



An Overview of Feathers Formation, Moults and Down Production in Geese

J. Kozák*

Szent István University, Faculty of Agricultural and Environmental,
Institute of Animal Husbandry, Gödöllő, Hungary

ABSTRACT : Feathers are one of the integument appendages that form the outer covering, or plumage, on birds. The goslings hatch with a downy coat of feathers formed in embryonic development. They moult the natal plumage into juvenile feathers between 3-5 weeks of age and than moult that juvenile plumage into adult plumage between 8-11 weeks of age. Feather weight of an adult goose makes up about 6.2% of its total body weight. Heritability of the feather production ability is relatively low ($h^2 = 0.35$). Within species or genotype, the quantity and composition of the plumage are affected by genetics (age, body weight or body surface area, feathering rate, sex) and environmental factors (nutrition and production system, weather, microclimate). After slaughter some 90-220 g marketable feathers can be obtained per goose. The yield of feathers and down from each hand-harvesting amounts to between 80 to 120 g per goose, depending upon the frequency and degree of completeness of the harvesting. (**Key Words** : Feather Formation, Goose, Moults, Yields and Quality of Feathers and Down)

INTRODUCTION

Geese are farmed for their meat, fatty liver as well as feathers and down. Of the 54 breeds of geese (FAO, 2000, op. cit. Bodó and Szalay, 2007), altogether 94 genotypes (breeds, hybrids, lines) (FAO, s.a.) the majority are found in the world. The downy and soft feathers from geese are used as high-grade insulation material in both clothing and bedding. An adult goose of medium to heavy breed produces a total of 150-230 g of valuable feathers (Camiruaga-Labatut, 2002). The quantity and quality of feathering are influenced by genetics and indirectly by the environmental or nutritional status (Leeson and Walsh, 2004).

This paper gives a brief overview of feather formation, plumages and moults in geese, as well as the output and quality of feathers and down in relation to the main factors influencing these traits.

FEATHER FORMATION

Feathers, the covering of birds, are peculiar appendages

of the epidermal and dermal layers of the skin (Szado et al., 1995). A feather develops in the follicle with a dermal papilla at the bottom from which the feather grows. Formation of all follicles and the initial feather cover occurs in the embryonic development (Lucas and Stettenheim, 1972). In geese, feather germs are first visible on the back on day 12 of incubation (Gergely, 1957) and by day 19 of incubation the entire body of the goose embryo is covered with initial downs (Mágory et al., 1991; Pécsi et al., 2010).

Feather germs appear only in specific areas along district tracts with a highly organised pattern of distribution (Stuart and Moscona, 1967). In geese, the prenatal downy follicles - subdivided as primary and secondary feather follicles - evolve independently of each other and form ranks in a linear fashion. The primary follicles of larger diameter develop contour and flight feathers in postnatal life, whilst the secondary follicles of smaller diameter emerge later and develop only downy feathers (Xu et al., 2007).

When a gosling hatches it has a coat of uniformly short, silky and fluffy down (Bögre and Bogenfürst, 1971). This natal (neoptile) plumage differs in colour as well structure from the definitive (teleoptile) plumage as it lacks for the coverts, remiges or retrices either (Nagy, 1973). Neoptile down appears as a bundle of fluffy branches, all springing

* Corresponding Author : J. Kozák. Tel: +3628-522-000,
Fax: +3628-410-804, E-mail: Kozak.Janos@mkk.szie.hu
Received September 10, 2010; Accepted December 14, 2010

from a very short infantine quill (Hungarian Standard, 1999). Unlike most birds, downy feathers of goose and ducks have but a short quill rooting in the follicular papillae. The fluffy down makes the newly-hatched gosling larger its real size (Rutschke, 1987).

THE FIRST MOULT

Goslings replace their natal down by a juvenile (teleoptile) plumage between about 3-5 weeks of age. This process is the first, called postnatal moult. The juvenile (immature) feathers emerge from the skin encased in a sheath (Bögre and Bogenfürst, 1971; Hungarian Standard, 1999). The first moult starts on the breast and belly at 3 weeks of age after hatching. The new feathers grow from the same follicular papilla, so the two generations of feathers (natal down and juvenile feathers) are adhered together (Kozák et al., 1992a; Kozák et al., 2010). The freely overhanging natal fluffs break down from the tips of the incoming juvenile feathers some week later (Rutschke, 1987). No suchlike duality occurs when coverts are replaced (Schneider, 1995).

Parallel with the moult on the breast and the root of the neck the wings also start to moult. By the end of the third week the tail and wing feathers also begin to grow intensively (Bögre and Bogenfürst, 1971). Lastly, the feathers on the mid-part of the back undergo moult at 5 weeks of age (Kozák et al., 1992a).

The new covert feathers are developing intensively in all body parts between 4-8 weeks of age (Kozák et al., 1992a). By the end of the 7th week, the entire body is covered with the new feathers; albeit these are not fully mature yet (Bögre and Bogenfürst, 1971). By 9 weeks of age the belly feathers appear already mature, and feathers in other body parts elongate but little. Feather maturation is completed last on the mid-part of the back sometimes only by the 11th week of age. Once feathers have attained full maturity in all body parts the coverts start to moult in a few days onwards (Kozák et al., 1992a). The post-juvinal moult takes place in growing geese between 9-11 weeks (Schneider, 1995) or 10-11 weeks of age (Kozák et al., 1992a).

Spring-hatched goslings (if nourished appropriately) come into a mature plumage between about 8-10 weeks of age and then start to moult. Autumn-hatched goslings (coming from the second laying cycle) attain mature plumage by 11 weeks of age and begin to moult from the 12th week (Kozák and Monostori, 1992). By this age, the replacement feathers start growing before the old ones are shed (Watson, 1963; Kozák, 1999) indicated by the pinfeathers emerging on the breast and belly in a week later. Thus, growing geese have started to moult naturally and

renewed again their plumage (Kozák and Monostori, 1992).

FEATHER GROWTH AND RENEWAL

In most birds, the entire feathering is renewed at periodic intervals. This renewal of the plumage is called moult. It is a physiological process controlled hormonally whereby the old, worn feathers are replaced by a new growth.

Once a feather is mature, the blood supply from the follicular papilla to the quill of feather recedes (Schneider, 1995). Thus, the dermal pulp retracts progressively from the quill, leaving it empty, until the feather becomes an inert, dead structure comprising 90% keratin (Del Hoyo et al., 1992). The pulp dries up and the reddish-blue colour of the quill fades out and an intense keratinisation commences at the base of the quill. This way the contact between the quill and the follicle ceases completely. By this process the maturation of the feather is completed. Finally the pressure of cellular proliferation concomitant with the growth of the new feather will push out the old feather. At the moulting time the mature feathers are easy to remove (without any pain or skin injuries) because their quill points are sticking very loosely in the feather follicles for lack of nutrient supply (Schneider, 1995). Well, it is the right time to perform the first manual feather-harvesting (Kozák et al., 1992b).

After the moult or the first harvesting, small pinfeathers are emerging on the entire body. They grow intensively between 12-16 weeks of age then grow at a slower rate in the subsequent one or two weeks. Finally, the new feathers attain maturity in all body parts by 18 weeks of age (Kozák et al., 1992b).

Breeding geese start to moult after the egg-laying period. Subsequent moults occur in growing geese and non-laying adult geese at every 6-7 weeks. A feather requires about 44 days for attaining full maturity. Thus, feathers arise from the same revitalised follicular papillae on sequential moults throughout the goose's lifetime (Schneider, 1995).

YIELDS AND QUALITY OF FEATHERS AND DOWN

Although feathers are known for their lightness, a bird's plumage weighs circa two to three times more than its skeleton, and about 5-7% of the total body weight (Del Hoyo et al., 1992).

Yields of feathers from the domestic fowls and their utility vary considerably by the species (Table 1). The most valuable are the feathers of waterfowls. In particular the goose feathers are valued as being a durable filling material for bedding with a shelf life of up to 50 years (Szado et al., 1995).

Table 1. Plumage and its composition in poultry species (According to Deregowski and Jusik, 1973)

Post-slaughter feathers	Goose	Duck	Hen	Turkey
Total, g	250-300	90-120	80-100	190-300
Down, g	50-60	20-25	-	-
%	20	20	-	-
Soft feathers				
Without down, g	125-150	50-64	64-80	125-195
%	50	53	80	65
Hard feathers, g				
%	30	30	20	35

Source: Szado et al., 1995.

Table 2. Variation in feather yields of geese by slaughter age

Slaughter age Week	Marketable feather g/goose	From the marketable feather		% Down in marketable feather
		Covert g/goose	Down g/goose	
9	90	70	20	22
16	160	110	50	31
23	205	140	65	32
30	220	150	70	32

Source: Schneider, 1995.

Body weight significantly influences the quantity of feathers. Feather weight of an adult goose makes up about 6.2% of its total body weight. Within species the yield of feathers varies considerably by the body weight. Notably, about 200-260 g feathers can be obtained from geese weighing 3.5-4.5 kg versus a yield of 290-327 g from geese weighing 5-7 kg according to previous works (Klosowicz and Kukiella 1955; Deregowski and Jusik, 1973, op. cit. Szado et al., 1995). The percentage of plumage in live weight amounts to 4.6% in broiler goose, 4% in liver goose (Ménési et al., 1964) and 6% in meat-type goose (Szigeti, 1987).

An adult goose of medium to heavy breed produces a total of 150-230 g of valuable feathers - the large feathers of the wings and tail are not included (Camiruaga-Labatut, 2002). After slaughter, 90-220 g marketable feathers can be obtained per goose (Table 2) with a total plumage weight of 250-300 g (Szado et al., 1995). In fattened geese feather yields differ significantly by breed and sex (Table 3).

The yield of feathers and down from each harvesting varies with the feather producing ability of the goose, its body size relative to age, the feeding and keeping conditions, and the degree of completeness of the feather gathering (Tóth et al., 1988), i.e., the area involved and the rate of feather removal.

Heritability of the feather production ability is relatively low, $h^2 = 0.35$ (Nagy et al., 1996); the genetic background of this trait have been studied little. The feathering rate may vary by genotype, sex and among individuals. There are some fast-feathering goose breeds known, such as the Czech goose for example, in which the post-natal moult

occurs earlier (Bogenfürst, 1992).

The quantity of feathers and down removable manually from the live geese is mostly determined by the size of the body surface area, which can be estimated from the body weight (Tóth et al., 1988). The output of feathers and down is obviously determined by the density of the feather follicles (Xu et al., 2007). A comparative study has demonstrated considerable differences in feather density among five breeds (Hungarian Upgraded, Rhenish, Landes, Dutch and Swan Goose). Of four body parts examined (back, rump, breast, belly) the belly seemed to have the densest plumage in all five breeds (Pacs, 1968). Noteworthy,

Table 3. Quantity of feathers obtainable from fattened-geese after slaughter

Breed	Live weight of Goose, g	Feather	
		Weight, g	% in live weight
Hungarian upgraded			
Female	7,853	273	3.47
Male	7,395	330	4.46
Rhenish			
Female	7,747	371	4.71
Male	7,932	347	4.36
Grey Landes			
Female	7,823	243	3.10
Male	9,354	280	2.98
Dutch goose			
Female	6,835	275	4.02
Male	6,705	325	4.84
Mean total:	7,793	306	3.92

Source: Pacs, 1968.

that the density of secondary feather follicles on the dorsal tract was found to be smaller than on thoracic and ventral tracts at same embryonic age of geese (Xu et al., 2007; Wu et al., 2008). The heavier breeds exhibit usually a lower feather density per unit area (Pacs, 1968).

The yield of feathers and down harvested manually from live geese varies in a positive correlation with the body weight. The corresponding correlation is moderate ($r = 0.51$; $r = 0.50$) in the Hungarian Goose breed in good agreement with previous values ($r = 0.56$; $r = 0.60$) reported by Szado (1972, op. cit. Szado, 1995) and it is weak ($r = 0.26$; $r = 0.31$) in the Grey Landes breed. Despite this moderate correlation no considerable increases can be achieved in feather production by increasing the body weight alone (Tóth et al., 1988). The feather and down production is known to differ by sex. On all three harvesting occasions more feathers and down could be collected from the ganders of larger body size than from their female half-siblings of smaller body. These between-sex differences were non-significant, however (Kozák et al., 1997).

As a rule of thumb adult geese provide more feathers than growing geese. It is confirmed by the corresponding yield records (Table 4). The difference may result in 50 g surplus feather yield in favour of adult geese per year (Pacs, 1968).

Growing geese attain about 80% of their adult live weight by the 9th week of age (Schneider, 1995) and they can approximate to their adult live weight by 6 month of age (Tóth et al., 1988). This fact accounts for the small difference between growing and adult geese in the feather yields coming from the second and third harvesting. The increase in feather yields by the second harvesting is due to the favourable changes in size and state of development of the coverts and downs from growing geese meanwhile their body weight has also increased.

The changes taken place in the feather length seem to be closely related with the changes in the live weight. Having attained a certain body weight the feathers grow no longer in any body parts. Postulated, that "feather development mainly depends on the body weight and not on the age" (Bögre and Bogenfürst, 1971). This supports that practical observation that feather yields obtained from older geese at the second and third harvesting are comparable, irrespective of the age.

A comparison of the feathers of growing geese coming from their first and second harvesting has demonstrated that the breast, belly, flank and back feathers are longer and more complete in appearance at the second occasion (Kozák, 1999). The feathers obtained at the first harvesting are less developed and have a lower down content in young geese. At the second harvesting a more complete plumage of good quality can already be obtained. By the third harvesting the growing goose becomes biologically fully mature and produces the most valuable feathers and down (Pálffy, 1980). The feathers of growing geese obtained at the first harvesting - called as "gosling feathers" - still bear the characteristics of the young, growing bird. Notably, the plumage is less resilient, the web is rather rare and the down shares in the plumage only by 14-18%. Feathers coming from the second and third harvesting have excellent resilience and fill power, the down content amounts to 25% at least. Breeding geese (after the laying cycle) can provide feathers with a down content of more than 30% (Ménési et al., 1964) and even 40% (Ádám, 2001) at their first feather harvesting. This high output of down is due partly to that breeding geese by their brooding instinct develop denser down to keep the eggs warm (Ménési et al., 1964) and partly to their natural moult starting after the laying period (Bögre, 1981). In the final phase of the laying cycle a part of coverts are lost only leaving thereby a relatively higher percentage of down in the plumage harvested manually.

Table 4. Feather yields of growing and adult geese over three successive harvesting periods

Feather yield g per head per plucking						Source
Growing geese			Adult geese			
1	2	3	1	2	3	
54	110	122	111	117	119	Römer, op. cit. Szentirmay, 1968
45	87.6	109.9	89.2	73.0	110.0	Bielinski, 1973. op. cit. Pingel, 1993
77.64	134.64	155.10	119.34	102.43	143.79	Kozák, 1999
95	-	-	120	150	-	Pacs, 1968
50-70	90-120	110-150	80-120	110-150	110-150	Schneider, 1995*
-	-	-	110-120	110-120% of the 1 st plucking data		Szentirmay, 1968
80-100	100-130	140-170	-	-	-	Pálffy, 1980
80-100	140-150	150	100	-	-	Bögre, 1981
80-100	140-150	150-170	-	-	-	Bogenfürst, 1992

* Values calculated from cumulated data.

A comparison of downy feathers from 14-16 and 22-24 week-old geese has revealed that the weight of 300 down increased from 0.308 g to 0.349 g (Szado et al., 1995). Thus, the difference between the two groups corresponds to plus 13%.

The state of development of downy feathers depends on the age of the goose but also affected by other factors, in particular the feeding and keeping conditions. A single down is weighing considerable less than a single feather does (Ménesi et al., 1964). According to previous data the weight of 100 downy feathers sampled from the third feather harvesting is 0.136 g for the layer and 0.143 g for the ganders on an average (Kozák et al., 1999). The kind of down is the most valuable that contains more fibre and these fibres are long. The number of downy fibres usually varies between 70 and 100 (Ménesi et al., 1964). A comparison of the feathers of growing geese coming from the third harvesting has revealed that a bigger down diameter is associated with a higher number of downy fibres. The number of downy fibres correlates positively with the down weight: $r = 0.7$ in females; $r = 0.4$ in males (Kozák et al., 1999).

ENVIRONMENTAL FACTORS AFFECTING FEATHER QUALITY

The prerequisite of obtaining feathers of good quality is to perform the manual harvesting only once the feathers have attained full maturity (Szado et al., 1995). Nutrition can influence the rate of feathering as well as feather structure, colour and moulting (Leeson and Walsh, 2004). Feather maturation can be enhanced by providing a high protein diet since 89-97% of feathers is protein (Fischer et al., 1981). The synthesis of feather keratin requires the sulphur containing amino-acids, cystine and methionine. Even marginal dietary deficiencies of these amino-acids may lead to abnormal feathering such as long sheathing, lack of even barbs and barbicels, feather's twisting (Deschutter and Leeson, 1986; Szado et al., 1995). Severe amino-acid deficiencies impede feather development and may predispose to cannibalism (Horn, 1978) concomitant with damages to feathers.

Nutrition of geese can also affect the percentage of fat in feathers. The average fat content is estimated to 1.6% that can increase to 3.2% in the down of geese fattened by cramming (Baczkowika, 1970, opt. cit. Szado et al., 1995).

The management of geese under extensive conditions with bathing facility is stimulative to feather growth and improving the down content as well. Extremely cold weather conditions have favourably effect on feather production and enhance down formation (Bogenfürst, 1992). Under colder climate geese develop denser plumage. Geese frequenting waters grow denser plumage than ones kept

under dry conditions. The regular contact with cold water stimulates the organism of goose to more vigorous feather production so as to protect its body (Szentirmay, 1968). Under overcrowded keeping conditions without bathing facility the feather development slows down (Bogenfürst, 2000). Feathers from geese kept in large groups without pasture and bathing facility contain more contaminated, yellowish ones or matted down whilst, percentage feather composition change no considerably (Paulska, 1994, op. cit. Szado et al., 1995). The plumage of geese kept in enclosures is usually more contaminated compared with geese kept in pastures (Szado et al., 1995).

In case of permanent housing, feather development is affected by stock density, ventilation, relative humidity and ammonia content of air. Inadequacy of these factors can lead to feathering disorders, in particular during the first moult (Bogenfürst, 1992). Feather development of young geese is adversely affected by a relative humidity higher than 70%. Feathers of geese kept overcrowded in humid, warm buildings get matted. The plumage of ill geese appears ruffled and mat. Inadequate nutrition can also lead to losing the lustre of the plumage (Bogenfürst, 2000). The coverts - especially on the lower belly - may become fragmented in overcrowded keeping. The plumage of geese kept on wet litter may also get fragmented at the belly. In lack of ventilation feather pecking may appear among the geese kept overcrowded that also damages the plumage (Bögre, 1981).

The plumage quality also declines during the laying cycle. At this time the goose frequently preens itself and thereby nips its feathers by its beak so as the plumage gets damaged. These feathers are called "goose-chewed" (Pálffy, 1980). The behavioural postures taken up during natural mating - the gander mounting the female, treading its back, holding its neck (Sauveur and Carville, 1990) - as well damage the plumage. Proportion of goose-chewed feathers may amount up to 6% of total feather yield harvested from breeding geese after the laying cycle (Ádám, 2001).

REFERENCES

- Ádám, I. 2001. A toll. A baromfitoll és feldolgozása (The feather. The poultry feather and its processing). Scriptor Kiadó, Budapest.
- Bodó, I. and I. Szalay. 2007. Génbázisok megőrzése a fenntartható állattenyésztésben (Conservation of genetic resources in sustainable animal production). *Állattenyésztés és Takarmányozás* 56:403-413.
- Bogenfürst, F. 1992. Lúdtenyésztők kézikönyve (Handbook of Goose Breeders). Új Nap Lap- és Könyvkiadó, Budapest.
- Bogenfürst, F. 2000. Lúdtenyésztés (Goose breeding). In: *Állattenyésztés 2. Baromfi, haszongalamb (Animal Breeding. Vol. 2 Poultry, Pigeon)* (Ed. P. Horn). Mezőgazda Kiadó, Budapest. pp. 225-280.
- Bögre, J. 1981. Lúdtenyésztés (Goose breeding). In:

- Baromfitenyésztők kézikönyve (Handbook of Poultry Breeders) (Ed. J. Bögre). Mezőgazda Kiadó, Budapest. pp. 559-625.
- Bögre, J. and F. Bogenfürst. 1971. A 0-12 hetes növendékludak tollazatának testtájankénti fejlődése és a fejlődés szakaszos jellege (Feather development of twelfth weeks young geese at different body parts and their section character). *Baromfiipar* 18:109-122.
- Camiruaga-Labatut, M. 2002. Goose production in Chile and South America. In: *Goose production, FAO Animal Production and Health Paper 154*. pp. 94-109.
- Del Hoyo, J., A. Elliott and J. Sargatal. 1992. *Handbook of the Birds of the World. Vol. I. Ostrich to Ducks*. Lynx Edicions, Barcelona, Spain.
- Deschutter, A. and S. Leeson. 1986. Feather growth and development. *World's Poult. Sci. J.* 42:259-267.
- FAO. s.a. *Goose production. FAO Animal Production and Health Paper, 154*.
- Fischer, M., S. Leeson, W. D. Morrison and J. D. Summers. 1981. Feather growth and feather composition of broiler chickens. *Can. J. Anim. Sci.* 61:769-773.
- Gergely, B. 1957. *A baromfikeltetés kézikönyve (Handbook of Poultry Incubation)*. Mezőgazdasági Kiadó, Budapest.
- Horn, P. 1978. *Tyúktenyésztés (Chick Production)*. Mezőgazdasági Kiadó, Budapest.
- Hungarian Standard. 1999. MSZ EN 1885 Toll és Pehely. Szakkifejezések és meghatározások (Hungarian Standard MSZ EN 1885 on Feather and Down. Terms and Measurements). Magyar Szabványügyi Testület, Budapest.
- Kozák, J. 1999. Magyarország baromfigazdasági és szabályozórendszerének EU-konformitása. Baromfitartás, piacszabályozás, állatvédelem (Poultry Industry of Hungary and its EU-conform regulation. Technologies, market regulation and animal welfare). Agroinform Kiadó, Budapest.
- Kozák, J. and I. Monostori. 1992. Adalékok a ludak tépéséhez. (Data to feather plucking of geese). *Baromfitenyésztés és Feldolgozás* 39:21-28.
- Kozák, J., K. Monostori and I. Acs. 1992a. Feather development of the goose during the first 11 weeks. In: *Proceedings of the 19th World's Poultry Congress, Vol. 3. Posen and Looijen, Wageningen, The Netherlands*. p. 311.
- Kozák, J., K. Monostori and M. Karsai. 1992b. Development of feathering in geese from hatch to week 18. In: *Proceedings of the 9th International Symposium on Waterfowl, The World's Poultry Science Association (Working Group N. 8) Waterfowl. NOVASTAMPA, Parma*. pp. 234-236.
- Kozák, J., K. Monostori, I. Ács and A. Pécsi 2010. Postnatal feather cycle of Hungarian Upgraded goose goslings. en.engormix.com/MA-poultry-industry/health/articles/postnatal-feather-cycle-hungarian_1470.htm [Accessed: 20/02/2010]
- Kozák, J., L. Bódi, M. Karsainé Kovács and I. Monostori. 1997. The effect of sex on the feather production of geese. In: *Proceedings of 1997 Australian Poultry Science Symposium. Vol. 9. University of Sydney, Sydney, NSW*. pp. 199-202.
- Kozák, J., S. Vargáné and T. Kawada. 1999. Examination of down-feather of geese from the third plucking. In: *Proceedings of the 12th European Symposium on Waterfowl, University of Cukurova, Faculty of Agriculture Press, Adana, Turkey*. pp. 137-141.
- Leeson, S. and T. Walsh. 2004. Feathering in commercial poultry II. Factors influencing feather growth and feather loss. *World's Poult. Sci. J.* 60:52-63.
- Lucas, A. M. and P. R. Stettenheim. 1972. *Avian Anatomy - Integument. Part II. Agricultural Handbook 362: Agricultural Research Services. US Department of Agriculture, Washington DC*.
- Mágyori, K., A. Pécsi and E. Nikodemusz. 1991. A photographic index for aging goose embryos. In: *Turkish Branch of the World Poultry Science Association: International Poultry Congress '91, Ankara University, Faculty of Agriculture, Istanbul*. pp. 161-162.
- Ménesi, J., I. Szekér and K. Takáts. 1965. *Baromfitoll (The Poultry Feather)*. Műszaki Könyvkiadó, Budapest.
- Nagy, E. 1993. Madarak - Aves. In: *Állattan mezőgazdasági mérnökök részére (Zoology for agricultural engineers) (Ed. Fábrián, Gy.)*. Mezőgazdasági Kiadó, Budapest. pp. 374-388.
- Nagy, N., E. Szabóné Willin and J. Tözsér. 1996. A gazdasági állatok értékmérő tulajdonságai (Production traits of farm animals). In: *Az állattenyésztés alapjai (Bases of Animal Production) (Ed. N. Nagy)*. Mezőgazda Kiadó, Budapest. pp. 174-199.
- Pacs, I. 1968. A ludak tolltermelő képességének vizsgálata. (Feather production examination in geese). In: *Az Agrártudományi Egyetem Közleményei, Mezőgazdaságtudományi Kar, Gödöllő (Ed. J. Manczel)*. Mezőgazdasági Könyvkiadó Vállalat, Budapest. pp. 103-110.
- Pálffy, D. 1980. Lúdarutermelés. Pecsényelőd, májliba és lúdtoll előállítás, feldolgozása (Goose Production. Production and Processing of Broiler Goose, Meat Goose, Liver Goose and Feathers). Mezőgazdasági Kiadó, Budapest.
- Pécsi, A., J. Kozák and E. Nikodemusz. 2010. A photographic guide to goose embryo development. <http://en.engormix.com/MA-poultry-industry/gentic/articles/photographic-guide-goose-embryo-development/1488.htm> [Accessed: 22/03/2010]
- Pingel, H. 1993. Genetics of growth and meat production in waterfowl. In: *Poultry Breeding and Genetics (Ed. R. D. Crawford)*. Elsevier Science Publishers B.V., Amsterdam-Oxford-New York. pp. 691-704.
- Rutschke, E. 1987. *Die Wild Gänse Europas. Biologie, Ökologie und Verhalten*. VEB Deutscher Landwirtschaftsverlag, Berlin.
- Sauveur, B., H. de Caville. 1990. *Le canard de barbarie*. INRA, Paris.
- Schneider, K. H. 1995. *Gänse. Eine Anleitung über ihre Züchtung, Haltung, Fütterung und Nutzung*. Deutscher Landwirtschaftsverlag Berlin GmbH, Berlin.
- Stuart, E. S. and A. A. Moscona. 1967. Embryonic morphogenesis: role of fibrous lattice in the development of feathers and feather patterns. *Science* 157:947-948.
- Szadó, J., E. Pakulska and E. Kapkowska. 1995. Influence of production factors on feather quality. In: *World's Poultry Science Association: Proceedings of the 10th European Symposium on Waterfowl, Halle (Saale), Germany*. pp. 331-341.
- Szentirmay, L. 1968. Lúdtartás-, nevelés-, hizlalás (Goose keeping, Raising and Fattening). Mezőgazdasági Kiadó, Budapest.
- Szigeti, M. 1987. Hulladékhasznosítás helyzete a baromfiiparban (Poultry waste utilisation in poultry industry). *Baromfitenyésztés és Feldolgozás* 34:39-45.

- Tóth, S., M. Szélné Szeri and D. V. Nguyen. 1988. A ludak tolltermelését befolyásoló tényezők (Factors affecting feather production of geese). *Állattenyésztés és Takarmányozás* 37:174-179.
- Watson, G. E. 1963. The mechanism of feather replacement during natural molt. *The Auk*. 80:486-495.
- Wu, W., R. F. Xu, X. Gu, C. H. Li and C. X. Wu. 2008. Characterisation of embryonic feather follicle development in the Chinese indigenous Jilin White goose. *Asian-Aust. J. Anim. Sci.* 21:346-352.
- Xu, R. F., W. Wu and H. Xu. 2007. Investigation of feather follicle development in embryonic geese. *Poult. Sci.* 86:2000-2007.