxis hinterher," and "Mit dem vorliegenden Buch wollen wir aber die zoologische Seite in den Vordergrund rücken, um endlich die genannte Lücke so sachverständig und so vollständig wie möglich zu schliessen." And they continue "Wir strebten also kein "Handbuch der Rauchwarenkunde" an – das hätte ganz anderen Umfang annehmen müssen -, sondern ein Buch, das die Pelzlieferanten – d.h. die Tiere -, seien es nun Wildformen, Haustiere oder Farmtiere, vorstellt und wichtige Angaben über Aussehen, Verbreitung, Biologie, Ernährung, das Fell und schliesslich die Naturschutzsituation der Art bringt. Blazej et al. (1989) made an "Atlas of Microscopic Structures of Fur Skins 1" – a work based on scanning electron microscopy. The primary object of this volume is "to partially fill the gap in the availability of reference micrographic material by presenting the exact descriptions and proper illustrations of the microscopic patterns obtained by up-to-date methods operating on a wide range of skin species." This book has three chapters entitled "Morphological and histological structure of animal fur skin", "Classification and nomenclature of morphological features of furs" including "The numerical code for description of the microscopic structures of furs" and "Morphological features of individual fur skins."

With the invention of transmission and scanning electron microscopes, computer-

assisted light microscopy, microscope photometry and other physical methods, the possibilities of objective or numerical, morphological analyses of the fur and its hair fibres have been improved. These possibilities have been used extensively also in examinations and descriptions of fur properties in farm-raised fur animals (see “Materials and Methods”).

The mink - general characteristics

According to Dunstone (1993), the mink (Figure 1) is a member of one of the largest groups of the order Carnivora, the family Mustelidae (the weasel family). It contains 67 species from 26 genera divided between four subfamilies. It is a medium-sized carnivore, smaller than an otter, yet larger than a stoat. Like all members of Mustelidae, the mink's body is elongated with relatively short limbs. There is a great variation in growth rate within the sexes, but that of the males is considerably in excess of that of females.



Figure 1. The mink. (Adapted from *Dansk Pelsdyravlforening*, 1960)

Examination of diverse features, including the morphology of the skull, the number and structure of the chromosomes and immunological evidence, indicates four main groupings within the subfamily Mustelinae. Two of these are the *lutreola* group including the European mink (*Mustela lutreola*), the Siberian weasel (*Mustela sibirica*), and the *vison* group including the American mink (*Mustela vison*). The European mink is rare or absent now in many of its traditional realms. It should be noted that the American mink and the European mink are not one and the same species (Dunstone, 1993). Dathe and Schöps (1986) mention the range of head – rump measures

for males and females, respectively: *Mustela lutreola*: 28.4 - 43 cm and 32 - 40 cm and *Mustela vison*: 33 - 45 cm and 31 - 40 cm.

Regarding production of farm-raised mink, the mink normally referred to is the American mink. According to Nes et al. (1988) three sub-populations of American mink have been the main contributors to the farm-raised mink of today: *M. vison vison* (small type with a short, fine and silky fur), *M. vison ingens* (larger and stronger type with a coarse fur and a good fertility), and *M. vison melampeplus*. Today, it is not possible to differentiate the farm mink according to the original sub-populations. Mink are unusual animals as they possess semi-aquatic habits; they commonly dive underwater to obtain their prey. This represents a degree of convergent evolution with their more distant cousins, the otters (subfamily Lutrinae). This has led to the suggestion that, in evolutionary terms, mink resemble a transitional state between the terrestrial mustelids and the otters (Dunstone, 1993). This author also comments on the coat: "A luxuriant and lustrous fur coat is synonymous with the mink. Aesthetic appeal aside, the thick waterproof coat of the mink is highly functional for its semi-aquatic habits in the cold northern temperate zone." And Toldt (1935) writes: "Die Güte des Pelzwerkes hängt neben der Beschaffenheit der Haare auch von der Haut ab.....Als haltbarste Pelzfelle gelten im allgemeinen die von Tieren, die abwechselnd auf dem Lande und im Wasser leben." Toldt (1935) also refers to a survey regarding the wearing qualities of different coats from fur animals. If the otter equals 100, the mink can be set to 70. Beaver equals 90. For further comparison sable equals 60 and silver fox 50. An interesting characteristic of swimming fur animals is that their guard hairs (projecting beyond the underfur) have a wider and flattened upper, lanceolate part (Toldt, 1935).

Native wild American and European mink are uniformly dark brown, almost black in colour. However, selective breeding has produced a plethora of coat colours, which, together with a high level of applicability (personal information from Saga International Design Centre, Denmark) and the above-mentioned properties, have made the mink pelt a very popular fur animal product.

Hair fibre types

When a tuft of hair is plucked or closely shaved from the back of a mammal's pelage (usually the winter coat), it will be seen to consist of three main types of hair fibres (the so-called "fox hair type constellation"), in which the hair shaft has developed differently (Toldt, 1935). Besides the length, the fibres can be distinguished from each other with respect to thickness along their length. In practice, the fibres are divided into

overhairs, guard hairs and underhairs (wool hairs) (Toldt, 1935; Brunner and Coman, 1974).

Overhairs

These sparsely distributed hairs are conspicuously longer than the other hairs. They generally show a circular cross-section along their length with tip and basis tapering. Usually they are more heavily pigmented. These fibres can be observed most clearly in the winter coat. The fibres possess gloss primarily due to scale morphology and a relatively high scale frequency of the cuticle (see later).

Guard hairs

These are more numerous, but shorter than overhairs and their length may vary considerably. They also vary in cross-sectional profile and thickness along their length. The hair shaft consists of tip + central portion + base. They include a type often described as shield hairs, where the base and the tip have a circular cross-sectional profile, the central portion gradually becoming flattened and wider to form a reinforced region known as the shield or the lanceolate part (Figure 2) or just the lanceet. These fibres possess gloss primarily due to scale morphology and a relatively high scale frequency of the cuticle (see later).

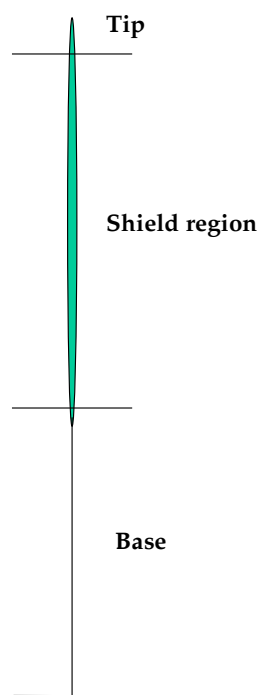


Figure 2. Outline of a mink guard hair. (*Outline: The author*)

Underhairs

This type of hair fibre makes up the main part of the underfur. Regarding the hair fibre terminology, underhairs are sometimes named underfur hairs, underfur fibres or just underfur (Blomstedt, 1989; Wentz and Hunt, 1951; Kaszowski et al., 1970) or wool hairs (“Wollhaare”) (Dathe and Schöps, 1986). They are normally most numerous, especially in the winter coat, but they are very fine and much shorter than the two other fibre types. They are frequently wavy and of constant thickness along their length except for the very tip, which narrows to a point. Their surface may be relatively rough due to scale morphology of the cuticle resulting in a relatively dull appearance (no lustre). A clear apical reinforcement is apparently missing. Toldt (1935) has in a very fine way illustrated the mentioned hair types in mink (Figure 3).

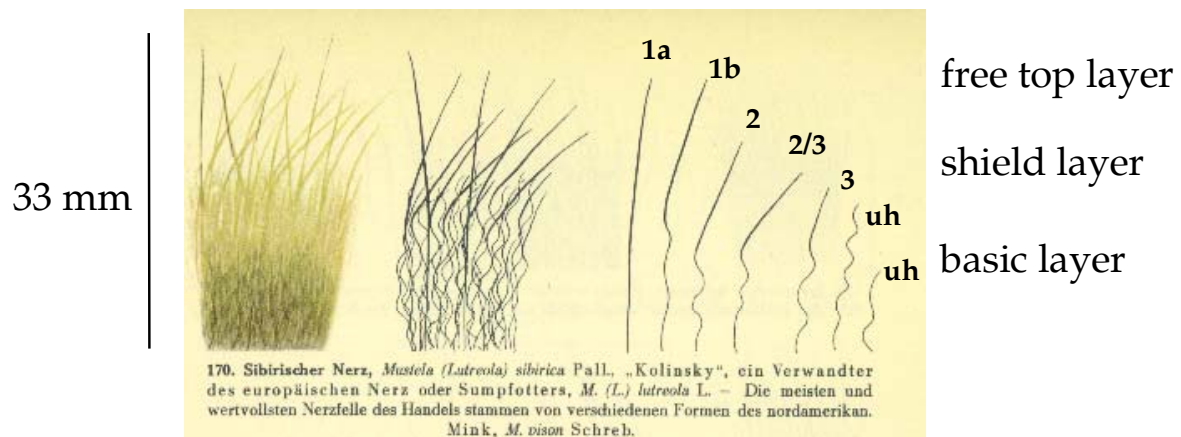


Figure 3. Hair fibre types from Siberian mink. The fur consists basically of three layers or regions in relation to the skin surface. (Modified after Toldt, 1935)

In mink, the fur consists of hair bundles, represented by two types (Blomstedt, 1989; Kondo et al., 2001): One consisting of a thicker guard hair and several finer underhairs (Figure 4 A), and the other of underhairs alone (Figure 4 B).

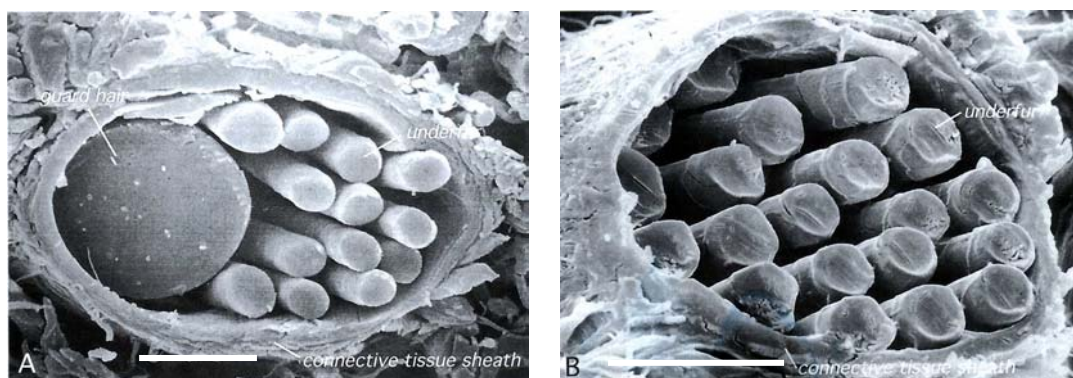


Figure 4. Hair bundle structures in winter coat of mink observed by scanning electron microscopy (SEM). Scale = 25 μm . (From Kondo *et al.*, 2001 with permission.)

The guard hairs (especially the lanceolate parts) mainly comprise the coverage of the mink fur. Different intermediate hair types make up transition forms between overhairs/guard hairs and guard hairs/underhairs, respectively. Hair fibres, ranging from long guard hairs to underhairs, may be classified in accordance with Ebbersten (1973). Referring to Figure 3, a type 1a guard hair protrudes from the underfur and is long and straight. A type 1b guard hair protrudes from the underfur and is long and bended. A type 2 guard hair is shorter than 1a and 1b, but it protrudes from the underfur, and its base is crimped and/or bended. A type 3 guard hair is as long or a little bit longer than the underfur, and its base is crimped. It is almost impossible to distinguish between the finest guard hairs of type 3 and the underhairs (uh).

The underhairs make up the volume of the winter coat in mink. According to Toldt (1935) and Skårman (1945) about 95% of the hair fibres can be classed with underhairs and the rest (5%) with guard hairs.

Fur structure

Based on the hair types mentioned above, the pelage or fur may consist of three layers or regions in relation to the skin surface (Toldt, 1935). This is the case in fox and mink (Figure 3):

The free top layer. It includes the tips of the longest hair fibres (overhairs and long guard hairs), and is a relatively loose layer.

The shield or lanceolate layer. It includes the hair shafts of the overhairs, the lanceolate part of the guard hairs and the apical parts of transition forms between guard hairs and underhairs and tips of underhairs. It makes up the protecting surface of the pelage

(Toldt, 1935; Dathe and Schöps, 1986) and is usually more heavily coloured (Toldt, 1935; Syred, 1991; Dunstone, 1993). This layer is less dense compared with the lowest, basic layer.

The basic layer. It includes hair shafts of all hair forms. It is very dense because of the high number of underhairs, their frequently wavy appearance and rough surface. In this way it functions as an air trap for insulation (thermal protection) (Toldt, 1935; Dathe and Schöps, 1986; Dunstone, 1993).

Hair fibre structure - microscopically

The main components of the single hair fibre or hair shaft have been described by Blazej et al. (1989). The main structural component of the hair shaft is the cortex, which is covered by a cuticle composed of a single layer of sheath-like overlapping keratinized cells. The third (and sometimes missing) central component of the hair fibre is the medulla, consisting of a series of loose cells with a number of cavities, usually arranged along the axis of the fibre. Variations in the detailed arrangement and size of the structural components in hair are observed both between animal species and within species between different hair types. In cross-section the three components are easily studied, as shown in Figures 5 and 6. Cross-sectional profiles of different parts of hair shafts representing different fibre types vary both within and between species. As illustrated in Figure 7 the cross-sectional profiles of different types of mink fibres pass from almost circular to an ellipsoidal outline (guard hairs), and a sort of polygonal profiles (underhairs) are seen, too.

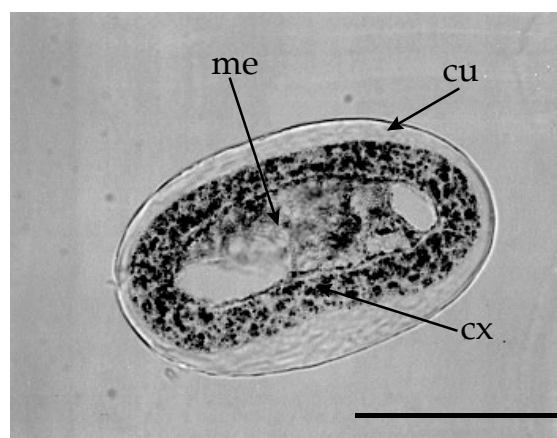


Figure 5. Cross-sectional profile of a guard hair from pastel mink (wider shield or lanceolate region, unstained) observed in the light microscope (LM). The cuticle (cu), cortex (cx) and medulla (me) are marked. Scale = 50 μ m. (Photo: The author)

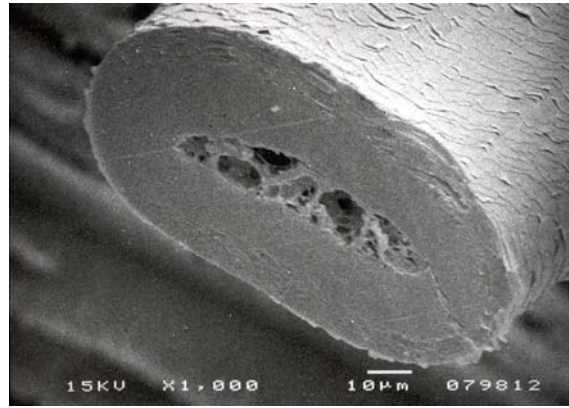


Figure 6. Cross-sectioned guard hair from mink (wider shield region) observed with a scanning electron microscope (SEM). Scale = 10 μm . (*Photo: The author*)

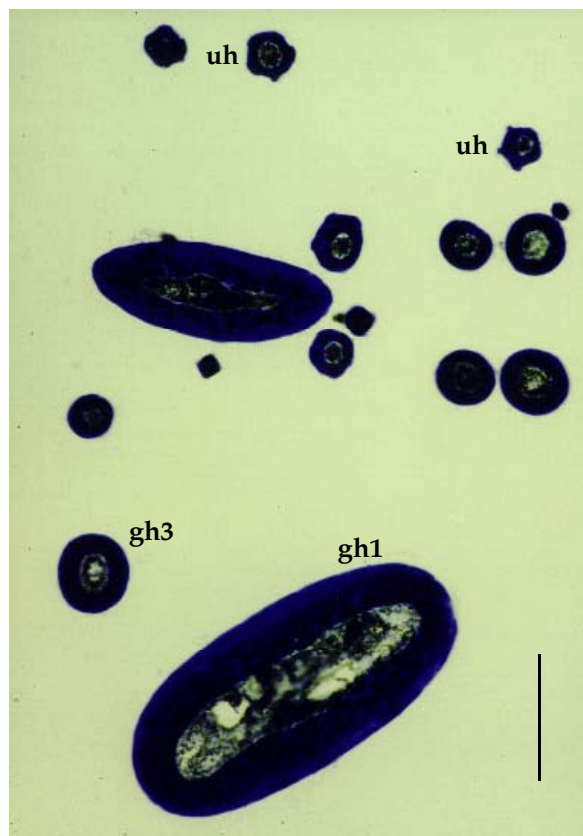


Figure 7. Cross-sectional profiles of different types of hair fibres in scanblack mink (stained with toluidine blue) seen in the light microscope (LM) at a level about 14 mm above the skin surface. Guard hair, type 1, wider shield region (gh1), guard hair, type 3, tip (gh3) and some underhairs (uh) are marked. Scale = 50 μm . (*Photo: The author*)

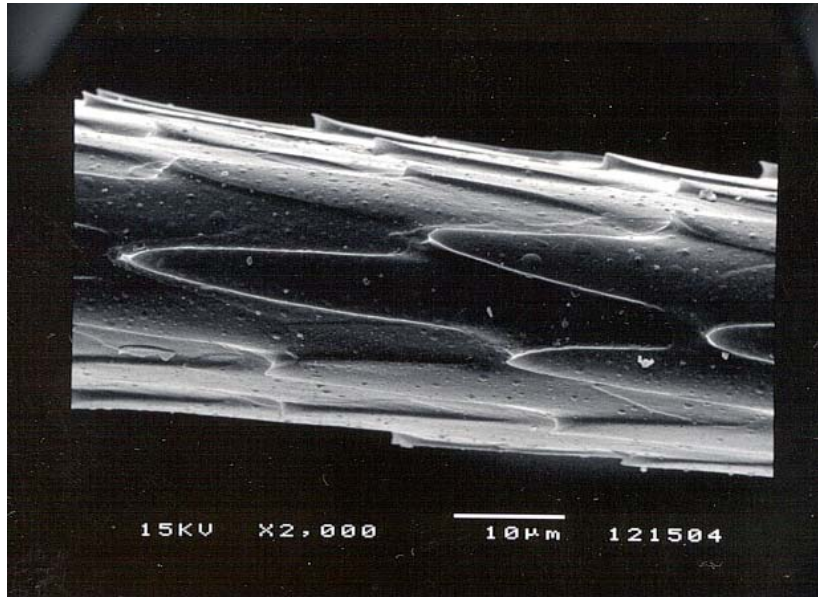


Figure 8. The surface of a mink guard hair (base region) observed with a scanning electron microscope (SEM). Scale = 10 µm. (*Photo: The author*)

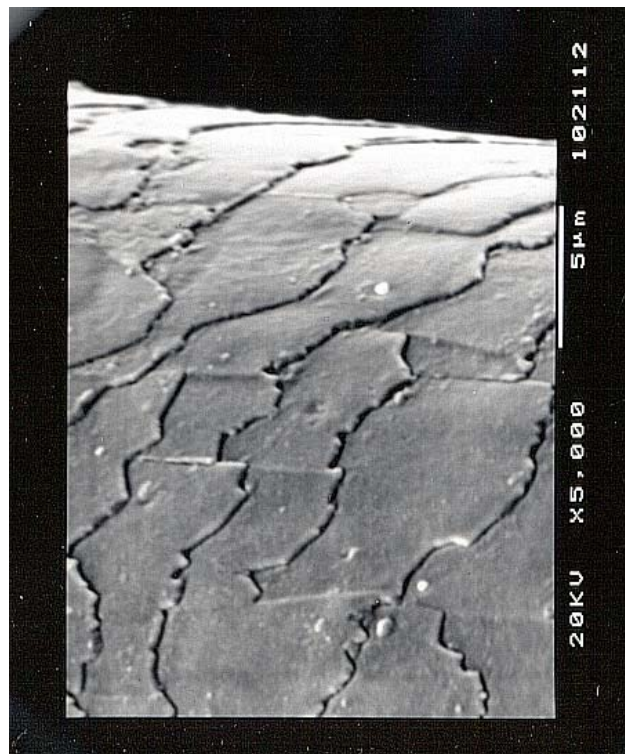


Figure 9. The surface of a mink guard hair (shield region) observed with a scanning electron microscope (SEM). Scale = 5 µm. (*Photo: The author*)

Going more thoroughly into details, and beginning from the outside, the following applies about the structure of single hair fibres:

Cuticle. It forms the (generally thinnest), outer-most part or layer, which consists of a single-layered, flattened keratinized cells. Although the cuticle is single-layered, the individual cells are so elongated that many overlap at certain places and form stacks akin to tiles on a roof with the leading edge of one scale obscuring the base of the one above (Montagne and Parakkal, 1974) (Figures 8 and 9).

Referring to Blazej et al. (1989), scales are 0.2 - 0.4 μm thick or height. Wortmann et al. (1988) reported mean scale heights of wool fibres between 0.7 μm and 0.9 μm , and for goat hairs, such as mohair and cashmere about 0.3 μm . Scales in the wider shield (lanceolate) region of long mink guard hairs, observed by the author with transmission electron microscope (Figures 10 and 11), were about 65 μm long and 0.25 μm high. A cross-section of the hair shaft often shows multiple layers (actually a stack) of cuticular scales. For example as many as 35 scale layers have been observed in coarse hair fibres from pigs (Blazej et al., 1989). In mink, Blomstedt (1980, 1992) reported a mean scale layer value of 45.5 for the thickest part of the cuticle. Stacks of 20 to 40 scale layers have been observed by the author by transmission electron microscopy (Figures 10 and 11). The cuticle cell is bonded to its neighbour cell or to the cortex by a cell membrane complex consisting of an intercellular cement layer and two lipid layers (Phan 1991). Completely keratinized cuticle cells consist of several layers, and the final scales are normally translucent and nonpigmented protecting the cortex (Montagne and Parakkal, 1974). This reference also states that cuticle cells that completely surround the hair are called coronal; those that do not are called imbricate. Further the scales can be divided according to size and shape. They form a distinctive pattern that is a key parameter for use in hair morphological descriptions and resulting identification. Differences in surface morphology and heights of cuticle scales are important characteristics (Phan, 1991) and influence the reflective power of the fibre and therefore the grade of sheen or lustre (Montagne and Parakkal, 1974; D'arcy, 1990).

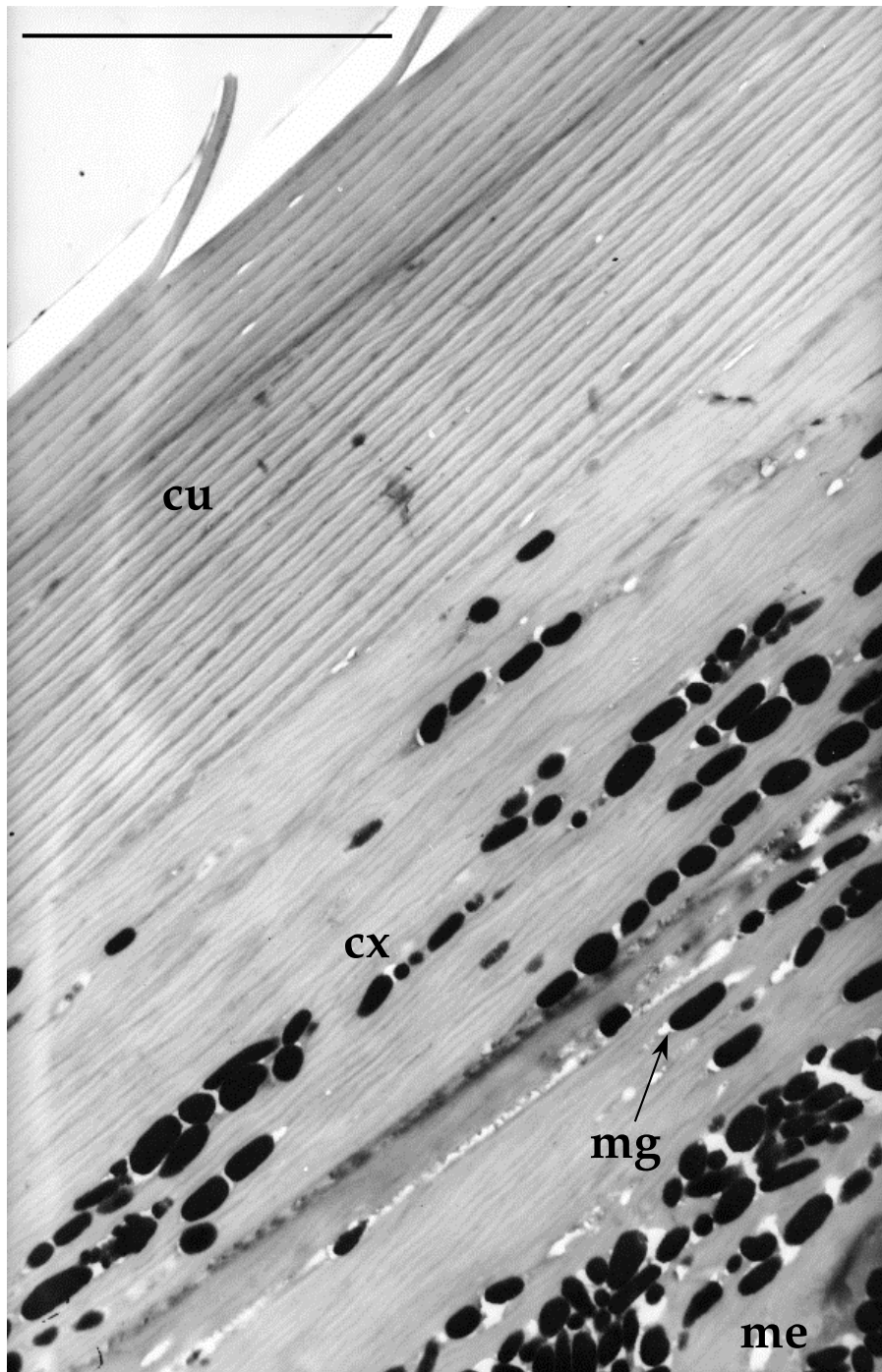


Figure 10. Longitudinal section (transmission electron microscopy, TEM) of a guard hair from dark mink (wider shield region). Cuticle (cu), cortex (cx) and medulla (me) and melanin granules (mg) can be observed. Scale = 5 μm . (Photo: *Spirogyra aps* and the author)

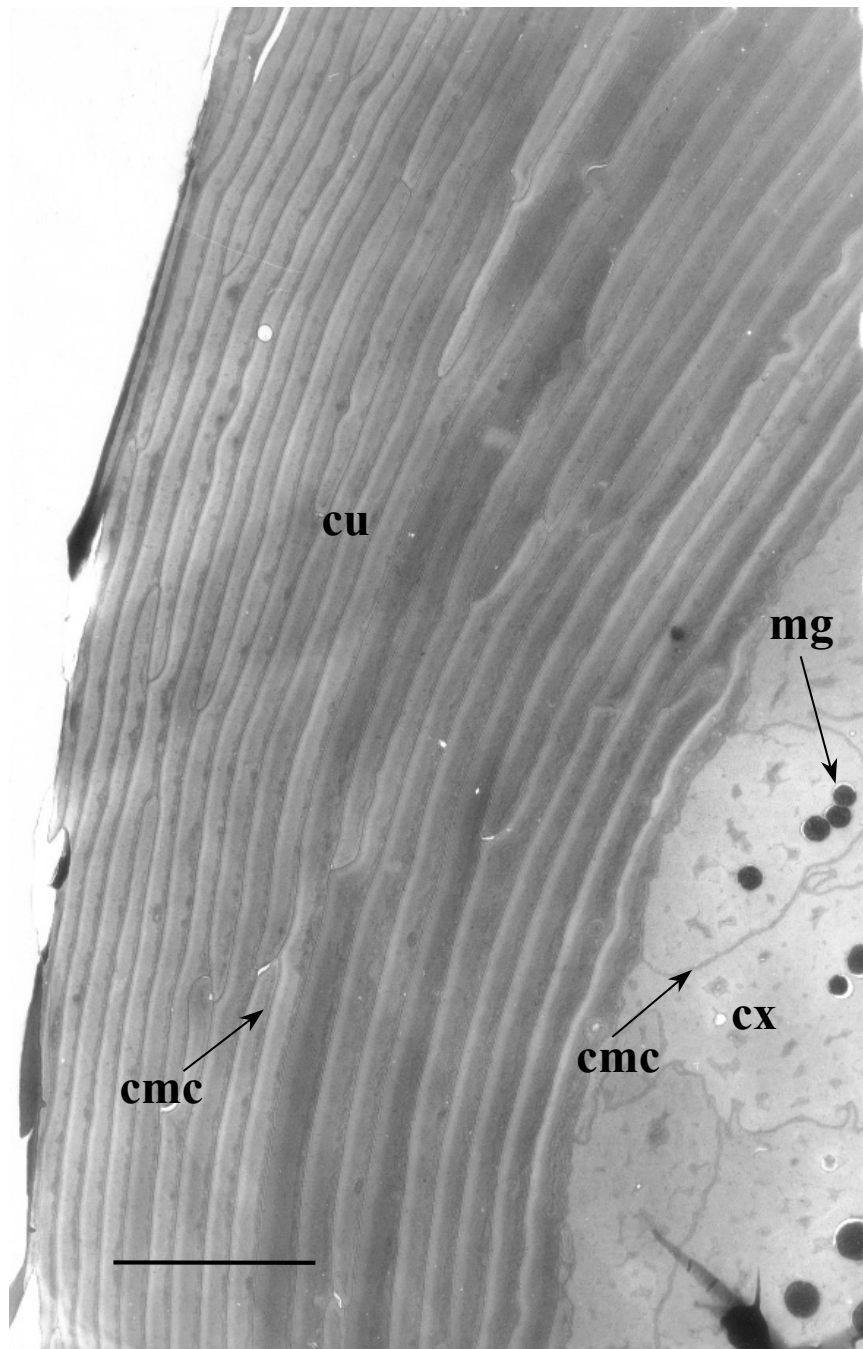


Figure 11. Cross-section (transmission electron microscopy, TEM) of a guard hair from dark mink (wider shield region). Cuticle (cu), cortex (cx), cell membrane complex (cmc) and melanin granules (mg) can be observed. Scale = 2 μm . (Photo: *Spirogyra aps* and the author)

Cortex. Usually, it forms the main bulk of the hair shaft. It consists of a cylindrical array of closely packed spindle-shaped (elongated), keratinized cells aligned in parallel to the fibre axis, and packed into a homogenous mass. The cells are 50 - 100 μm long and 3 - 8 μm in diameter and are bounded by a cell membrane complex (Phan, 1991), and adjacent cells are closely interlocked. The major proportion of each cortical cell is occupied by close-packed macrofibrils. As a particular case, the cortex of non-medullated, highly crimped wool fibres (sheep) contains two segments (a bilateral structure), commonly called orthocortex and paracortex (Phan, 1991). In pigmented hairs, melanin granules are aligned longitudinally in the cortex (Figure 10), and their type and distribution are important for the hair colour (described below). Thus, in the absence of pigment, hair fibres appear dull white or translucent (Montagne and Parakkal, 1974).

Medulla. It occurs usually as a central or innermost core/region composed of large keratinized cells, which are highly vacuolated, containing air spaces. Continuous or discontinuous (fragmented) medullae are seen form and size varying widely in and between species, and are classified into different types (Montagne and Parakkal, 1974). Depending on the hair type, the medulla varies considerably in width from being almost totally absent to constituting the greater part (in respect of volume) of the hair fibre. The medulla may contain pigment granules. However, as mentioned by Montagne and Parakkal (1974) large intra- and intercellular air spaces in the medulla greatly also influence the colour shades of the hair (structural colours).

Guard hair fibres and underfur fibres in the mink types referred to in this work are medullated (except for their tips).

Hair Colour and Hair Pigmentation

We perceive a certain colour when light rays of wavelengths between about 380 nm and 770 nm (the visible spectrum of light) reach the retina of the eye (McAdam, 1985). A coloured structure may transmit, absorb and reflect just some of the components of the incident white light. The differences in colours of solid objects are therefore due to the fact, that the objects to different degrees reflect the radiation (light) of different wavelengths in the visible spectrum (Kornerup and Wanscher, 1974; McAdam, 1985).

The colour impression of the mammalian coat depends on the co-effect or -contribution of the single hair fibres. It is well known that hair fibres in the same coat often have different colours. Further the single hair may have different colours in proximal-distal direction (at different levels above the skin surface). This means that both the single hair fibres and the different layers of the fur are very important regarding fur appearance as described by Toldt (1935). Zoologists have used different methods in order to designate colours of animals (Sumner, 1927; Lubnow, 1963; Lubnow and Niethammer, 1964; Dyck, 1966, 1987; Sumner et al., 1994; Rasmussen, 2000).

The colour of mammalian hair fibres depends on the presence (or absence) of different types of discrete pigmented granules in the keratinized fibre-forming cells. Normally the pigment involved is melanin, which is derived from tyrosin and situated in melanosomes i.e. melanin granules (Figures 10 and 11). The colour effect produced by melanins depends on the type (its colour when illuminated) and on the concentration of melanin granules (melanosomes). The colour is intense where the granules have been thickly deposited and pale where they are few. Quantitative and qualitative factors of melanin pigmentation in fur-bearing animals have been characterized (Russell, 1946, 1949; Shackelford, 1948; Ebbersten, 1971). This includes colour measurements on melanin granules by means of reflection spectrophotometry (see later), interdependence among characteristics such as total pigment volume, medullary and cortical granule number, and variation in size, shape and arrangement (clumping) of granules. Air spaces inside the cortex or the medulla also contribute to colouration and are therefore important, too (Toldt, 1935).

Two major types of melanins are produced by mammalian melanocytes and are termed eumelanins and phaeomelanins, which are black/brown or yellow/reddish, respectively (Furumura et al., 1996). They differ from each other chemically. Eumelanin is insoluble in almost all solvents and resistant to chemical treatment; only

phaeomelanin is soluble in dilute alkali (Jimbow et al., 1976), and is slightly fluorescent in ultra-violet light of wavelength 366 nm (Searle, 1968). When examined by light microscopy (Russell, 1946) and transmission electron microscopy (Laxer et al., 1954), morphological differences have been observed. In yellow hairs (mouse) Russell (1949) found that yellow granules were uniformly round and of approximately same intensity and size ($0.66\text{ }\mu\text{m}$ - $0.83\text{ }\mu\text{m}$), whereas black granules were much more variable in their characteristics presenting different colour intensities and shapes, i.e. long, oval, round and shred. After the investigation of different black- or brown-coloured mammals, Laxer (1954) reported that lengths and diameters of isolated melanin granules between species varied from $0.53\text{ }\mu\text{m}$ - $1.33\text{ }\mu\text{m}$ and $0.16\text{ }\mu\text{m}$ - $0.43\text{ }\mu\text{m}$, respectively. In mink and fox guard hairs, Shackelford (1948) observed that the characteristic “rod shaped” granules with rounded ends varied in mean length from $0.4\text{ }\mu\text{m}$ - $0.74\text{ }\mu\text{m}$ and $0.74\text{ }\mu\text{m}$ - $0.97\text{ }\mu\text{m}$, respectively. Ebbersten (1971) studied melanin granules in different colour types of mink. In beige and light brown types, the melanin granules were more round; the ranges of length and diameter were $0.37\text{ }\mu\text{m}$ - $0.50\text{ }\mu\text{m}$ and $0.20\text{ }\mu\text{m}$ - $0.24\text{ }\mu\text{m}$, respectively. In black, dark brown and blue-greyish types, the melanin granules were longer; the ranges of length and diameter were $0.64\text{ }\mu\text{m}$ - $1.36\text{ }\mu\text{m}$ and $0.25\text{ }\mu\text{m}$ - $0.58\text{ }\mu\text{m}$, respectively. The largest melanin granules were observed in the blue-greyish Aleutian type. In this type (unlike the other types) most of the granules were restricted to the medulla showing a clumped distribution.

The range of colours available to mammals is apparently not so large. It goes from white via grey to black, and from black via brown to yellow and orange-red (Searle, 1968). However, some species have structural (iridescent) colours (Dathe and Schöps, 1986). In several species (e.g. black and brown mink) the overhairs and guard hairs are relatively more pigmented compared with the underhairs (Toldt, 1935). In profile some species (e. g. fox and rabbit) show a regional distribution of eumelanin and phaeomelanin pigments in the coat - the agouti colouration. Hair fibres in the wild type of agouti coats are characterized by a terminal or sub-terminal band of yellow, due to phaeomelanin pigment granules, the rest of the hair showing the black or brown of eumelanin pigment (Searle, 1968).

Materials and Methods

Mink pelts and hair fibres

The dried mink pelts used in the studies were all of dark mink types (*Mustela vison*), popular in Danish mink production. All pelts examined by the author originated from animals with a winter coat judged to be in prime condition (hair follicles in telogen, i.e., in quiescent, not active stage). All pelts were dried pelts. The types included black ("standard") and brown ("wild") mink with focus mostly put on males. The specimens for examinations ranged from the microscopic to the macroscopic level. Hair fibres came from standardized skin samples with intact fibres, which were separated from the skin manually with a scalpel. Both guard hair and underfur fibres were specially prepared for morphometric analysis. Whole and intact pelts were examined, too.

Morphometric methods

Macroscopic methods for measuring hair length and quantity

The average hair length (mm) was simply measured with a ruler, the hair fibres coming from standardized skin samples (diameter = 5 mm), cut out from dried pelts. In this connection an important calculated parameter was the so-called nap value. The "absolute nap" is the length difference (mm) between the average underhair length and the average guard hair length. The "relative nap" is the ratio of the average underhair length to the average guard hair length (Reiten, 1978). The procedure was usually combined with an estimation of the hair mass (mg/cm²). By simple weighing of cut fibres from standardized punched-out skin samples (diameter = 13 mm) from dried pelts, objective information about the hair quantity per skin area was obtained (Rasmussen, 1988a; Rasmussen and Lohi, 1988). The hair density (fibres/skin area) was only occasionally estimated on samples from pelts.

Histotechnical hair fibre preparation for light microscopy (LM)

For light microscopical measurement on cross-sectional profiles (i.e., morphometry) of hair, units of mounted single hair fibres and hair fibre bundles were embedded in different embedding media and cross-sectioned with a microtome.

When using a semi-automatic computer-assisted image analysis system (Rasmussen, 1989a, 1992b, and 1996a), it was necessary to stain the cross-sectioned fibres (especially the cuticle) selectively either with toluidine blue (Horobin, 1988) or carbol fuchsin in order to obtain correct values of cross-sectional areas and morphometric axes.

For fast LM examination of surface structures in the hair fibre cuticle, a surface replica (matrix) was produced and examined in place of the hair. Various media were available (Schell et al., 1986; Brunner and Coman, 1974). However, usually nail polish was used (Rasmussen, 1992a).

Scanning (SEM) and transmission (TEM) electron microscopy

For three-dimensional studies with SEM primarily of guard hair surfaces, cut fibres were either mounted directly or, if needed, occasionally cleaned/dehydrated with acetone or absolute alcohol before mounting and finally coating with gold. TEM preparation and studies of cross-sections were made in co-operation with a professional laboratory (Spirogyra aps, Copenhagen); standard methods were used.

Computer-assisted image analysis applied to hair fibres

The CSM (Cross-Section Method) (Rasmussen, 1995, 1996a; Lohi et al., 1996) was used both on single prepared fibres and bundles of underhairs from mink (in other respects from goat and sheep). After special preparation (referred to above), each single microscopic image contained almost exclusively separated cross-sectioned hair fibres, their number depending on the fibre type (for underhairs it was over 100). The image was processed by a computer-assisted image analysis system (Scan Beam, 1992) (Figure 12). Pixels belonging to the objects of interest could be filtered out by global thresholding and all pixels connected to each other belonged to the same object. Calibration was done with a stage micrometer.

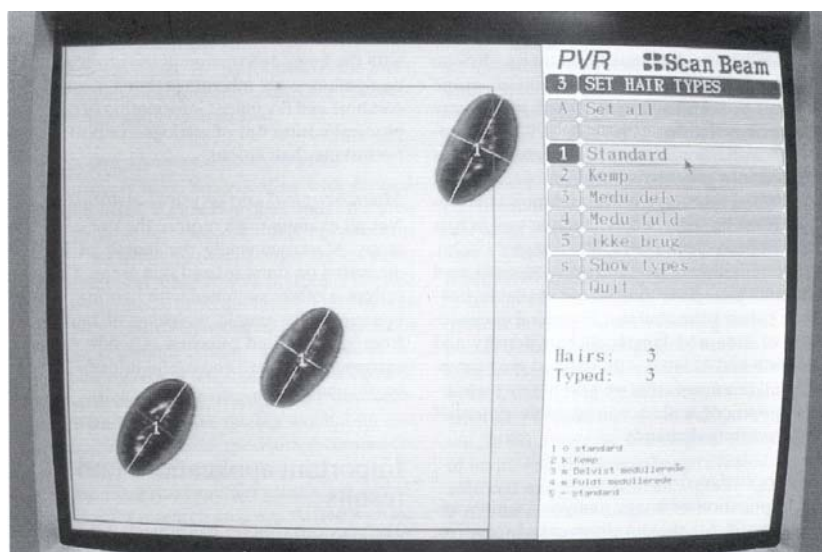


Figure 12. Computer-assisted image analysis applied to cross-sections of mink guard hairs. (From Rasmussen, 1993)

The system automatically computed/measured the cross-sectional area (csa), the mean diameter ($= \sqrt{(4\text{csa}/\pi)}$) and the length of different types of axes including the maximum (a) and minimum (b) axes of each single profile. The ratio b/a could be computed as a sort of hair fibre roundness index. In this way, the composition and distribution of different types of hair fibres were investigated. Similar studies on human and animal hair fibres have been reported several other places (Brunner and Coman, 1974; Teasdale et al., 1981; Blankenburg and Philippen, 1988; Syred, 1991).

Photometric methods

Optical macro-description of light reflecting properties in pelt surfaces

The objective was to characterize the dorsal surfaces in two groups of brown mink pelts from males by detailed optical measurements of their reflecting properties. This included the directional distribution of reflected light. Further, optical variables were related to visual grades of silkiness. A relatively simple goniophotometer was constructed especially for measuring pelts (Figure 13) (Rasmussen and Dyck, 2000). The method was non-destructive. Using white light as light source, and calibrating with a matte white piece of fibre board (white reference), the relative intensity of reflected light (reflectance, %) was observed at all angles in the plane containing the angle of incidence for a fixed illumination angle. By changing the observation angle while keeping the angle of illumination fixed, the spatial distribution of reflected light intensity and the maximum reflectance (specular gloss) could be determined by angular reflectance curves (reflection indicatrix). General linear models describing the correlation with visual grades of silkiness were investigated (Rasmussen and Dyck, 2000). The methods used were inspired by or based on textbook information, reports and reviews concerning directional properties of light reflections from surfaces in general (Hunter, 1937; Kortüm, 1969), textile fibers (Kasswell, 1953; Meredith and Hearle, 1959; Krochmann and Gerstenberg, 1973; Heinrichs et al., 1986), wool and human hair (Bereck and Blankenburg, 1983a, 1983b, 1983c; Czepluch et al., 1993), and feathers (Dyck, 1987).

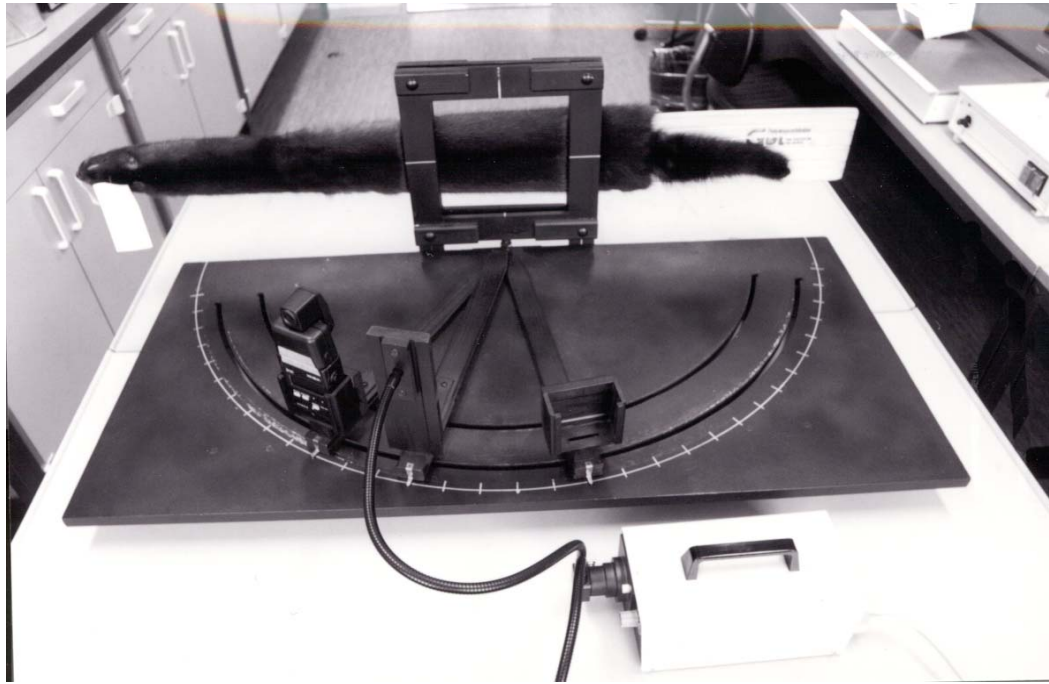


Figure 13. Apparatus for measuring gloss in mink pelts. (From Rasmussen and Dyck, 2000 with permission from American Society of Animal Science)

Optical micro-description of hair colour by microscope spectrophotometry

Photometry with the microscope is both a special use of photometry and a special use of the microscope. With a photoelectric detector (photomultiplier), the amount of radiation reflected from the specimen is compared with the radiation reflected from a white standard (reference). The measuring field on the specimen of specially prepared underhair bundles (Rasmussen, 2000) was 1 mm². In pilot experiments on dark-brown guard hairs involving transmission measurements, the measuring field was considerably smaller (0.03 mm²) (Rasmussen, 1994).

For increasing wavelengths in the visible spectrum (400, 430, 460.....700 nm), two measuring values relating the one of the specimen to the one of the reference were obtained. The interaction factor (IF) referred to the relative amount of radiation (light) reflected from the object. If the IF-value of the reference material was known (98% for MgO, white standard), the IF (reflectance, %) of the specimen could be calculated (Piller, 1977). By using a strip interference filter, the reflectance of the specimen was obtained at a certain number of fixed wavelengths, and a characteristic reflectance curve could be drawn. Based on this type of curve, the XYZ tristimulus values were determined for a standard illuminant C. The lightness (L*) and the chromaticity coordinates of the red (a*) and yellow (b*) colour direction were calculated (MacAdam, 1985). Based on this kind of microcolourmetrical variables, general linear models

describing the correlation with visual grading of colour shades were investigated (Rasmussen, 2000).

Statistics

The statistical analyses were all carried out by means of SAS procedures (SAS Institute Inc. 1985, 1987). Regarding specific procedures please see the cited articles themselves, however, especially Rasmussen (2000) and Rasmussen and Dyck (2000).

Fur Properties in Mink with Reference to Product Quality

Introduction

As mentioned earlier the currently most important economic property of the pelt is its size. However, also the fur properties must be given a lot of attention because they are also heritable to a considerable degree. By means of careful animal selection techniques of breeding animals with special or demanded properties and by fur formulation devices, the mink breeders can improve the quality, including colour, of their pelt production (Wehr et al., 1982). Generally a large variation regarding fur quality can be observed between farms served by the same feed supplier (Hillemann, 1984).

Describing fur quality with one single word is not possible, because it is a combination of many sub-traits (Lohi, 1988). In broad outline fur quality can be divided into 1) guard hair quality and 2) underfur quality (Dansk Pelsdyravlerforening, 1988). Each of these traits depends on sub-traits such as the number (density) and length of hair fibres, mutual relations such as coverage and nap, hair fibre alignment and morphology, especially related to several optical properties (e. g. named silkiness, metallic, singe etc.), together with the overall appearance. The division of fur quality seems to differ slightly. Lønne (1994) for example divides the fur quality into 1) hair quality (only guard hairs), 2) guard hair covering, and 3) fur texture including underfur characteristics.

The idea of fur texture is apparently difficult to describe in a uniform way. So Skårman (1945) wrote: „Vid bedömningen av minkens fäll tages förutom till färgen hänsyn även till täckhårens och underullens längd och textur ävensom till pälsens ”allmänna intryck”. Texturen är ett mycket omfattande begrepp, vilket bl.a. inbegriper hårens utseende och mjukhet, fällens jämnhet o.s.v. För dessa egenskaber bör hårens finlek och form spela en framträdande roll.” This is comparable to Wentz and Hunt (1951), who wrote: „The use of the underfur diameter to measure texture seems valid. ”Lønne (1994), however, wrote: „Tekstur. D.v.s. lengdeforholdet mellom dekkhår og underpels.....For at beskrive tekturen brukes betegnelserne: long nap, medium nap og short nap.

Betegnelsen nap er et uttrykk for hvor stor en del av dekkhårene (-spissene) som er over underpelsen (frie dekkhårsspisser).” She also includes underfur characteristics: “Underpelsen skal være tett og elastisk.”

The idea (and problems) of fur texture will be discussed more thoroughly later under the head of “Associated fur properties”. Nevertheless, altogether this means that single factors (sub-traits) and their mutual relations will act on the final fur quality.

Besides the above-mentioned quality parameters of guard hairs and underhairs, other fur properties are important and to a certain degree controllable. This refers to the general lightness of the fur and the colour shade of the underfur. However, properties as lightness and colour shade are only important in certain colour types (Dansk Pelsdyravlerforening, 1988). Also the contrast between guard hair lightness and underfur lightness is important, i.e., the guard hairs should be relatively darker taking the right underfur colour into consideration.

Last but not least, several fur defects can be observed in the mink production. Many defects are connected with the guard hairs. Guard hairs showing minor diverging forms causing changed light reflecting properties of the fur surface (e.g. metallic, singe, bended guard hairs) are frequently observed in certain colour types. Scattered populations of too dark guard hairs can also be a problem (spots). Other defects can be related to the underfur, for example poorly developed underhairs (underfur fibres), mostly observed on the hips.

Measurements

In the following, properties of specified hair fibres will be explained and discussed in relation to product quality. This involves important morphological and optical sub-traits and how these can be measured. Certain defects regarding single hair fibres or their complete appearance are included, too.

It should be expected that the production of fur animals (and other domestic animals) would be improved, if the desired product quality is known exactly. In order to optimize and control any production, it is useful to procure objective parameters for detailed numerical descriptions of the product(s) in question. This means that measurements and definitions of different fur deficiencies and the superior quality are required, excellently explained by Skårman already in 1939 and by Hardy and Hardy in 1942: „.....assisting the fur industry in the analysis and interpretation of merit in commercial furs or serving as a guide in breeding better ones”, including an improvement of subjective (sensory) assessments. However, as for many of the characters, measurements can usually be done on a small scale (in research and experimental trials). Regarding certain physical/optical methods, examination and testing on a “larger scale” are possible and have been carried out (Lohi and Thorhauge, 1991; Lohi et al., 1995; Lohi et al., 1996; Rasmussen and Dyck, 2000).

A point must be underlined: It is very important always to use standardized measuring or sampling fields on pelts which are to be compared regarding actual parameters. Jørgensen and Eggum (1971) and Reiten (1978) clearly demonstrated the topographic variation on mink pelts in respect to hair quantity (mg hair/cm²) and length (mm), respectively (see later).

Generally, it is preferable, if these measuring parameters/variables are correlated with the subjective evaluation of the concerned character. However, the correlation also depends on the accuracy and reproducibility of the subjective evaluation/grading of the character performed by different graders/judges.

Guard hair quality

Appearance

The appearance of the guard hairs (subjectively evaluated) constitutes a decisive and important part of the quality concept (Hillemann, 1984). It is advised that a mink pelt of high quality must possess a suitable number of guard hairs with an appropriate average length in order to cover the underfur properly. If the guard hairs are too long in proportion to the underhairs, the guard hairs do not get enough physical support resulting in a disordered fur. Compared with underhairs, guard hairs are more lustrous primarily due to the scale morphology and relatively high scale frequency of the cuticle resulting in a smooth hair fibre surface. Further the property "colour" is primarily represented by the visually judged lightness of the guard hairs compared with the general impression of the pelt. Depending on the colour type in question, the lightness of the fibres is judged either on the edge, the ventral or on the dorsal side of the pelt. Regarding very black pelts, the lightness highly depends on the lightness of the underfur. In certain brown colour types, a high contrast between relatively dark guard hairs and relatively light underfur fibres may be desirable. The colour of individual guard hairs of scanbrown mink has been characterized with micro-photometric methods (Rasmussen, 1994); both within and between individuals, the lightness vary considerably. Furthermore, it is preferable, if the guard hair fibres are strong and elastic, not too thick, straight, with a smooth surface, of almost equal length and aligned in parallel. Keeping the last five conditions in balance is necessary in order to obtain a silky pelt surface, which is highly desirable. Rasmussen and Dyck (2000) used goniophotometry in order to define and characterize the optical surface appearance (silkeness) of scanbrown mink pelts numerically.

Morphological variation

Thickness and form - Cross-sectional profiles

According to Skårman (1939) measurement of morphological hair fibre characteristics in fur animals (hair fibre morphometry) originated from J. I. Hardy's microscopical examinations of wool fibres from sheep in 1935. The purpose was determination of fibre fineness and cross-sectional variation in relation to qualitative and technical properties. In mink fur, too thick guard hairs are considered as a negative characteristic (Dansk Pelsdyravlerforening, 1988). Regarding the study of natural morphological variation of hair fibres in farm-raised mink, several methods and observations have been reported. Laboratory chief Skårman (1945) carried out a small, but very instructive measuring experiment in which he tried to demonstrate the variation of certain morphological hair properties (i.e., hair length, cross-sectional profile including proportions between max. and min. axes) from a group of first class animals (FC). He wanted to compare these data with corresponding data from another group of animals not approved for breeding (NA). The objective was first of all to determine indications about the desired hair type at that time (the ideal). He observed that compared with the NA-group, especially guard hairs in the FC-group were significantly shorter ($P = 0.001$) with indications of a more flat lanceolate part. Skårman determined the mean ratio (b/a)_{mean} between minimum axis ($b_{FCmean} = 62.60 \mu\text{m}$ and $b_{NAmean} = 65.20 \mu\text{m}$) and maximum axis ($a_{FCmean} = 116.30 \mu\text{m}$ and $a_{NAmean} = 112.80 \mu\text{m}$) of cross-sectional profiles in guard hairs at their thickest lanceolate part (about 5 mm from the tip) for FC and NA. The b/a _{mean} - values estimated for FC and NA were 0.54 (i.e., relatively flat) and 0.58, respectively. This difference was significant ($P = 0.05$). Skårman concluded that with exact methods it was possible to determine several hair fibre properties. It was also recommended to carry out a large-scale investigation in order to document possible differences between high quality animals and to show in which way these results could be used in practical breeding.

In order to obtain an objective and detailed information about the variation in guard hair composition in representatives of various strains of Danish farm-raised scanblack mink, a similar investigation was done many years later (Rasmussen, 1988a; Lohi and Rasmussen, 1991). One hundred pelts representing good quality (Saga Selected/Saga) coming from 20 farms (each represented by 5 pelts) were examined. On average, 31 prepared guard hairs in a histological specimen represented a standard test field (the hip) in each pelt. At that time the available technique only allowed the author to measure the profiles one by one manually, in total 3110 profiles. The following mean values and standard deviations were observed: Cross-sectional area ($= a/2 \times b/2 \times \pi$) = $7171 \mu\text{m}^2 \pm 2905 \mu\text{m}^2$; $b = 71 \mu\text{m} \pm 17 \mu\text{m}$; $a = 123 \mu\text{m} \pm 27 \mu\text{m}$; $\text{ratio}_{b/a} = 0.57 \pm 0.06$. The average guard hair length was $22.1 \text{ mm} \pm 1.3 \text{ mm}$.

The results of the morphometric investigations reported were comparable. There was a slight tendency that the guard hair type in Danish quality pelts was coarser than the type described by Skårman (1945). From these studies it can be concluded that large variations are found in both lanceolate thickness and form (cross-sectional profiles) in animals representing different farms.

Supplementary it should be pointed out that the distribution of sampled guard hairs from different individuals and groups of farm-raised mink regarding the maximum cross-sectional area of the lanceolate part is not normal, but usually bimodal and skew. It may therefore be inaccurate to use only the mean or the median of the determined fibre diameter when making an objective evaluation of hair type.

By means of micromorphological methods, computer-assisted image analysis and descriptive statistics, detailed information about the variation in guard hair type was demonstrated on representatives of various mink strains (Rasmussen, 1992b). The SAS Univariate Procedure (SAS, 1985) calculated the quantiles Q1 (the lower quartile or twentyfifth percentile) and Q3 (the upper quartile or the seventy-fifth percentile), the median, the mean and Q-range ($Q3 - Q1$) regarding the distribution of cross-sectional areas of fibres. The hair fibre compositions were in this way described in detail. For example, a low Q1-value simply documented that a rather low mean value was caused by relatively many thin guard hairs and not of a generally thin guard hair type.

Fibre length

According to Dansk Pelsdyravlerforening (1988), the quality of guard hairs also depends on their length. If the guard hairs are too short, they cannot make a satisfactory coverage of the underfur, and if they are too long their direction or alignment may be difficult to control (the fibres may cross each other). Therefore the guard hair length has received much attention in several reports. As mentioned above, Skårman (1945) compared a group of first class animals (FC) with a group of animals not approved for breeding (NA). For both groups he calculated the mean guard hair length ($ghl_{FCmean} = 21.8$ mm and $ghl_{NAmean} = 24.4$ mm) indicating the problems caused by too long guard hairs.

Reiten (1978) made an instructive study on pelts from dark mink. The objective of his work was to study the variations in length of guard hairs and underfur within and between animals and the differences in hair length between animals of different sex and age. Examined hair samples showed large variations in hair length within very small areas of the pelt. He demonstrated that the measured mean (only one measurement per hair sample) overestimated the real mean length, when this was based on

measurements of each single guard hair in the sample, due to the contribution of the usually numerous intermediate hairs.

Reiten (1978) also measured the hair length at 40 different test areas of pelts from 5 mink kits of each sex. He showed that the ratio of the average underhair length to the average guard hair length (called relative nap) varied between 0.45 and 0.65. The relative nap was higher at the dorsal and lateral sides (the edges) and lower at the ventral side. Hairs were longer at the dorsal side compared with the ventral side and longer on the hind part than towards the snout (caudal-cephalic direction). It was demonstrated that pelts of adults had longer hairs than pelts of kits and that male pelts had longer hairs than female pelts. It was also shown that sensory grading of nap was determined to a greater extent by the guard hair length than by the ratio between length of underfur and guard hairs. Lohi and Rasmussen (1991) estimated an average relative nap value of 0.68 in Danish scanblack mink, with a slight tendency towards the pelts with long guard hair presenting low relative nap values. Extremely high values of relative nap are observed in the American short-nap mink (0.75). A morphological study by Rasmussen (1991a) showed that compared with normal Danish scanblack mink, the American short-nap mink had shorter guard hairs with apparently modified proportions. The underfur length corresponded to the normal type, but the number of underhairs per hair follicle group (Figure 4) was significantly increased (28 ± 6 versus 22 ± 2).

The variation between hair type populations became quite obvious when guard hairs from 100 scanblack pelts (mentioned earlier) were studied. The average guard hair length was $22.1 \text{ mm} \pm 1.3 \text{ mm}$. Within populations ($N = 5$) SD varied between 0.3 mm and 2.4 mm (Rasmussen, 1988a; Lohi and Rasmussen, 1991).

Defects

Many defects in mink fur originate from different abnormalities of guard hairs (Dansk Pelsdyravlerforening, 1988). Research to identify the nature and cause of such defects providing a basis for their prevention is therefore important. For that reason the microstructure of defective mink guard hairs, probably with changed optical (light reflecting) appearance, has been investigated by several scientists. Mostly micro-morphological or pigmentary causes are involved resulting in names as spotted fur, red hip, hooked tips, abnormal guard hairs, bended guard hairs, singe, metallic singe and last but not least metallic illustrating a nomenclature not free from some confusion. In some references metallic and metallic singe are named singe (Ellis et al., 1983). Furthermore, certain defects are especially attached to certain colour types of mink. In this report focus will be put on studies concerning changes of the microstructure of

dark mink guard hairs especially resulting in a metallic and singe-like appearance. However, in the following there will be discriminated between the conditions singe and metallic. The various conjectures about their causes will not be included here.

Singe

According to Johansson (1940), fur breeders and other fur experts at that time observed and complained about a peculiar type of guard hair that appeared in some pelts (particularly male pelts of the dark strain). This resulted in a singed appearance of the pelt surface. By close examination, relatively more guard hair fibres with a hooked lanceolate (distal) part were observed in pelts with singe. Unfortunately the report referred to does not mention in detail the orientation of the hooked part of the fibres. Some hair samples indicated that microscopic cross-sectional profiles of singed fibres were flatter. However, this observation was equivocal.

Le Grande C. Ellis et al. (1983) wrote: „Of concern to the mink producer is whether the trait is genetically transmitted to the young or if the singe results from environmental influences on the guard hair. Equally frustrating to the producer and the scientist is an understanding of just what singe is, what causes it, and if there is more than one type of singe. To add to these frustrations, those researchers who have reported on singe have not described just what it is that they studied. It would be especially helpful in the future if researchers would describe the defect that they studied in terms of its distribution on the pelt and the morphological characteristics of the singed hair.” However, metallic and metallic singe are referred to as singe by Le Grande C. Ellis et al. (1983). They classified the topographical distribution of singe on mink pelts with respect to the size and shape of the pelt areas with singed hairs, and names were given to these areas according to their shape - chevron, streak, patch, or diffuse in the case where the singed hairs were distributed uniformly over most of the pelt. The singed hairs were also classified as to their morphological nature - i.e., hooked tips and along with this defect split tips, clubbed tips, abnormal lancets with aneurysmal bulges and irregularly orientated hairs. Le Grande C. Ellis et al. (1983) also found that hooked lancets appeared to be the predominant type of abnormality found in singed hairs. Wu et al. (1977) stated that scale patterns somewhat different from those found in the normal mink could be observed in singed guard hairs, and it was possible that these variations in the cuticle pattern contributed to the characteristic appearance of the abnormality. Perhaps more importantly, their SEM photographs clearly showed and defined differences in the cross-sectional architecture of normal and singed guard hairs. Normal guard hairs were oval in cross-section; singed hairs were angular, indicating that the angular exterior might contribute to an alteration of light reflectance patterns.

Metallic

Ebbersten (1973) stated that the metallic mink fur seems to be very wavy and therefore shows a metallic lustre. In the study by Ebbersten (1973), guard hairs from normal mink and metallic mink were separated into different types. No significant differences were found regarding the frequency of different hair types in normal and metallic animals, and no differences in hair length and thickness were found. Microscopic examinations of metallic pelts disclosed the existence of guard hair types not seen in normal animals. Fibres having an angular cross-sectional profile instead of the normal oval one were more frequent in metallic furs (Figure 14). Fibres being uneven in thickness with aneurysmal bulges, whirls and minor irregularities were likewise more frequent in metallic furs. However, the majority of fibres in metallic animals had normal characteristics. Ebbersten concluded that the optical reason for metallic might be found in the very flat surface of the defect fibres in combination with the circumstance that the fibres lay in whirls in close contact with the body.

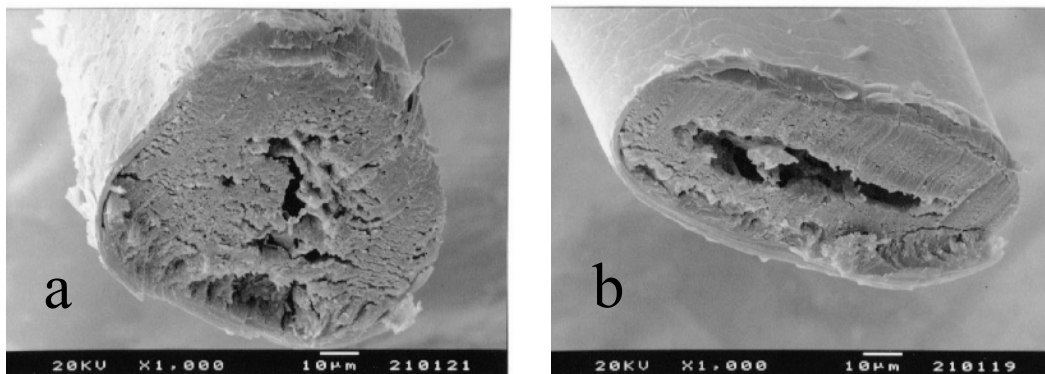


Figure 14. A metallic fibre (a) has an angular cross-sectional profile instead of the normal (b) oval one (SEM). Scale = 10 µm. (Photos: The author)

Reiten (1973) stated that the metallic defect is difficult to judge, especially on live animals and that some confusion exists regarding the idea of metallic. Based on a material of 950 animals, metallic seemed to be negatively correlated with several properties of quality such as hair density, hair quantity and coverage. However, the darkest pelts generally showed the highest degree of metallic.

By the examination of metallic animals Blomstedt (1979), confirmed the existence of guard hairs with bended (or curved) lanceolate parts expressing and grading the bending by using the parameters k (bending height) and l (bending length). For the examined Finnish material, the l/k ratios of metallic and normal animals were $16.26 \pm$

2.56 and 37.31 ± 7.23 , respectively. Blomstedt (1980, 1992) reported that the number of cuticle scale layers in metallic and normal guard hair fibres (the middle of the lanceolate part) differed, the metallic fibres having less scale layers on corresponding sides. The number of cuticle scale layers on the convex and concave sides of long guard hairs in normal and metallic animals was 45.5 ± 5.0 ; 36.5 ± 0.7 and 34.7 ± 0.6 ; 28.3 ± 0.6 , respectively.

Morphological and optical characteristics of bended guard hairs

A certain type of abnormal guard hairs observed in Danish mink was characterized morphologically by microscopy (Rasmussen, 1988b). On the dorsal side of dark pelts, guard hairs, apparently light or silver in colour, differed optically from the adjacent (normal) guard hairs (Figure 15). No differences between normal, long guard hairs and abnormal ditto were found regarding cross-sectional forms, the degree of pigmentation or the ultra-structure of the cuticle. On the other hand it was observed that the tips or the greater part of the lancets of the abnormal hairs were curved (bended) to different degrees (Figure 16).



Figure 15. Bended guard hairs observed in situ in a dark mink pelt. (Photo: The author)

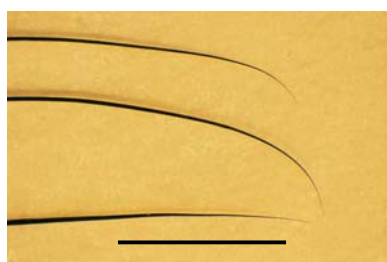


Figure 16. The tips of two bended and a straight guard hair from dark mink. Scale = 4 mm. (Photo: The author)

From a morphological point of view, the lanceolate part of bended guard hairs did not look like that of metallic guard hairs, but there could be some resemblance to the type of singed guard hairs characterized by hooked tips. However, the bending of the so-called bended guard hairs included in several cases a relatively greater part of the lancet (shield) than normally observed in hooked tips. The characteristics of bended guard hairs were believed to effect an altered orientation of the hair fibre causing a modification of light reflection resulting in the observed light or silver colour. Optical properties of these bended guard hairs were investigated afterwards (Rasmussen, 1989b, 1991b). By using microscope photometry, differences in luminance (lightness) caused by diffuse and specular reflections from straight and bended guard hairs were recorded in distal-proximal direction and compared. Straight hairs showed a more or less straight luminance curve; moderately bended hairs showed a gradually falling curve whereas extremely bended hairs showed a more or less bell-shaped luminance curve documenting specular reflection (Figure 17).

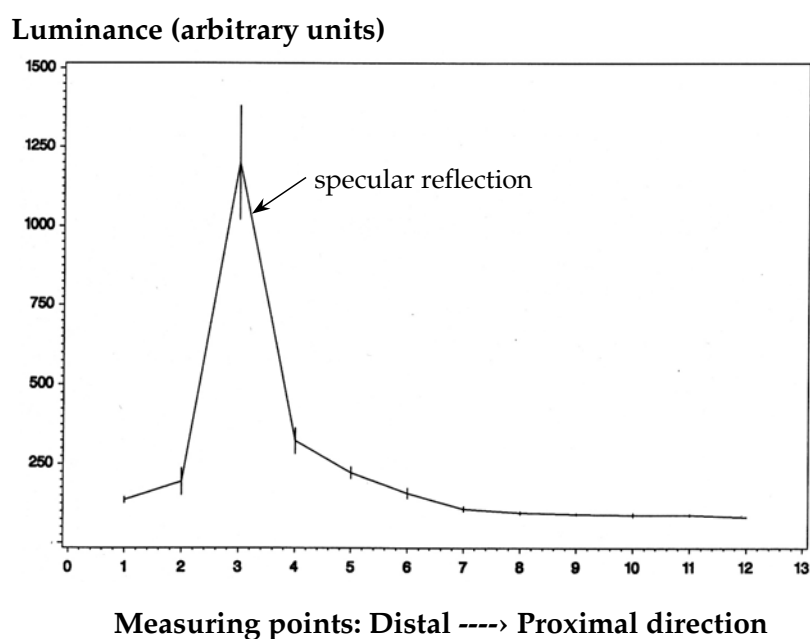


Figure 17. Luminance curve of an extremely bended guard hair from dark mink. At a certain location (point = 3), the light reflection is specular. (*Modified after Rasmussen, 1991b*)

Kondo et al. (1988) examined the morphological structure of “bending” tips in mink guard hairs. In extreme cases the bending hairs appeared on the abdomen of the mink, but mainly on the back. The bending characteristics varied among individual guard

hairs. In some cases the bending angle was only 10-30 degrees, but in extreme cases, this angle was as large as 30-60 degrees. In the same investigation, the arrangement of the cuticle scales in the bending part was observed by scanning electron microscopy and compared with normal guard hairs. The distance between scales in normal hairs was longer than in bending hairs (4-15 μm against 2-4 μm); the number of scales per mm hair fibre was 150 in normal hairs and 500 in bending hairs.

Silky hair type expressed numerically

The idea of silkiness (pelts with a silky surface) has been explained briefly above. As a pilot experiment the author investigated silkiness in mink (Rasmussen 1992a, 1993). Several obvious morphological and optical parameters and their presumed interdependency in scanblack and scanbrown mink were included. Morphometric guard hair variables such as length, thickness, cross-sectional profile and scale frequency observed on the lancet were related to the visual and tactile impression of the pelts examined. It was indicated that a fine fibre diameter and a high cuticle scale frequency were positively related to a sensory fine and silky fur surface.

Sensory, silky and smooth hair fibres are usually more glossy (Löhle and Wenzel, 1984). Rasmussen and Dyck (2000) tried to define and characterize the optical surface appearance of scanbrown mink pelts numerically by using relatively simple and non-destructive goniophotometric measurements. The pelt material originated from a selection trial and consisted of two groups (1992 and 1994) with focus put on silkiness. Angular reflectance curves were obtained. The measurements were performed along the guard hairs and across them, and the curve from the first type included a maximum (Figure 18). Specular gloss, indicated by the maximum reflectance (s) in the direction of mirror reflection, was positively correlated with silkiness. In respect to Group 1994: $s = 72.94 + 0.49 \times \text{silkiness}$ ($r^2 = 0.33$, $P = 0.0003$). Correspondingly, an area representing specular (S) plus diffuse (D) reflectance ($S + D$) under the curve was positively correlated with silkiness. Measures of contrast gloss involving relations or differences between specular and diffuse reflectance were not particularly suitable.

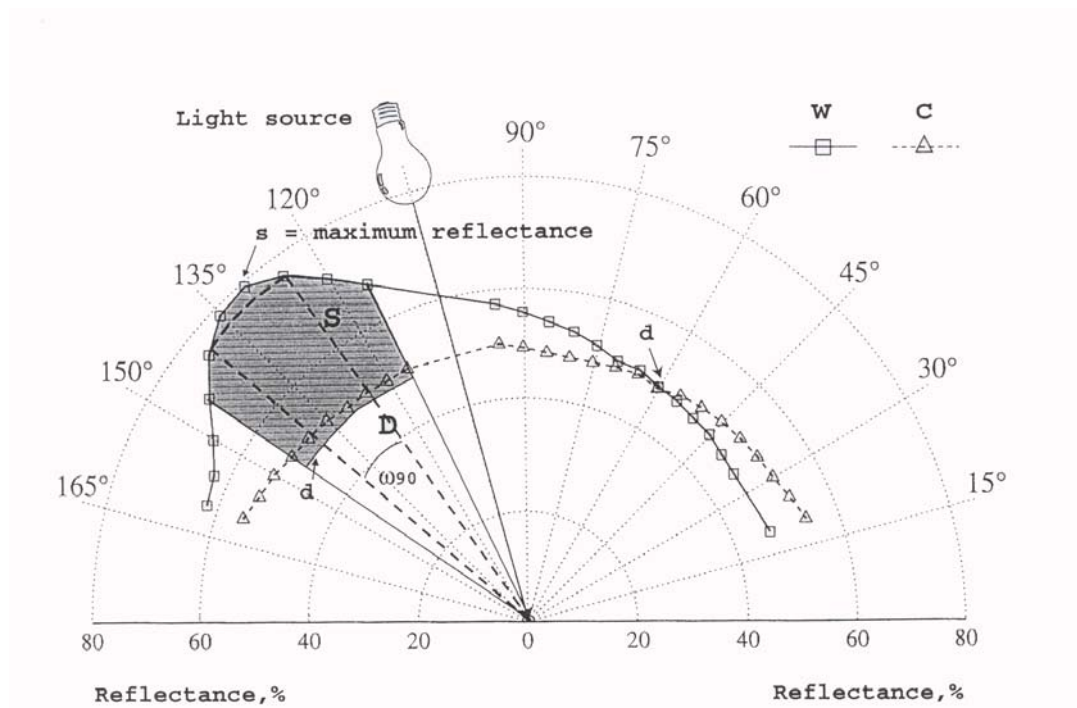


Figure 18. Angular reflectance curves obtained from a brown mink pelt. (From Rasmussen and Dyck, 2000 with permission from American Society of Animal Science)

These results showed that a high degree of specular gloss, indicated by s , could explain and was related to an essential part of silkiness and general sensory quality of the pelt material investigated. At the same time, s was relatively easy to measure. So, even if the objective variables did not correlate perfectly with visual judgments, s was considered to be the most usable objective variable in characterizing silkiness.

Underfur quality

Appearance

The underfur of a high quality mink pelt is specified as being dense, firm, springy and of a certain uniform length (Dansk Pelsdyravlerforening, 1988; Lønne, 1994). These characteristics are primarily determined by the number of hairs per skin area and type of underhairs (Lønne, 1994) emerging from skin pores in tufts (Hardy and Hardy, 1942; Kondo et al., 1989) (Figure 4). Further a firm underfur is capable of controlling the direction of the guard hairs preventing these hair fibres to cross each other. Underhairs in mink are wavy, and their cuticle consists of well-developed scales (Wentz and Hunt, 1951). The relatively rough fibre surface obviously results in a different light reflection (dull colours) compared with the very smooth and lustrous surface of the lanceolate part of guard hairs (Toldt, 1935; Wehr et al., 1982). The visual colour shade of brown and black colour types is primarily judged by the colour shade of the underfur seen on the edge of the pelt. Certain types are judged on the back. Blue-greyish to reddish

colour shades are observed depending on the colour type in question (Dansk Pelsdyr-avlerforening, 1988; Wentz and Hunt, 1951; Hillemann, 1984). Colour measurements have been used by Rasmussen (2000) in order to understand the visually graded colour shades in scanbrown mink.

Morphological variation

Thickness and form - Cross-sectional profiles

According to Wentz and Hunt (1951), underhairs (having 4-6 crimps) are nearly constant in diameter below a slightly wider region adjacent to the tip. These researchers measured the thickness of fibres originating from the hip and side (lateral) samples. In this case widths were taken on a curving portion of the fibre where scaliness was well developed. The average diameter was estimated to $13.08 \mu\text{m} \pm 0.38 \mu\text{m}$, ranging between $12 \mu\text{m}$ and $15 \mu\text{m}$. Skårman (1945) found an average value of $12.48 \mu\text{m}$. With the light microscope it can be observed that underhairs are approximately tetragonal or pentagonal in cross-section. By using computer-assisted image analysis on cross-sectional profiles, the author determined the diameters of underhairs (not published) on the basis of their cross-sectional areas. Here, two scanblack pelts of poor and medium fur density, respectively, were examined. From each pelt four skin samples (with hair) lined up parallel to the longitudinal axis were cut from the hip (standard sampling area). Cross-sections of underhairs were made. The fibre sections represented a level 9 mm above the skin surface. A relatively high fibre density and high mean fibre diameter were observed in the pelt of medium fur density (Table 1). Further the coefficient of variation (%) of the fibre diameter was determined for both pelts. In the poor fur density pelt, the CV-range was 12.7%-18.3%, and in the medium fur density pelt the range was 13.8 %-17.2 %. This indicates that the diameter of underhairs of mink at the 9 mm level concerned may vary considerably.

Wentz and Hunt (1951) reported, that the diameter of underhairs measured with the ocular micrometer agreed very closely with the judges' estimates on texture, when this parameter was defined and graded as 1) too fine, 2) right and 3) too coarse fibres. They concluded that a diameter ranging between $11.5 \mu\text{m}$ and $12.2 \mu\text{m}$ is ideal since neither over-fine, easily crushed, nor a coarse, hairy underfur is desirable.

Table 1. Means, standard deviations and numbers of fibre diameters (underhairs) measured on the hip area in scanblack mink pelts representing one pelt with poor fur density (PFD) and one with medium fur density (MFD).

	Mean diameter of underhairs (μm)			
	<i>Sample 1</i> (hindmost)	<i>Sample 2</i>	<i>Sample 3</i>	<i>Sample 4</i>
PFD	11.0 $\pm$ 1.6 (N = 427)	10.9 $\pm$ 2.0 (N = 347)	10.8 $\pm$ 1.6 (N = 447)	12.6 $\pm$ 1.6 (N = 521)
MFD	12.0 $\pm$ 2.0 (N = 728)	13.4 $\pm$ 2.3 (N = 655)	12.8 $\pm$ 1.8 (N = 742)	13.0 $\pm$ 1.8 (N = 566)

Fibre length

The underhairs are normally of a more uniform length in comparison to guard hairs (Reiten, 1978). According to Dansk Pelsdyravlerforening (1988), the underfur must be of a “certain length” and not too weak. The lengths of underhairs and guard hairs are usually positively correlated. Coefficients of correlation ranging between 0.7 and 0.8 have been reported (Lohi and Rasmussen, 1991; Reiten, 1978). The variation between hair type populations became quite obvious, when samples of underhairs from 100 scanblack pelts were studied (Rasmussen, 1988). The pelts represented good quality and originated from 20 farms (5 pelts per farm). The average length of underhairs was 15.0 mm $\pm$ 0.7 mm, ranging between 14.4 mm and 15.7 mm. Within populations standard deviations varied between 0.3 mm and 1.4 mm (Lohi and Rasmussen, 1991). Regarding the influence on the parameter nap, please see the section dealing with guard hair length.

Defects

With reference to the next section (about associated fur properties), only one defect shall be mentioned: Poor underfur development or “reduced hair growth on hips” (RHG) (Figure 19). In the case concerned, Rasmussen and Lohi (1988) and Rasmussen (1989c) documented that there were relatively few underhairs in the hip area in mink with this defect. The total mass of hair (weighed) was reduced by 6-22% depending on how pronounced the defect was. The hair fibres also had a tendency to be shorter (Rasmussen and Lohi, 1988).

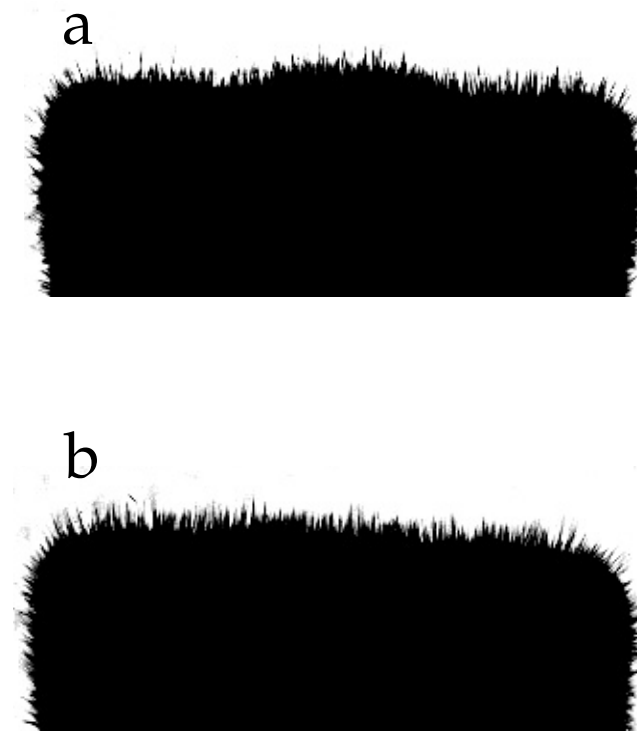


Figure 19. RHG pelt (a) shows an uneven fur layer compared with a normal (high quality) pelt (b). (*Modified after Rasmussen and Lohi, 1988*)

Colour shades of underfur expressed numerically

The colour shade of the pelt is traditionally judged by sensory (visual) methods, and it is primarily determined by the colour of the underfur (Dansk Pelsdyravlerforening, 1988). Blue-greyish to reddish colour shades are observed depending on the colour type in question (Dansk Pelsdyravlerforening, 1988; Wentz and Hunt, 1951; Hillemann, 1984).

Microspectrophotometric methods were used to provide objective correlates to the visually judged colour shade (CS) of the underfur in scanbrown mink pelts (Rasmussen, 2000). The study included 21 scanbrown mink pelts (winter coat), representing a larger group of 87 mink pelts coming from a feeding trial with experimental and control animals. The pelts were visually graded from "1" (blue-greyish) to "5" (reddish) primarily in respect to the CS (in auction classification = clarity of colour) of the underfur seen on the edge of the pelt. Prepared samples of underhairs (underfur fibres) showed in visual inspection a gliding change of colour from paler to darker in proximal-distal direction and were consequently examined at three levels above the

skin surface. The means of the dominant wavelengths (hues) were 589.40 nm, 588.00 nm and 586.70 nm, respectively, indicating that the variation between levels was small. The investigation of the small pelt material concerned showed that CS correlated with the measured lightness (L^*), the red chromaticity coordinate (a^*), and with the yellow chromaticity coordinate (b^*) of the underhairs. The predicted mean value of the colour shade was written as: $CS = -33.16 + 1.56L^* - 0.018L^{*2} + 0.12a^* + 0.56b^*$ ($R^2 = 0.58$, $P = 0.005$). In this investigation it was also shown that an underfur with a visually blue-greyish colour shade was relatively dark and relatively less yellow compared with an underfur having a reddish colour shade. However, data and the model estimating the colour shade demonstrated that for the material concerned visually very reddish underfur colour shades were not found in the lightest coloured pelts.

Associated fur properties

Fur texture

The idea of fur texture is difficult to describe uniformly. Torsten Berg (1942) explained guard hair texture in the following way: „Täckhårens textur. Först er det kanskje bäst att klargöra, så gott det går, vad vi mena med textur i detta avseende. I begreppet innefattas alltså täckhårets utseende (det skall vara rakt og mjukt), täckpälsens tæthet, glans, silkighet og jæmnhet samt täckhårens inbördes förhållande till varandra, d.v.s. pälsen får icke vara oredig, ha brutna hår e. d., icke vara torr eller spröd. Textur är således ett mycket omfattande begrepp, og poängbedömningen av densamma det svåraste vid bedömningen av mink. And: „Otvivelaktigt är det täckhårens og kanskje i ännu högre grad underpälsens textur, som har det största inflytandet på skinnets utseende....”

Skårman (1945) wrote: „Vid bedömningen av minkens fäll tages förutom till färgen hänsyn även till täckhårens og underullens längd og textur ävensom till pälsens ”allmänna intryck”. Texturen är ett mycket omfattande begrepp, vilket bl.a. inbegriper hårens utseende og mjukhet, fällens jæmnhet o.s.v. För dessa egenskaber bör hårens finlek og form spela en framträdande roll.” This is comparable to Wentz and Hunt (1951), who wrote: „The use of the underfur diameter to measure texture seems valid.” They reported that the diameter of underhairs measured with the ocular micrometer agreed very closely with the judges’ estimates on texture, when this parameter was defined and graded as 1) too fine, 2) right og 3) too coarse fibres.

Lønne (1994), however, wrote: „Tekstur. D.v.s. lengdeforholdet mellom dekkhår og underpels.” And: „For at beskrive teksten brukes betegnelserne: long nap, medium nap og short nap. Betegnelsen nap er et uttrykk for, hvor stor en del av dekkhårene (-

spissene) som er over underpelsen (frie dekkhårsspisser).” She also includes underfur characteristics and writes: „Underpelsen skal være tett og elastisk” (Figure 20).

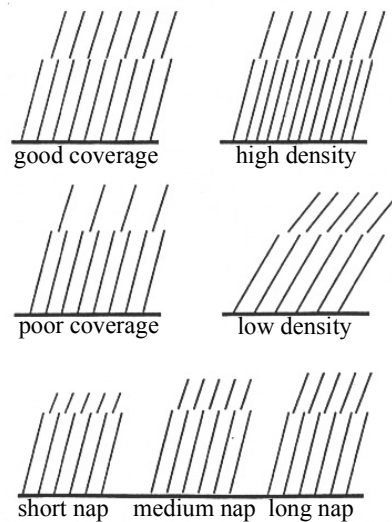


Figure 20. Important fur properties of mink. (Modified after Lønne, 1994)

Fortunately Toldt (1935) also discussed the idea of texture: „Die „Rauche” oder „Textur” ergibt sich für den Fachmann gefühlsmässig beim Angreifen des Felles (‐Fingerspitzengefühl”, vgl. auch den ‐Griff” bei der Schafwolle); bei guter Qualität verursacht sie ein Gefühl wie bei weicher Seide. Mit Rauche wird nach Demoll (zit. nach v. Würth) „eine Eigenschaft des Pelzes zum Ausdruck gebracht, die sich aus vielen Komponenten zusammensetzt, die jedoch im einzelnen nicht festgestellt sind. Die Rauchheit wird bedingt durch mehrere physikalische Eigenschaften des Haares, und zwar unter Zusammenwirkung bestimmter Eigenschaften der Grannenhaare und der Unterwolle”. Die Leithaare sind wegen ihrer meist geringen Anzahl diesbezüglich weniger von Belang. Nach v. Würth sollen bei einer guten Rauche die 3 Haarhaupttypen in typischer Weise (Form und zahlenmässiger Verteilung) ausgeprägt, die Übergangsformen unterdrückt sein. Bei milderer Rauche finden sich viele Haarsorten in unregelmässiger Verteilung. - Im engeren Sinne bedeutet „rauch” ein Fell mit dichtem Unterhaar gegenüber einem glatten („flachen” oder „leichten”) Fell.” In this last explanation, particularly the hair fibre distributions (overhairs, guard hairs and underhairs) are in focus.

Based on the above-mentioned references, fur texture is first and foremost the quality of the fur layer that can be decided by touch; this means the degree to which the fur is

smooth or rough, soft or hard. The smoothness/roughness of fur is determined by several concurrent physical properties of both guard hairs and underhairs (sufficient density), especially their thickness, smoothness (relatively thick hair fibres usually means a rough and undesirable fur texture). Also their length ratios combined with the distributional conditions of the main hair types are influential. This means that to achieve the right fur texture, the transition hair forms should be avoided.

Nap

Regarding this property, which is used both as the relation between lengths of underhairs and guard hairs (relative nap) and as the difference between lengths of underhairs and guard hairs (absolute nap), please see the section “Fibre length” under “Guard hair quality”.

Hair quantity

According to Dansk Pelsdyravlerforening (1988) and Lønne (1994), a high quality pelt is characterized by having enough guard hairs to cover a dense underfur. This also means that hair density is a very important sub-trait and quality parameter in pelts, and therefore it is necessary to specify it quantitatively. In order to get information about hair density indirectly (correlates), Rasmussen and Lohi (1988) and Lohi and Rasmussen (1991) determined the hair mass (mg/cm²) of guard hairs and underhairs in pelts from Danish scanblack mink (100 pelts representing 20 farms). The weight of fur per cm² skin depended on the number of hairs, hair type (i.e., cross-sectional area) and hair length. The mean weights (mg/1.3 cm² ± SD) were 40.1 ± 5.4, 15.3 ± 2.3 and 55.4 ± 6.9 for underhairs, guard hairs and underhairs + guard hairs, respectively. Correlations between hair weight per skin area and the mentioned hair morphological parameters were positive and in most cases significant, yet always stronger regarding samples taken from the hips compared with samples taken from the middle of the back. The fur quantity expressed as hair weight could also reflect the subjective, sensory grading of general quality and fur density. Correlations were higher, when samples from the hip region were used, which demonstrated the importance of this region in the grading process (Table 2).

Table 2. Correlations between hair morphological parameters (hair weights/cm²) and sensory grading of general fur quality and fur density. (After Lohi and Rasmussen, 1991)

	Sensory grading	
	General quality	Fur density
<u>Samples from the back line:</u>		
Guard hair weight	0.21**	0.23***
Underhair weight	0.24***	0.38***
Total hair weight	0.25***	0.37***
<u>Samples from the hip region:</u>		
Guard hair weight	0.56***	0.23***
Underhair weight	0.58***	0.65***
Total hair weight	0.62***	0.37***
** P<0.01, *** P<0.001		

Rasmussen (1995) and Lohi et al. (1996) showed that physical measurements (radiation technique) on 75 scanblack male mink pelts regarding the estimated hair density (mg/cm³, 9 mm level above the skin surface, successive samples) correlated positively ($r = 0.6$ to 0.8) with corresponding hair weights (mg/cm²). It was further documented that the total hair weight (mg/cm²) correlated positively with both the number of hair fibres per cm² ($r = 0.5$) and the total cross-sectional area of hair fibres per cm² ($r = 0.6$). Hair weights and hair lengths were correlated to minor degrees.

Hair density

Hair density is one of the most important characteristics of domestic animals produced for their pelage (Kaszowski et al., 1970). Several investigators have attempted to develop objective means of determining hair density. As referred to above a high quality pelt is characterized by having enough guard hairs to cover a dense underfur. This means that hair density is a very important sub-trait and quality parameter and therefore important to specify quantitatively.

In order to examine and quantify the hair density in dressed mink pelts objectively, Kondo et al. (1989) used light and scanning electron microscopy. They determined the

average number of guard hairs + underhairs at different positions in three dressed male pelts; the number of hairs per pore observed ranged between 15.6 and 26.3. There were no significant differences between pelts regarding the average number of skin pores per unit skin area, except around the neck. However, the pelts in which hair density was judged sensorially to be high had a high number of hairs per skin pore. It was concluded that determining the number of hairs per skin pore was the most effective method for judging hair density in mink.

Morphometric studies on black mink pelts including samples representing three levels above the skin surface (9 mm, 14 mm and 19 mm) demonstrated how the total cross-sectional area of hair fibres per cm² skin surface (a correlate to density) and the total number of hair fibres per cm² (another correlate to density) correlate with each other (Rasmussen, 1995). For the levels mentioned, significant coefficients of correlation were 0.9, 0.7 and 0.8, respectively. This indicated that especially at the 14 mm level ($r = 0.7$, i. e., the lowest r -value), the hair fibre thickness played a determinant role regarding the size of the total cross-sectional area of hairs in the samples studied.

Wentz and Hunt (1951) stated that the weight per cm² of fur is not a sufficiently accurate indicator of the fur density: „In addition to the total number of guard hairs and underhairs in the sample, the other variables in determining weight per square centimetre are mass per unit volume, diameter and length of both underhairs and guard hairs. Therefore, a correction must be made for fibre length and width before weight can be used as a measure of density.” These investigators corrected the weight of underfur or guard hair by using “the coefficient of density” (an index of fibre number) considering the fibres as a field of cylinders. The formulas used to compute the coefficient of density for underhairs or guard hairs are not considered further in this paper. It was reported that compared with the “naked eye” observations, the results were satisfactory.

Kaszowski et al. (1970) estimated the density of hairs in samples taken from dressed mink pelts (and living animals, too) through the use of formulae which (among others) included hair number, the entire cross-sectional area of the hair sample and the skin area from which the sample was taken. It was suggested that the variation in density of underfur between individual pelts might give the opportunity for selection and heritability studies of fur density in mink.

Conclusions

The methods and investigations reviewed and discussed in this summarising report have produced very interesting results including certain correlates, which may help to 1) explain and to 2) provide a background for the subjective (sensory) judgment and grading of visual/tactile impressions of the fur and different fur defects. However, it must be remembered that correlations between objective parameters and subjective judgments are to a certain degree determined by the accuracy (and reproducibility) of the subjective/sensory judgments.

Combined the methods and results may contribute to rationalize some concepts of grading and selection, serving as a kind of fur formulation devices and thus improve fur quality and its control.

Danish summary

Det overordnede tema i denne artikel er kvaliteten af pelsprodukter fra farmproducerede mink, primært de mørke farvetyper. I form af et studie af minkpelsen, med særligt henblik på produktkvaliteten, er der vedrørende definitioner, måling og variation redegjort for vigtige hårmorfologiske og optiske pelsegenskaber.

Kvaliteten af pelsprodukter fra farmproducerede mink kan styres og dermed kontrolleres i retning af de krav, der stilles af især købere og designere. Ved udvælgelse (selektion) af avlsdyr kan den enkelte minkavler modificere vigtige produkttegenskaber vedrørende kvantitative egenskaber som størrelse, hårtype, hårtæthed og hårfibrenes farvenuance hos den pågældende farvetype. I praksis bliver pelsdyravlerens sortering af livdyr og tørrede skind samt salgsorganisationernes sortering af tørrede pelsdyrskind med hensyn til pelskvalitet foretaget på grundlag af subjektive, sensoriske, det vil sige visuelle og/eller taktile metoder. Imidlertid er pelskvalitet sammensat af en række delegenskaber, hvilket vil sige morfologiske hårfiberegenskaber som hårfiberdiameter, hårfiberlængde, hårfiberantal/-tæthed, forhold mellem dækhår og uldhår, dækhårenes orientering og parallelitet og underpelsens farvenuance. Inden for disse parametre eksisterer der en forholdsvis stor variation. Mangfoldigheden af delegenskaber gør bedømmelse og sortering af pelskvalitet til en ret vanskelig sag. Med henblik på at forbedre sortering, selektion og dermed avlsarbejdet er et vigtigt formål med forskning i pelskvalitet at fremskaffe detaljerede, objektive kvalitetsparametre, som korrelerer signifikant med den sensoriske vurdering af pelsens egenskaber.

Denne artikel er et studie af pelsen på tørrede minkskind. Indledningsvis gives et sammendrag vedrørende det skind- og hårfibermateriale, som blev benyttet i studiet samt diverse metoder vedrørende præparation, mikroskopi, analyser, herunder makro- og mikrofotometriske målinger. Baseret på adskillige referencer og personlige undersøgelser redegøres der herefter for en række punkter:

Hårmorfologi og pelsstruktur hos pelsdyr (inkl. mørk mink) generelt. Der gives her en kort morfologisk beskrivelse af de almindeligste hårfibertyper og af pelsens struktur baseret på en opbygning i tre lag. Hårfiberstrukturen beskrives mikroskopisk med fokus på kutikula, cortex og medulla. Med en kolorimetrisk indgangsvinkel omtales hår- og pelsfarve og forhold vedrørende hårpigmentering (eumelanin og phaeomelanin) og morfometrien af forskellige typer melaninkorn.

Pelsegenskaber hos mink med særligt henblik på produktkvalitet, og hvorledes forskelle i disse egenskaber kan angives numerisk ved anvendelse af morfometriske, mikroskopiske og

fotometriske metoder, f.eks. ved undersøgelse af egenskaber såsom silkethed / glans og farve.

Vigtige håregenskaber, som har direkte betydning for pelsens kvalitet, herunder pelsfejl, som kan deles op i a) dækhårskvalitet, med morfometrisk karakteristik af tværsnitsprofiler (fibertykkelse), hertil hårlængder (inkl. nap) og en gennemgang af flere defekter (singel / metallic) b) uldens (underpelsens) kvalitet, fibertykkelse, -længde og -antal / -tæthed c) andre komponenter af pelskvalitet, med diskussion af begrebet tekstur, som først og fremmest fortolkes som den pelskvalitet, der kan bestemmes ved berøring; d.v.s. graden ved hvilken pelsen føles glat eller ru, blød eller hård; fysiske egenskaber, f.eks. overfladebeskaffenhed og tykkelse hos både dækhår og uldhår samt deres fordeling er især bestemmende herfor. Der refereres til undersøgelser vedrørende vægtbestemmelser af hårmassen, og hvorledes denne korrelerer med sensorisk bedømmelse af generel kvalitet og pelsfylde. Endeligt omtales undersøgesler af pelsens densitet (tæthed).

Det er et faktum, at fremtoningen af en bestemt farve eller overflade ofte opfattes forskelligt af forskellige mennesker. Set i lyset heraf bliver det i denne artikel konkluderet, at udvikling, tilpasning og anvendelse af objektive målemetoder med fordel kan fremskaffe detaljeret information om deskriptive og årsagsmæssige forhold i forbindelse med adskillige delegenskaber og deres variation hos minkpelsen. Metoderne og undersøgelserne, som er diskuteret i denne sammenfattende artikel, har tilvejebragt en del interessante resultater, herunder bestemte korrelater, som kan være en hjælp til at forklare og dermed til at danne baggrund for den sensoriske bedømmelse og sortering af skind i praksis. Imidlertid vil korrelationer mellem objektive parametre og subjektive, sensoriske vurderinger til en vis grad bestemmes af nøjagtigheden af den sensoriske vurdering. Det er oplagt, at metoderne og resultaterne sammenlagt kan bidrage til at rationalisere nogle begreber inden for sortering og selektion af skind og således forbedre styring/kontrol af pelskvaliteten.

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common object has always been to provide objective and numerical information about fur properties, information which may be related to sensory judgments of the fur product - the pelt.

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