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Artificial insemination in geese

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Currently most breeds and lines of geese in use at a commercial scale are derived from two wild species; the swan goose (*Anser cygnoides* L.) and the true goose-greylag (*Anser anser* L.). Interestingly, local selections performed for centuries from these two ancestors have resulted in strains or breeds expressing large differences for a range of phenotypic traits including size, body weight, feather colour, behaviour and physiology (including reproductive performance), along with carcass characteristics, flavour and chemical composition of the meat.

When compared with other poultry species, the main factors that have limited geese production and geese meat consumption in Europe are the seasonality of its reproduction and the low fertility of breeder flocks (*e.g.* egg production, fertility and hatchability rates, low male to female ratio, poor semen quality) associated with, on average, relatively high proportions of lipid tissues in the carcasses of their progeny. Some of the above problems can be eliminated or at least reduced by the application of artificial insemination procedures and by selective breeding on fertility and seasonality.

The present paper reviews the main particularities of artificial insemination techniques developed in the goose with regards to the morphology and physiology of male reproductive organs. The main characteristics of ejaculates along with some morphological aspects of sperm morphology, semen collection procedures and semen quality assessment are also described. Finally, geese insemination procedures along with their interests and limits are discussed.

Keywords: goose; artificial insemination; semen quality assessment

Introduction

During previous decades poultry species have received increasing interest as sources of proteins of animal origin dedicated to feeding a growing world population. This rapid success has resulted in a rapid shift of poultry meat production towards second place after swine meat production (FAO sources). Such a huge progression in poultry productivity is a consequence of several biological, genetic and management factors, including short inter-generation intervals, high heritability of several traits (*e.g.* egg production, growth

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rate) associated with rapid progress in management systems and feed availability and quality. However, a continuous selection for growth rates, high meat yield and feed utilisation has also significantly impaired aspects of reproductive performances including semen quality, egg fertility, embryo survival and the number of chicks hatched per hen (Renema *et al.*, 2007). In the case of geese, the reproductive efficiency has also been impaired, but to a lesser extent than in more intensively selected species such as the chicken or turkey.

In contrast with most poultry species and despite the fact that geese were probably the first domesticated avian species (Crawford, 1990), their reproductive characteristics are still relatively comparable with wild geese regarding traits such as reproductive seasonality, low male to female ratio (usually no more than 3 to 4 females per one male in the parent flock), social and sexual behaviour, and high adaptivity to various environments. As a consequence of this, some fertility problems observed in geese reproductive flocks at different periods of their reproductive cycle are similar to that of other intensively produced poultry species, however in other cases they may require different approaches than those used in species expressing traits issued from domestication (*e.g.* chickens). For example, the partial or total replacement of males in the course of the reproductive cycle (known as 'spiking') or separate sex feeding as is practised in naturally mated broiler breeder flocks cannot be of the same practical value in geese.

Another characteristic of the goose is that its digestive tract can ingest and digest large quantities of relatively cheap and easy accessible, high fibre feedstuffs. Despite this, and also despite the fact that juveniles grow rapidly and are easy to manage (Romanov, 1999), geese production has, up to date, been limited to a few Asian and European countries.

Phylogenetically, geese are represented by 35 species, but the most popular commercial breeds have been selected from only two wild species;

- the swan goose (*Anser cygnoides* L.).
- the true goose - greylag (*Anser anser* L.), itself represented by two subspecies:
  - o the western type (*A. a anser*).
  - o the eastern type (*A. a. rubrirostris*) (Crawford, 1990).

Both wild ancestors and derived breeds differ in size and body weight, feather colour, behaviour, physiology (*e.g.* reproductive performance), as well as in the quality of the carcass, flavour and chemical composition of the meat. Such differences result mainly from the local availability of the breeds, performed intensity of selection and genetic improvement.

In regards to reproductive characteristics, the various breeds of domesticated geese share some specifications which may act as limiting factors to their development as an intensively used poultry species. Thus, compared with other poultry species, domesticated geese are characterised by a relatively low reproductive performances and a strict seasonality of their reproduction, making it difficult to produce goose meat all year round for a given market. On the other hand, in contrast with other poultry species, goose breeders may be kept for several seasons (usually 3 to 4) as is routinely practiced in European countries (Rosiński *et al.*, 1986; Nitsan *et al.*, 1988; Toth *et al.*, 1988; Behr and Hartmann, 1992). In some cases, depending on economic conditions, fertility performances may remain at acceptable levels up to 6 seasons (Bielińska and Rosiński, 1988). According to data published by the National Poultry Council - Chamber of Commerce (2009) White Koluda® geese (derived from *Anser anser* L.) produce on average, from 49 (2^{nd} reproductive cycle) to 40 hatching eggs (4^{th} cycle) with a laying intensity varying from 29 to 33%; egg fertility from 79% (in the 4^{th}

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reproductive cycle) to 82% (in the 2nd cycle), while hatching success of set eggs ranges from 60 to 65%. According to Nitsan *et al.* (1988) goose egg fertility in naturally mated flocks varies from 48 to 79%.

Interests in artificial insemination in geese

As in other species raised for economic purposes, an important aspect of geese production is to maintain the reproductive performance at acceptable levels for a prolonged period of time. Under natural mating conditions, this objective is often difficult to attain as a number of uncontrolled factors may alter egg fertility and embryo development. Thus, poor semen quality is often observed in most breeds while behavioural problems, such as preferential mating of a male with a single female, may cause durable alteration to reproductive performance. Other causal factors known to impair fertility in these flocks include male leg disorders, excessive body weight, and copulatory organ malformation, low biological value of eggs and low efficacy of sperm acceptance in the oviduct of aging females.

In order to circumvent these problems, artificial insemination (AI) has been used as a powerful alternative to natural mating conditions as it provides a range of ways to control, replace or improve the defective factors causing fertility problems. Of practical use for decades in turkeys, ducks and guinea fowl, AI know-how has, over recent years, demonstrated its usefulness in geese and chickens, thus emerging as a significant achievement of poultry physiologists transferred to the industry. In addition to providing alternative solutions to control fertility and reduce gosling costs by decreasing the male/female ratio, AI is also of practical interest in selection, as this technique creates favourable conditions for a more efficient use of the best sires in pedigree farms (*e.g.* 1♂:10-12♀ in AI flocks compared with 1♂:3-4♀ in naturally mated flocks). Overall, this results in stronger selection pressure on favourable traits and additional genetic gains at each generation. Another profitable and promising advantage of AI is crossbreeding or integeneric crossing leading to increases in meat content and decreased fatness of progeny carcasses. Such improvement can be obtained by crossing commercial goose breeds with goose from conservation flocks of local origin (Mazanowski and Smalec, 1998), wild goose *Anser anser* L. (Chrzanowska and Chełmońska, 1997; Mazanowski and Chełmońska, 2000) or *Branta canadensis* L. (Kowlaczyk *et al.*, 2007a; 2007b; 2008).

In addition to pre-cited advantages, AI practice in geese selection and multiplication should also be considered as an interesting and relatively cheap way to limit the risks of transferring pathogens during copulation. Thus, ejaculates may be either checked individually for the presence of pathogens and the correspondent male(s) treated or, semen can be diluted in diluents containing *ad hoc* antibiotics, thus suppressing the transfer of pathogens to the female oviduct (however, not every type of antibiotic allows optimal sperm survival in *in vitro* storage).

Another interesting aspect of AI and semen technology is to facilitate the transportation of male gametes from a male to a female site. This has, indeed, been of practical interest to the turkey industry ('stud farms') to optimise production costs and facilitate yield management in breeder flocks. In geese, as in other poultry species, the duration of *in vitro* sperm storage remains relatively limited (1 to 2 hours), but recent progress in semen cryopreservation offers new pathways to protect gene pools and limit the risks of extinction in endangered breeds (Blanco *et al.*, 2009).

Assuming the above, it appears that AI practice in geese breeding and multiplication offers several definite advantages including:

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- general improvement of fecundity levels;
- more efficient use of ganders with high genetic potential;
- acceleration of genetic progress due to higher selection pressure;
- risk limitation of pathogens and diseases transferred during natural mating;
- possibility of transferring genes from point A to point B without moving birds;
- facilitates integeneric/interbreed crosses if natural mating has proven unsatisfactory, or in order to produce progeny of different meat taste and quality;
- cryo-preserved semen allows gene pool preservation.

Difficulties and limiting factors to perform AI in geese

Despite recent progress, AI technology (which includes semen collection, its assessment and handling, as well as semen deposition in the female tract) remains relatively complex to perform in the goose. In practice, the avian semen collection is currently performed using one of the two following methods:

- dorso-abdominal massage (Burrows and Quinn, 1937), as routinely used in turkeys, chickens, and several feral species (Blanco *et al.*, 2000; Saint Jalme *et al.*, 2003; Klimowicz *et al.*, 2005; Siudzińska and Łukaszewicz, 2008). This method was first transferred to ganders by Johnson (1954);
- stimulation of the male by the presence of a teaser female (technique also known as artificial vagina method) used in Muscovy ducks, quails and ostriches (Rybnik *et al.*, 2007; Chełmońska *et al.*, 2008).

From the two above methods, the dorso-abdominal massage, although usually applied for gander semen collection, remains quite inefficient, in contrast to other poultry. Its success rate is relatively limited (*e.g.* only 40% Landes ganders respond to semen collection procedure under these conditions) with ejaculates averaging 0.3 ml in volume and $150x10^6$ sperm/ml (Sellier *et al.*, 1995). Meanwhile, it appears that the response to this stimulation may be breed-dependent as shown by studies by Chełmońska and Łukaszewicz (1995). These authors indicated that the frequency of positive reactions of non-selected White Italian ganders (*Anser anser* L.) ranges between 60 and 70%, while Kuban ganders (*Anser cygnoides* L.) respond positively in about 90% of the cases. Despite these encouraging observations, it remains however, that only 30% and 50 %, respectively, of the positive responses result in ejaculates classified as 'valuable' for insemination purposes.

Overall, it appears from the author's experience, that the success of AI in geese depends mainly on the genetic origin of male breeders, along with the semen collection and handling procedures, AI equipment and insemination techniques. However, the basic criterion for successful AI operations is the reproductive value of male and female breeders, associated with a thorough expertise of the staff at controlling flock environment (light, feed, floor surface allowance and preparation).

Factors affecting semen quantity and quality

Compared with males from other poultry species, such as chickens, ducks or turkeys, ganders have a relatively limited testicular development at adulthood, which results in fewer sperm produced per unit time than in other species (Chełmońska, 1972). As a consequence, sperm concentrations are relatively low, as are the main other quantitative characteristics of ejaculates (*e.g.* 1 ejaculate characteristics of *Anser anser* L. derived

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ganders: volume = 0.15 to 0.3 ml; sperm concentration: 340-1020x10^6/ml (Łukaszewicz, 2002); *e.g.* 2 ejaculate characteristics of *Anser cygnoides* L.: volume = about 0.4 ml; sperm concentration: 700x10^6/ml (Liu *et al.*, 2008)).

Interestingly, one characteristic of geese sperm which makes it distinguishable from other poultry, is its extremely low percentage of morphologically normal sperm which, depending on many elements (*i.e.* age, breed, reproductive season), may vary from only 27 to 50% of the total population when it is in the 80-85% range for chickens and turkeys. Thus, values above 50% of morphologically normal and viable sperm are only sporadically observed in gander semen (Łukaszewicz, 2002; Liu *et al.*, 2008), while the level of viable sperm is generally within 90-95%, a range similar to that observed in turkeys or chickens. This indicates that gander sperm should be assessed for parameters, which, besides viability/motility, should also include microscopic observation to assess their morphology. This explains why the authors have been interested in developing a global test known as Semen Quality Factor (SQF), which comprises the three most important semen characteristics; volume, cell concentrations and percentage of live normal spermatozoa (Łukaszewicz and Kruszyński, 2003), which has since proven valuable to predict the potential of fertilization of collected semen. It allows the estimation of the number of cells expected to become candidates for the fertilization of an ovum and how many insemination doses can be made from a particular semen sample. In ganders it varied from 26 (Łukaszewicz, 2002) to 84 (Liu *et al.*, 2008) (*Figure 1*), while it reaches values over 130 in the chicken (Siudzińska and Łukaszewicz, 2008). Moreover, Liu *et al.* (2008) found high (P≤0.01) correlation between SQF and fertility in *Anser cygnoides* L.(r=0.985).

Table 1 shows the characteristics of semen collected during the entire reproductive cycle from 1-, 2-, 3- and 4-year-old ganders kept in the same environmental system.

Table 1 Effect of age of White Italian (Anser anser L.) gander on the fresh semen characteristics evaluated within one reproductive cycle lasting from February to the middle of June (means ± SD; each group represented by 10 males) (Łukaszewicz, 2002).

Evaluated traits	Age group of ganders			
	1-year-old	2-year-old	3-year-old	4-year-old
Number of semen collections during entire reproductive cycle	**42**	**53**	**53**	**51**
Single ejaculate volume (ml)	$0.15^{A1)}$±0.05	0.20^{B}±0.05	0.16^{BC}±0.06	0.16^{BC}±0.06
Spermatozoa concentration (x10^6/ml)	409.64^{A}±134.29	550.47^{Ba}±161.63	655.47^{Bb}±203.34	833.04^{Bb}±243.45
Semen Quality Factor per male	26.47^{A}±17.91	45.56^{B}±18.91	51.65^{B}±20.34	68.33^{C}±24.95
Forms of spermatozoa (%)				
Live in total	91.79^{A}±2.67	94.08^{B}±2.72	94.77^{B}±2.57	93.7^{B}±3.38
Live normal	39.28^{A}±7.0	40.42^{A}±7.14	50.46^{B}±6.2	50.01^{B}±9.38
Macrocephalic	22.80^{A}±5.26	21.31±5.18	20.90±4.12	19.35^{B}±4.88
Bent-neck	15.83^{A}±3.67	16.30^{A}±3.44	10.46^{Ba}±2.7	12.86^{Bb}±4.36
Midpiece deformed	4.91±2.61	5.82^{A}±2.23	4.11^{Ba}±1.76	5.12^{b}±2.27
Spermatids (Immature)	2.92^{A}±1.67	6.36^{Ba}±3.05	5.35^{Bb}±2.6	3.16^{A}±1.90
Other deformities	6.05^{A}±2.96	3.86^{B}±2.74	3.48^{B}±2.67	3.27^{B}±2.85

[1)] Values with different superscripts within rows differ significantly (A, B - P ≤ 0.01; a, b - P ≤ 0.05).

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The quality of fresh semen is one of the most important features in regards to its insemination and short or long term storage. The quantity and quality of semen collected manually from ganders depend on various factors including species (Stasko *et al.*, 1973; Chełmońska and Łukaszewicz, 1995), male age (Merritt and Leman, 1963; Csuka and Ledec, 1984; Bieliński and Rosinski, 1988) (*Table 1*), reproductive cycle (Guangxi *et al.*, 1988; Łukaszewicz, 2002) (*Table 2*; *Figure 1*), management system (Rosinski *et al.*, 1995; Sellier *et al.*, 1995; Willin and Kovats, 2000; Brun *et al.*, 2003), feeding (Sauveur *et al.*, 1988), semen collection technique and collection frequency (Grunder and Pawluczuk, 1991; Łukaszewicz, 2000), as well as on individual gander properties (Tsarenko *et al.*, 1979; Łukaszewicz, 2002).

During the semen collection procedure, certain few factors have to be taken into consideration. Firstly, due to differences in the copulatory organ structure of *Galliformes* and *Anseriformes*, as well as the way of ejaculation, in order to maximise the semen quality, particular care has to be taken during collection to avoid any semen contamination with the cloacal products. Gander erection centre, as in all male birds, is located near the cranial end of the kidneys, therefore properly performed massage has to simultaneously stimulate both the dorsal part of the gander's body and the abdomen, as the female does during natural mating. Moreover, the avian male reproductive tract, unlike the mammal one, does not possess any accessory sex gland. Seminal plasma (known as 'transparent fluid') is excreted from the vascular body of the cloacal wall during copulatory organ erection and semen ejaculation. Thus, proper and sufficient stimulation has to be made in order to provoke the gander for spontaneous ejaculation which, together with the slight pressure applied above the receptaculum, should help to collect dense, good quality semen. To maximise the percentage of ganders producing semen and to ensure good semen quality, males should be kept individually and their feed should be removed 12 hours before semen collection.

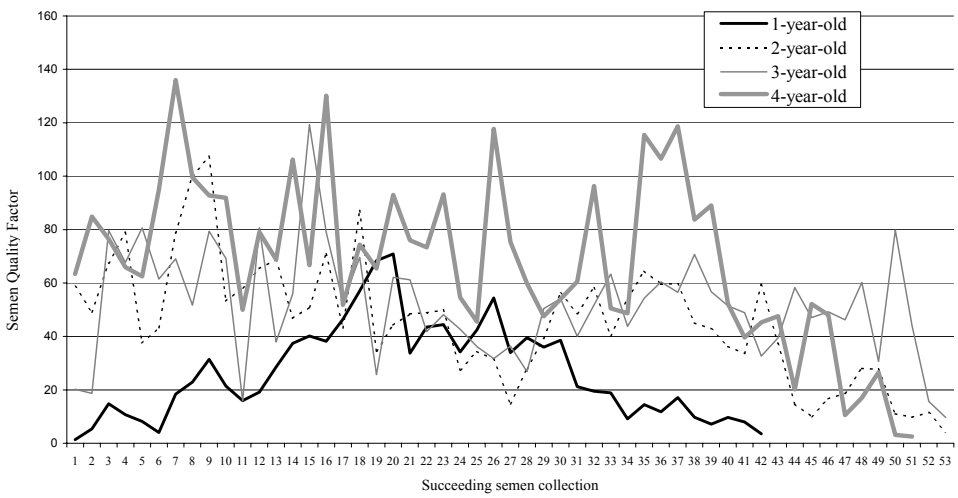


Figure 1 Semen Quality Factor of 1, 2, 3 and 4-year old White Koluda ganders.

Table 2 presents the quantitative and qualitative traits of semen collected from the same ganders in their 1st, 2nd and 3rd reproductive cycle.

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Table 2 Characteristics of White Italian (Anser anser L.) gander fresh semen collected in their 1st, 2nd and 3rd reproductive cycle (means ± SD) (Łukaszewicz, 2002.

Evaluated traits	1st cycle	2nd cycle	3rd cycle
Number of semen collections in one reproductive cycle	**41**	**48**	**53**
Single ejaculate volume (ml)	0.23^{A}±0.06	0.18^{B}±0.06	0.16^{B}±0.06
Spermatozoa concentration	323.41^{A}	483.33^{B}	655.47^{C}
($x10^{6}$/ml)	±93.451	±174.15	±203.34
Sperm Quality Factor	33.44^{A}±17.16	45.32^{B}±26.38	51.65^{B}±20.48
Sperm forms (%)			
Live in total	91.37^{A}±4.41	93.78^{B}±2.56	94.77^{C}±2.57
Normal	42.87^{A}±10.98	50.64^{B}±11.12	50.46^{B}±6.24
Macrocephalic	26.51^{A}±10.09	23.07±7.53	20.90^{B}±4.12
Bent-neck	10.33±3.24	10.05±3.18	10.46±2.71
Midpiece changed	6.22^{A}±2.33	3.89^{B}±1.89	4.11^{B}±1.76
Spermatids	4.36±2.06	4.71±2.29	5.35±2.55
Other deformities	1.24^{A}±1.15	1.43^{A}±1 .03	3.48^{B}±2.67

[1)] Values with different superscripts within rows differ significantly (A, B - $P \leq 0.01$; a, b - $P \leq 0.05$)

Ganders subjected to semen collection for the first time, as well as older males, have to be trained for holding and massage once or twice a week at the onset of every reproductive cycle, as well as selected on the basis of their positive reaction to massage, *i.e.*, reaction ending with ejaculation, the appearance of the copulatory organ and quality of the first ejaculates. These characteristics determine the degree of gander usefulness as reproducers. A high significant correlation (r=0.80) between the number of positive reactions during the first three weeks of the reproductive cycle and the results of the total amount of semen and average ejaculates volume during the entire season has been reported (Chełmońska, 1972). This correlation enables an early pre-selection of males. The experiments of Kurbatov *et al.* (1976) indicated that selecting ganders for AI purposes is significant and therefore worth performing. With the heritability of h^2=0.24, the selection can be effective (Stasko *et al.*, 1973).

Despite the gander age, a decline in semen quality can be observed about six weeks before the end of the reproductive cycle. Also, during the first month of reproduction, 1-3-year-old ganders produce ejaculates of lower quality. Unfavourable changes in the spermatozoa morphology also occur, which significantly affect the effectiveness of insemination, particularly in the second half of the reproductive period. The results of experiments (Łukaszewicz, 2000; Łukaszewicz *et al.*, 2000) suggest that semen collection can best be done twice a week during the periods of lowered fertilising potency of ganders and three times in the middle of the cycle. Moreover, a decline in semen quality of ganders of different ages occurred in different months of the reproductive cycle and semen quality was male age dependent. In the case of AI, this problem can be overcome by pooling semen of age-differentiated males. It can be supposed also, that differences in fertility rate of naturally mated geese, observed within the entire reproductive cycle and resulting probably from fluctuations in semen quality, can be eliminated by having ganders of different ages in the geese flock.

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Goose insemination

In most cases, artificial insemination in the goose is used throughout the entire reproductive cycle at a frequency of one insemination per week. Alternatively it is also performed once or twice a week as a complement to natural mating, at periods when fertility is impaired. Techniques to introduce semen into the lower oviduct may vary from farm to farm, depending on the inseminator's experience and skills. Since, contrary to chicken or turkey hens, it is difficult to evert the goose oviduct, the safest and most effective way for semen deposition is, to our view, the finger guided method (also known as the palpation method) (Johnson, 1954; Tai, 1984; Grunder and Pawluczuk, 1991; Łukaszewicz, 2002). Alternatively, the finger can be replaced by a speculum. Finger or speculum-guided palpation is required to determine the opening of the oviduct. In most occasions, semen is deposited intravaginally and, as suggested by Kurbatov *et al.* (1976), at a depth of 3 to 4 cm. For intergeneric crosses semen may be deposited deeper (*i.e.*, closer to the utero-vaginal junction) to limit the high intensity of sperm selection in the lower part of vagina. An alternative to deep intra-vaginal insemination is intra-magnal insemination which is more effective and seems to have little impact on the number of oviposited eggs. Depending on the technique in use, artificial insemination is performed by either two (intra-vaginal) or three (intra-magnal) people.

As in other species, for AI success, it is very important to maintain the fertilizing potency of spermatozoa kept *in vitro*. Therefore, unless insemination is performed within 20 to 30 minutes of semen collection, diluents have to be added (Bakst, 1990). No decrease in fertility rate was observed after geese insemination with semen diluted 1-fold with EK diluent (Łukaszewicz, 2002) and stored for 3 hours at 4°C.

The percent of fertile eggs depends on the spermatozoa number introduced into the female reproductive tract, the frequency of insemination, and the insemination technique. For fertility, the proper timing for insemination is particularly important, so that critical periods coinciding with the ovulation stage, egg-shell formation, or oviposition can be avoided (Raud and Faure, 1990). Since most geese lay eggs during early morning, the best time for insemination is at midday or 1 to 2 hours before. Moreover, it is well known that as the reproductive cycle progresses, there is an increasing demand for spermatozoa to be deposited in the oviduct in order to sustain a high and persistent fertility rate, whereas the male's reproductive capacity decreases (Brillard, 1993). This phenomenon is particularly well seen in fertility rates of geese mated naturally (Chełmońska, 1972; Behr and Hartmann, 1992). It can be overcome, however, by the use of AI.

Opinions on the frequency of geese insemination and number of inseminated spermatozoa necessary for satisfactory fertility level are not univocal. However, one observation seems to be clear; geese do not need as many spermatozoa to be deposited in order to gain a satisfactory fertility rate compared to chickens and turkeys. For domestic chicken hens a dose consisting of 100 million progressively motile sperm cells is recommended for each weekly fresh semen insemination. For geese insemination Davtian and Pimenow (1970) suggested 30 to 40 million spermatozoa every 6 days, while Grunder and Pawluczuk (1991) inseminated geese once or twice a week with 14 million progressively motile sperm cells, and obtained respectively 54% and 83% fertile eggs. According to Borys *et al.* (1978), fresh gander semen dose should contain 2.7 million spermatozoa per day and geese two years and older can be inseminated at 12 days intervals, while one year old flocks need insemination every 9 days. In the experiments of Łukaszewicz (2002), 9 million progressively motile, live normal spermatozoa inseminated weekly with fresh semen

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resulted in 89% fertility, while the increase in sperm number to 20 million resulted in 95.5% fertile eggs.

Conclusions

Artificial insemination can now be considered as an efficient method of reproduction in geese breeding and reproduction. Studies conducted over the past decade have demonstrated its ability to improve the effectiveness of commercial geese production by increasing the number of goslings and by facilitating the feasibility of performing crossbreeding and intergeneric crosses for genetic purposes. Despite this, geese reproduction remains relatively complex due to the physiological and behavioural specificities of the species. This justifies additional research to better comprehend the underlying mechanisms which can impact on sperm quality. Research on geese spermatogenesis and on genetic x physiological interaction at this level may be of major interest in the future.

References

BAKST, M.R. (1990) Preservation of avian cells, in: CRAWFORD (Ed.) *Poultry Breeding and Genetics*, Chapter 4: 91-108.

BEHR, K.P. and HARTMANN, U. (1992) Artificial insemination of geese under field conditions. *Proceedings of 9th International Symposium on Waterfowl.* Pisa, Italy: 112-114.

BIELINSKI, K. and ROSINSKI, A. (1988) Influence of the age of White Italian geese on their reproductive performance. *Proceedings of International Symposium on Waterfowl Production, The Satelite Conference for the XVIII World Poultry Congress,* Beijing, China: 223-227.

BLANCO, J.M., GEE, G., WILDT, D.E. and DONOGHUE, A.M. (2000) Species variation in osmotic, cryoprotectant, and cooling rate tolerance in poultry, Eagle, and Peregrine Falcon spermatozoa. *Biology of Reproduction* **63**: 1164-1171.

BLANCO, J.M., WILDT, D.E., HOFLE, U., VOELKER, W. and DONOGHUE, A.M. (2009) Implementing artificial insemination as an effective tool for *ex situ* conservation of endangered avian species. *Theriogenelogy* **71**: 200-213.

BORYS, H., BIELINSKI, K. and STASIAK, K. (1978) Effect of different doses of diluted semen and insemination frequency on fertility of goose eggs. *Roczniki Naukowe Zootechniki* **5(2)**: 43-51.

BRILLARD, J.P. (1993) Sperm storage and transport following natural mating and artificial insemination. *Poultry Science* **72**: 923-928.

BRUN, J-M., DELAUNAY, I., SELLIER, N., ALLETRU, B., ROUVIER, R. and TIXIER-BOICHARD, M. (2003) Analysis of laying traits in first cycle geese in two production systems. *Animal Research* **52**: 125-140.

BURROWS, W.H. and QUINN, J.P. (1937) The collection of spermatozoa from the domestic fowl and turkey. *Poultry Science* **16**: 19-24.

CHEŁMOŃSKA, B. (1972) Seasonal changes in ganders reproductive organ in artificial insemination aspect. Part I II. *Polskie Archiwum Weterynaryjne* **15**: 575-611.

CHEŁMOŃSKA, B. and ŁUKASZEWICZ, E. (1995) Current state and future of artificial insemination in waterfowl. *Proceedings of 10th European Symposium On Water*fowl. Halle, Germany: 225-240.

CHEŁMOŃSKA, B., JERYSZ, A., ŁUKASZEWICZ, E., KOWALCZYK, A. and MALECKI, I. (2008) Semen collection from Japanese Quail (*Coturnix japonica*) using a teaser female. *Turkish Journal of Veterinary and Animal Science* **32(1)**: 19-24.

CHRZANOWSKA, M. and CHEŁMOŃSKA, B. (1997) Investigations on the reciprocal crossbreeding of White Italian and Greylag geese with the use of artificial insemination method. *Zeszyty Naukowe Przeglądu Hodowlanego PTZ* **31**: 185- 188.

CRAWFORD, R.D. (1990) Origin and history of poultry species, in: CRAWFORD (Ed.) *Poultry Breeding and Genetics*, Chapter 1: 1-41.

CSUKA, J. and LEDEC, M. (1984) Development of the reproduction parameters of gander over three years and their correlations. *Živočisna Vyroba* **29(7)**: 635-640.

DAVTIAN, A. and PIMENOV, B. (1970) Geese artificial insemination (in Russia). *Ptitsevodstvo* **11**: 29-31.

https://doi.org/10.1017/S0043933910000632 Published online by Cambridge University Press

GRUNDER, A.A. and PAWLUCZUK, B. (1991) Comparison of procedures for collecting semen from ganders and inseminating geese. *Poultry Science* **70**: 1975-1980.

GUANGXI, L., JIAQI, Z. and SHANSHAN, T. (1988) Researches on using short intervals of lighting to change the seasonal breeding of the Greed of Guangdong geese and increase its reproductivity. *Proceedings of International Symposium On Waterfowl Production, The Satelite Conference for the XVIII World Poultry Congress*, Beijing, China: 252-255.

JOHNSON, A.S. (1954) Artificial insemination and duration of fertility of geese. *Poultry Science* **33**: 638-640.

KLIMOWICZ, M., ŁUKASZEWICZ, E. and DUBIEL, A. (2005) Effect of collection frequency on quantitative and qualitative characteristics of pigeon (*Columba livia*) semen. *British Poultry Science* **46**: 361-365.

KOWALCZYK, A., CHRZANOWSKA, M., ADAMSKI, M. and ŁUKASZEWICZ, E. (2007a) The effect of crossbreed between Canada Goose (*Branta canadensis L.*) males and White Kołuda® geese females on slaughter value and carcass tissue composition of progeny. *Animal Science* **58(1)**: 70-71.

KOWALCZYK, A., CHRZANOWSKA, M., ŁUKASZEWICZ, E., KORZENIOWSKA, M. and BOBAK, Ł. (2007b) Chemical composition and fatty acid profile of breast and leg muscles of crossbreed hybrids of Canada Goose (*Branta canadensis L.*) and White Kołuda® geese. *Animal Science* **58(1)**: 72-73.

KOWALCZYK, A., ŁUKASZEWICZ, E., WALASIK, K., KORZENIOWSKA, M. and ADAMSKI, M. (2008) Meat quality of hybrids of Canada Goose (Branta canadensis L.) males and White Koluda® goose females. *Proceedings of XXXII World's Poultry Congress*, Brisbane, Australia.

KURBATOV, A.D., TSARENKO, R.G. and POPOV, I. (1976) Improving of AI in geese. *Proceeding of VIII International Congress on Animal Reproduction and AI,* Kraków, Poland Vol. IV: 1009-1012.

LIU, S.J., ZHENG, J.X. and YANG, N. (2008) Semen quality factor as an indicator of fertilizing ability for geese. *Poultry Science* **87**: 155-159.

ŁUKASZEWICZ, E. (2000) Effect of frequency of semen collection from White Italian ganders on quantitative and qualitative traits of semen during entire reproductive cycle. *Zeszyty Naukowe Przeglądu Hodowlanego PTZ* **49**: 447-457.

ŁUKASZEWICZ, E. (2002) Cryoconservation of gander semen. *Zesztyty Naukowe Akademii Rolniczej we Wrocławiu* **440**: 1-111.

ŁUKASZEWICZ, E. and KRUSZYŃSKI, W. (2003) Evaluation of fresh and frozen-thawed gander semen of individual ganders by assessment of spermatozoa motility and morphology. *Theriogenology* **59**: 1627-1640.

ŁUKASZEWICZ, E., FURUTA, H., XI, Y.M. and FUJIHARA N. (2000) Comparative study on semen quality of one and two-year old ganders during the entire reproductive season. *Asian Journal of Andrology* **2**: 139-142.

MAZANOWSKI, A. and CHEŁMOŃSKA, B. (2000) The effect of reciprocal crossing of White Kołuda and graylag crossbred with Slovakian geese. *Annales of Animal Sciences-Roczniki Naukowe Zootechniki* **27(4)**: 85-103.

MAZANOWSKI, A. and SMALEC, E. (1998) Rearing performance of 12-week-old crossbreds geese from genetic reserve flocks compared with White Koluda. *Roczniki Naukowe Zootechniki* **25(4)**: 191-205.

MERRITT, E.S. and LEMAY, J.R. (1963) Age and performance of geese. *World's Poultry Science Journal* **19**: 191-193.

NATIONAL POULTRY COUNCIL-CHAMBER OF COMMERCE (2009) Results of the evaluation poultry performances in the year 2008. Warsaw, May, 2009.

NITSAN, Z., NIR, I. and DVORIN, A. (1988) Reproductive performance of laying geese kept in flocks or in individual pens. *Proceedings of International Symposium On Waterfowl Production, The Satelite Conference for the XVIII World Poultry Congress,* Beijing, China: 278-280.

RAUD, M. and FAURE, J.M. (1990) Rhythmic occurrence of sexual behaviour and egg laying activity of Muscovy ducks. *British Poultry Science* **31**: 23-32.

RENEMA, R.A, RUSTAD, M.E. and ROBINSON, F.E. (2007) Implication of changes to commercial broiler and breeder body weight targets over the past 30 years. *World's Poultry Science Journal* **63**: 457-472.

ROMANOV, M.N. (1999) Goose production efficiency as influenced by genotype, nutrition and production systems. *World's Poultry Science Journal* **55**: 281-294.

ROSIŃSKI, A., BIELIŃSKI, K. and BIELIŃSKA K. (1986) The results of geese reproduction in the same flock during subsequent three years. *Roczniki Naukowe Zootechniki* **13**: 127-132.

ROSIŃSKI, A., ROUVIER, R., WĘŻYK, S., SELLIER, N. and BIELIŃSKA, H. (1995) Reproductive performance of geese kept in different management systems. *Proceedings of 10th European Symposium On Waterfowl*, Halle, Germany: 20-28.

RYBNIK, P.K., HORBAŃCZUK, J.O., NARANOWICZ, H., ŁUKASZEWICZ, E. and MALECKI, I.A. (2007) Semen collection in the ostrich (*Struthio camelus*) using a dummy or a teaser female. *British Poultry Science* **48(5)**: 635-643.

SAINT JALME, M., LECOQ, R., SEIGNEURIN, F., BLESBOIS, E. and PLOUZEAU, E. (2003) Cryopreservation of semen from endangered pheasants: the first step towards a cryobank for endangered avian species. *Theriogenology* **59**: 875-888.

https://doi.org/10.1017/S0043933910000632 Published online by Cambridge University Press

SAUVEUR, B., ROUSSELOT-PAILLEY, D. and SELLIER, N. (1988) The effect of dietary energy level on breeding performance of Landaise geese. *Proceedings of International Symposium On Waterfowl Production, The Satelite Conference for the XVIII World Poultry Congress*, Beijing, China: 228-232.

SELLIER, N., RUSSELOT-PAILLEY, D. and DE REVIES, M. (1995) Artificial Insemination of Geese. *INRA Productions Anim*ales **8**: 127-133.

SIUDZIŃSKA, A. and ŁUKASZEWICZ, E. (2008) The effect of breed on freezability of semen of fancy fowl. *Animal Science of Reproduction* **26(4)**: 331-340.

STASKO, J., MASAR, T. and SPRONC, A. (1973) The variability and correlations of some 'Insemination' properties of ganders. *Acta Zootechnica Universty of Agriculture* **Nitra XXVI**: 67-75.

TAI, C. (1984) Duck breeding and artificial insemination in Taiwan, in: FARRELL, D.J. & STAPLETON, P. (Eds) *Duck production science and world practice*, pp. 193-203 (University of New England).

TOTH, S., BUCZOLICS, E. and SOAD SAAD EL-DIN (1988) Investigations of sperm production of ganders during successive production periods. *Bulletin of University Agricultural Sciences,* Godollo, Hungary 1: 65-69.

TSARENKO, R.G., KURBATOV, A.D. and MAVRODINA, T.G. (1979) Effect of very low temperatures on the storage, characters of semen from individual ganders. *Bulletin VNIRGJ* **40**: 35-39.

WILLIN, E.S. and KOVATS, E. (2000) Investigation of the reproductive performances of Gray Landes geese kept in semi-intensive management system. *Proceedings of XXI World Poultry Congress,* Montreal, Canada.

https://doi.org/10.1017/S0043933910000632 Published online by Cambridge University Press

https://doi.org/10.1017/S0043933910000632 Published online by Cambridge University Press