Effect of Repeated Gathering and Age on the Quality of Zatorska Goose Feathers

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Running title: Goose feathers quality

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Abstract

We investigated a reproductive flock of Zatorska geese. The birds were divided into four groups: three-year-old ganders (n = 10), and one-, two-, and three-year-old layers (n = 30). Mature feathers were collected from the birds between July and September (i.e., after breeding). Before collection, the feathers and down were evaluated to determine their maturity. The quantitative composition of each sample of feathers was evaluated manually. The evaluated quality traits of the feathers were turbidity of an aqueous extract, acidity, oxygen index number, and fat content. The data were analyzed using the SAS statistical package with multivariate analysis of variance for repeated measures.

The weight of feathers collected from all three gatherings was the highest for the three-year-old ganders. In subsequent gatherings, the weight of the collected feathers tended to increase. There was a statistically significant difference in down composition between the first and the subsequent two gatherings in all age-groups of geese. Neither the age nor the gender of the birds had an effect on the quantity of down obtained, which was 80–85 g.

The turbidity of the feather extract was lowest for feathers collected in the first gathering. For the layers, the turbidity of the feather extract was lowest in feathers obtained from the one-year-old birds. The feathers ranged from slightly acidic to neutral, with pH values between 5.9 and 7.2. The fat content was lowest in feathers collected in the first gathering (2.4–2.7%), and tended to increase in subsequent gatherings. There was no statistically significant difference in the oxygen index number between individual gatherings, or between the three-years-old layers and the ganders.
Keywords: down, feathers, geese
Introduction

Feathers (*pennae*) are epidermal growths comprising water (42.5%), nitrogen compounds (54%), fat (1.5%), and ash (2%) (Dereżowski and Jusik, 1973). Keratin accounts for almost 90% of the weight of a feather; it is a mechanically durable fibrillary protein that is insoluble in water but also hygroscopic (Okanović *et al.*, 2009). The plumage of waterfowl comprises several types of feathers. Structurally, feathers can be divided into: contour feathers (soft and hard); hard feathers on the wings (flight feathers) and tail; and down feathers (or plumules) (PN-EN, 1885:2000).

Throughout its life, a bird’s plumage protects it from adverse weather conditions, and enables it to fly, swim, float, navigate on water or snow/ice (penguins), and maintain control of its core body temperature. Moreover, feathers may be important for the sensations of feeling and hearing (owls). Plumage also facilitates hunting (herons), can serve as nest-building material and camouflage, and conveys important visual signals (Dawson, 2006). As a raw material, feathers are a valuable filling for duvets, pillows, jackets, and sleeping bags, but damaged feathers become waste material that needs to be processed (Zuchowski, 1997).

During the life of a bird, feathers becomes damaged and worn, and finally fall out. As with any keratin structure, feathers must be renewed. Molting is a natural process related to the hormonal balance of the organism. A seasonal increase in the concentration of thyroxine and prolactin initiates the molting process (Mueller *et al.*, 2013). In nature, birds molt when there is no need for migration or reproduction. In wild birds, the timing of the molt depends on the species and the climate zone in which it lives. In the course of natural molting, wild geese are unable to fly for 25–40 days.
According to Schneider (1995), adult wild geese molt only once per year after the termination of the incubation period.

Feathers can be obtained from geese during their life (natural molt) or postmortem. The total number of gatherings collected from domesticated European geese depends on the time the birds are kept in a flock. This means that feathers can be collected 3–4 times during the first year, and 3–4 times in the subsequent 4 years of a bird’s life. Therefore, it is possible to collect feathers from a single domesticated goose up 15 times during its life (Břtner et al., 2010).

Feathers from the third gathering are resilient and become the most valuable raw material for the bedding industry (Deręgowski and Jusik, 1973; Mazanowski, 2013). Kozák (2011) noted that the most valuable resource is down feathers from water birds. According to Deręgowski and Jusik (1973), the highest quality feathers are from geese, because they have low thermal conductivity, and are soft, light, elastic, and durable. Furthermore, the feathers collected from birds antemortem are more elastic than those obtained postmortem.

In reproductive flocks, feathers may be collected when the reproductive period is completed. Collecting feathers in this way is not much more stressful than daily handling (Tóth et al., 2012). Among other things, the quality of the feathers depends on the nutrition, health, and welfare of the birds, and on the manner of feather acquisition (Pakulska and Bielińska, 2004). Commodity scientists assess feathers for their quantitative and qualitative characteristics. The qualitative features of feathers include the humidity of the sample, the fat content, the oxygen index number, the acidity, and the turbidity of an aqueous feather extract.
The quantitative composition is determined by separating waterfowl feathers into different categories, including down or plumules (Deręgowski and Jusik, 1973; PN-EN, 12131:2000). Based on the industry standard (BN-88/8035-02), feathers can be divided into three classes (A, B, C), where the evaluated characteristics are, for example: the content of down feathers, the content of the plumule, the percentage of hard or damaged feathers, and the percentage of fat.

In 2015, Poland obtained 379.5 metric tons of feathers in total, including 160.4 metric tons from individual farms. The combined value of the feather purchase amounted to EUR 2.86 million. Although the feather market is important, little research has been carried out regarding feather quality.

The production of down and goose meat in Poland is based almost exclusively on commercial hybrid White Kołuda® geese. Apart from the continuously improved White Kołuda® breed, flocks of geese included in the program protecting the genetic resources of waterfowl also play an important role. Zatorska geese are included in this specific category. Since 2000, they have belonged to the category of genetic resources of farm animals, and are listed in the general book of the National Centre of Animal Breeding as strain ZD-1 (Rabsztyn, 2006). Additionally, since 2000, Zatorska geese have been on the Food and Agriculture Organization (FAO) World Watch List for Domestic Animal Diversity (FAO, 2000).

To date, there have been few studies on the quality of feathers, and most results were published many years ago in the native languages of the authors.

The aim of the present study was to analyze the quantity and quality of feathers obtained *antemortem* from Zatorska geese in relation to subsequent gatherings.
Materials and Methods

Birds and management

Research was carried out on a reproductive flock of Zatorska geese. Strain ZD-1 is kept at the experimental station of the University of Agriculture in Cracow (Rząska near Cracow, 50°09′N/19°84′E). Three-year-old ganders (n = 10), and one-, two-, and three-year-old layers (n = 30) were used. In the period between the research stages, the birds remained in a flock with other birds. The geese were fed a commercial mixture (ME\textsubscript{N} = 10 MJ/kg and crude protein = 120 g/kg), used pastures, and had ad libitum access to water.

Research structure

Mature feathers were collected from birds from July to September, i.e., after breeding. Before collecting, the feathers and down were evaluated to determine maturity. Subsequent gathering was carried out every 6–7 weeks. Food was withheld from the afternoon on the day before gathering feathers to eliminate any possible contamination by feces. The feathers were obtained by manual collection. The people carrying out this procedure were well experienced in this technique. The person responsible for feather collection placed the goose belly on their knees so that the neck and wings were below the collector’s knees. The legs of the goose were kept together with one hand, and mature feathers were collected with the other, starting from the abdomen and around the breast, and subsequently from the crop area. The feathers collected from each bird were packed into a separate bag and sent to Animex Foods Sp. z o.o. for laboratory analysis.

Statistical analysis
The results were evaluated using the SAS statistical package (SAS, 2014). The data were subjected to two-factor multivariate analysis of variance (ANOVA) for repeated measures. The age of a given goose was the inter-object factor and the subsequent date of feather collection was the intra-object factor. Post hoc analyses were carried out using Šidák’s test.

Methods of laboratory analyses
Quantitative composition of feather and down

The basis of this method depends on the separation of the individual components of the feathers into separate marked containers. The contents of those containers are weighed to determine the weight of a given component. The relative share (percentage) of that component is then calculated (PN-EN, 12131:2000).

Prior to separation, the samples obtained from the birds were conditioned for 24 h at room temperature. They were then weighed separately to within 0.01 g on a laboratory balance (Axis, Gdańsk, Poland). The weighing containers and lids were weighed to within 0.01 g on an analytical balance (Axis, Gdańsk) and properly described. The whole feathers, down, and other components were then placed inside the containers. The containers with lids and contents were weighed again. The percentage share of the total sample weight of particular feather components was then calculated.

The second categorization concerned only the containers with down. Other weighing containers with lids were weighed to within 0.001 g and assigned to include: mature down, nestling down, tangled down, and coupled down. The weighing containers with lids and contents were weighed again. The percentage share of the total sample weight of individual feather components was then calculated.
Physical features of feathers

Turbidity of the aqueous extracts

The turbidity of the aqueous extracts was evaluated using a measuring cylinder (PN-EN, 1164:2000) and a 2020 Turbidity Meter (LaMotte, Chestertown, Maryland, USA) (IDFL, 2000).

An analytical balance (Axis, Gdańsk) was used to measure out 5 g of feathers, which were then placed in a beaker. Distilled water (500 mL) was then added, and the mixture was shaken for 60 ± 5 min at room temperature using an IKA shaker (Staufen, Germany). Next, the suspension was filtered into a 2-L beaker using a glass Buchner funnel with a sintered glass disc (d = 10 cm, P160). The previously filtered mixture was then poured into a measuring cylinder. At the same time, the height of the filtrate was observed—assuming a perspective from the top of the cylinder—until the cross at the bottom of the cylinder was no longer visible. The height was expressed in mm.

To determine turbidity, aqueous feather extracts were prepared as described above. The filtrates were then placed in the 2020 Turbidity Meter vials, and turbidity was determined in nephelometric turbidity units (NTUs).

Acidity

The acidity of the feathers was determined according to the international standard (PN-EN ISO, 3071:2007). We used a Hi-8314 pH meter (HANNA Instruments, Olsztyn, Poland). Prior to the analysis, equipment calibration was validated in accordance with the manufacturer's recommendations, using buffers 4 and 7.
An analytical balance (Axis, Gdańsk) was used to measure 5 g of feathers, which were cut into pieces no larger than 1.5 mm. The pieces were conditioned for 24 h at room temperature (20°C, 65% humidity). The prepared sample (1 g) was placed in a conical flask and 70 cm$^3$ of distilled water was added. The sample was left in a glass-stoppered flask for 3 h with occasional stirring. Finally, the pH of the solution was measured three times.

**Fat content and oxygen index number**

**Determination of the oxygen index number**

The main principle of the method is based on titrating an aqueous extract of the feathers using 0.02 M potassium permanganate (PN-EN, 1162:1998). An analytical balance (Axis, Gdańsk) was used to measure 10 g of feathers, which were then placed in a shaker. Distilled water (1 L) was added to the solution, which was shaken for at least 60 min at room temperature using an IKA shaker (Staufen, Germany). The extract was then filtered into a 2-L beaker using a G-1 filter without squeezing the excess water from the feathers. The filtrate (100 mL) was transferred using a pipette into a 400-mL beaker, and 3 mL of 3 M sulfuric acid (VI) solution was added. The filtrate was then titrated with 0.02 M potassium permanganate until it remained pink for 60 s. The values were expressed in mg of oxygen per 100 g of feathers.

**Determination of fat content**

Feathers (2 g) were taken from an average laboratory sample, weighed using an analytical balance (Axis, GdańskGdansk, Poland), and placed in the equipment tube. Dichloromethane solvent (10 mL) was then added. The tube was covered with a lid and...
left for 15 min. A clean, dry weighing bottle was weighed. The extract was then squeezed from the tube with a piston. The weighing bottle with the extract was dried in an oven at 104°C (Memmert GmbH, Schwabach, Germany) to allow the solvent to evaporate. The weighing container was then cooled and weighed. The fat content (F) was calculated using the formula:

\[
F(\%) = \frac{(\text{weight of weighing bottle with fat extract (g)} - \text{weight of dry weighing bottle (g)})}{\text{weight of sample (g)}} \times 100
\]

**Results**

*Quantitative composition of feathers*

The weights and quantitative composition data of the feathers and down are shown in Table 1. The three-years-old ganders yielded the greatest weight of feathers collected during all three gatherings. The differences between the weights of feathers collected from the layers of different ages were not statistically significant, which suggests that the age of the females had no effect on the weight of the gathered feathers. The weight of the feathers collected in the subsequent gatherings tended to increase.

The proportion of mature down in the feather samples (from three collections) from the layers in the different age-groups was similar. There were statistically significant differences between the first and the subsequent two gatherings in all age-groups of layers. Ganders had the lowest percentage by weight of down in their overall feather composition. Nevertheless, owing to the highest total weight of feathers, the ganders yielded 83.5 ± 3.0 g of down. Only the three-year-old females yielded a greater amount of down (85.97 ± 5.11 g). There were no statistically significant differences in
the weight of down between the age-groups of layers, and between the three-year-old layers and the ganders. The sex and age of the birds had no effect on the amount of down obtained, which was 80–85 g.

The three-year-old ganders yielded the highest feather content in the first gathering. With each gathering, the proportion of feathers in the overall weight of the samples increased in all the groups of geese. The average content of feathers differed significantly between each gathering for all the birds (P < 0.05). Furthermore, there was a statistically significant difference between the average content of feathers from the three-year-old layers and that from the three-year-old ganders (P < 0.05).

The largest amount of down in 0.1 g of sample was recorded during the first gathering, regardless of gender and age. The average amount of down was 81.2 pcs./0.10 g for all birds. This was followed by an increase in down size, and consequently the amount of down in 0.10 g, but the size of the down decreased in the subsequent gathering. There were no statistically significant differences in the volume of down between the layers in the different age-groups, and between the three-year-old ganders and the female geese.

The largest amount of residual matter in the total weight of feathers was recorded in the second gathering (1.6%), and was statistically much higher than in the other two gatherings. However, there was no statistically significant difference in the amount of residual matter between the first and the third gatherings.

The proportions of abnormal forms of down are shown in Figure 1. The percentages of nestling, tangled, and coupled down were low. The volume of nestling down tended to increase with age in the layers. However, the differences were not
statistically significant. The content of tangled down did not exceed 1% in any of the gatherings, and the largest average value for all birds was in the first gathering.

**Physical features of feathers**

The physical characteristics of the feathers, including the turbidity of the aqueous extracts, the residual matter content, and the acidity are presented in Tables 1 and 2.

**Turbidity of the aqueous extracts**

The results for the turbidity data obtained using a measuring cylinder are given in mm. The higher the column of aqueous feather extract, the cleaner the feathers. The cleanest raw material was collected from the birds in the first gathering. For the females, the cleanest feathers were obtained from the one-year-old birds. The average height of the column of the aqueous feather extract for all birds during the first gathering was $42.8 \pm 2.1$ mm, which was statistically significantly different from the results obtained for the second and third collections. The turbidity of the aqueous extracts decreased with each subsequent gathering.

The data obtained using the 2020 Turbidity Meter (LaMotte, Chestertown, Maryland) are given in NTUs. The lower the value, the cleaner the sample of the tested down. In line with the previous method, analysis of the results showed that the cleanest feathers were collected during the first gathering. There were statistically significant differences between the NTU values for individual gatherings from all birds.

**Acidity**
The feathers ranged from slightly acidic to neutral, with pH values between 5.9 and 7.2. The pH values in each age-group of birds were highest in the feathers from the first gathering. The average pH value for all ages was 7.1. In subsequent gatherings, the average pH decreased to 6.3.

Fat content and oxygen index number

The fat content percentages and oxygen index numbers for the feathers are shown in Table 3.

Fat content

The fat content of the feathers was the lowest in the samples from the first gathering (2.4–2.7%). The fat content tended to increase in subsequent gatherings, with the exception of three-year-old layers, which yielded the highest fat content during the second gathering. The average fat contents for all the birds in subsequent gatherings were 2.6%, 2.9%, and 3.2%. There was no statistically significant difference in fat content in relation to the age of the geese.

Oxygen index number

The oxygen index numbers fluctuated in subsequent gatherings, but there was no constant trend. The lowest values were observed in the first gathering (average of 70.33 mg of oxygen/100 g of feathers), and the highest were found during the second gathering (average of 85.83 mg of oxygen/100 g of feathers). The average oxygen index number in the third gathering of feathers was 81.61 mg of oxygen/100 g of feathers.
There were no statistically significant differences between individual gatherings from females, or between three-year-old layers and ganders.

**Discussion**

Waterfowl feathers are a valuable raw material for industry. Their physical properties make them useful in many areas of processing. Feathers make an excellent filling material, which retains heat. In contrast to many other clothing materials, feathers are also very light. Furthermore, feathers remain an important material for export.

This research presents an analysis of the quality of feathers obtained from Zatorska geese. The conclusions of this study complement the scarce source literature. They also provide valuable information on the use of the breeds included in the genetic resources protection program to the benefit of the feather processing industry.

Kozák (2011) reported that a single goose provides 250–300 g of feathers *postmortem*, with the percentage of down reaching 20%. In the present study, the weight of the feathers exceeded 250 g for all ages of layers and ganders; the percentage of down from the females was greater than 30%, and from the ganders it was almost 27%. Schneider (1995) observed that the percentage of down depends on the age of the bird. For nine-week-old geese, it reaches 22%, whereas for thirty-week-old geese the percentage can be as high as 32%. In the present study, feathers were only collected from adult birds, which confirms the source reports.

Kozák (1997) discussed a highly significant correlation between the body weight of the geese and the weight of down. In the present research, more down was obtained from the Zatorska geese than in another study by Bielińska and Tabiszewska (1973) on White Kołuda geese. Bielińska and Tabiszewska (1973) reported that 208.1 g of
feathers and 57.2 g of down were obtained from layers, and 225.3 g of feathers and 51.6 g of down were obtained from ganders in three gatherings. In later studies on adult White Kołuda geese, 84 g of down was obtained from males and 66.5 g of down was obtained from females during an additional fourth plucking (Pakulska and Bieliński, 1997). In the present study, the female Zatorska geese provided a total of 81–86 g of down/bird in three gatherings, and the ganders provided 84.5 g/bird.

Saatci (2008) reported a larger percentage of down from native Turkish geese. He collected 129.3 g from the males and 104.9 g from the females. Furthermore, significant proportions of black, piebald, and yellow down were reported, with samples taken from 10–12-week-old birds.

One-year-old reproductive White Kołuda geese provided 274.9 g of feathers and 51.2 g of down in three gatherings. In the present study, it was possible to obtain 263.6 g of feathers and 81.5 g of down from the one-year-old layers. There is a greater proportion of down from Zatorska geese yielding lower weights of feathers (Pakulska and Bieliński, 1997).

In the present study, we noted a reverse trend in the proportion of down in the total weight of feathers. The largest proportion of down was obtained during the first gathering, was smaller in the second gathering, and smallest in the third gathering. Following a study on White Kołuda geese, Pakulska and Bielińska (2004) indicated different results. Their study showed that, depending on the strain of geese (W11-female component or W33-male component), the proportion of down could reach 19.9–20.1% in the first gathering and 37.0–37.3% in the third gathering. Higher values were recorded for the W33 strain. However, the research was carried out on young (nine-week-old) geese, and the experimental group comprised a mixture of layers and ganders.
Such young geese (regardless of gender) yield small amounts of the least valuable down. It is possible to collect better-quality down in the second gathering.

The highest proportion of down from layers in the first gathering may result from the fact that these birds have a highly developed brooding instinct and grow denser plumage on their belly area for warming the eggs. Furthermore, geese commence natural molting immediately after the reproductive period, which may also result in a higher proportion of down (Kozák, 2011).

Deregowski and Jusik (1973) reported that mature down is characterized by numerous long barbs. According to Kozák (2011), the weight of 100 downs obtained in the third gathering should be between 0.136 g (for layers) and 0.143 g (for ganders). We observed such values during the third gathering for layers and ganders in the present study. These values were 0.140 g (for one-year-old females), 0.141 g (for two-year-old females), 0.137 g (for three-year-old females), and 0.147 g (for ganders). The obtained results are corroborated by those from a study by Saatci (2008), which showed that ganders have significantly heavier feathers and down than layers.

Residual matter comprises quill shafts, quill points, and fragments of quill shafts (PN-EN, 1885:2000). Values below 2%, which were obtained in the present study, are acceptable. The low content of natural contaminants indicates that mature feathers were collected. The content of residual matter in subsequent gatherings suggests that the feathers had grown properly, which was corroborated by the assessment of the people collecting the feathers. Moreover, the manual collection of the feathers ensured that additional contamination was minimized. The use of pastures by the geese could also have contributed to the low levels of natural contamination in the feathers. Szado et al.
(1995) reported that geese kept in closed buildings generate a higher proportion of residual matter than those using pastures.

According to the European standard (PN-EN, 1162:1998), the oxygen index number is a measure of the amount of oxidative substances and solvents present in the filtrate obtained from the aqueous extracts of the sample. This method makes it possible to determine the purity of the raw material tested. In the present study, the oxygen index numbers for the feathers exceeded those recommended by the International Down and Feather Testing Laboratory, namely 20 mg of oxygen/100 g of feathers as the limit value, 10 mg of oxygen/100 g of down for clean samples, and 1.6–3.2 mg of oxygen/100 g of down for very clean samples. Pakulska and Bielińska (2004) also reported higher oxygen index numbers, but the trend of change was reversed. Higher values (40–41 mg of oxygen/100 g of feathers) were determined for feathers from the first gathering, and the smallest values (26–27 mg of oxygen/100 g of feathers) were obtained in the third gathering. High oxygen index numbers may be the result of unfavorable weather conditions during the collection period (Bielińska and Tabiszewska, 1973). The high values obtained in the present study may also have resulted from using unwashed feathers for the research. According to the European Norm (PN-EN, 12935:2002), the aerobic count is an indicator of the purity of the tested material, and should be seen as the first level of testing, not a direct hygiene indicator. Treatment of the raw material is recommended if the feathers have an oxygen index number above 50 mg/100 g of feathers. Southey et al. (2011) reported that washing the feathers resulted in a six-fold reduction in the oxygen index number. In the studies mentioned above, the oxygen index number decreased from 24–26.4 mg to 2.6–4.6 mg of oxygen/100 g of feathers, whereas the turbidity of the samples increased from 60 mm to over 1000 mm.
It should be noted, however, that feathers with an oxygen index number of 4.8 mg of oxygen/100 g of feathers and a turbidity above 550 mm are considered hypoallergenic (IDFL, 2000). Analysis of the obtained results suggests that the feathers required cleaning.

The European standard (PN-EN, 1163:1999) and the International Down and Feather Testing Laboratory indicate that the fat content of the finished product should be 0.5–2.0%, whereas the Polish industry standard extends it to 3.5%. According to Kozák (2011), a higher level of fat in feathers may be related to bird nutrition, with the average value ranging from 1.6 to 3.2%. In the present study, the percentage of fat in the feathers increased with subsequent gatherings.

Feathers are also a valuable source of nitrogen compounds. Laboratory analyzes may also include the determination of protein and sulfuric amino acid components. Saravanan and Dhurai (2012) have described such an assay; they reported that chicken feathers contain nearly 9% cysteine. Such research should be carried out when the feathers are to be used as a source of fertilizers or animal meal. Geese feathers are valuable, and are perfect for the production of quilts, pillows, and jackets. The most important indicators are those described and applied in the present research (quantitative feather composition, turbidity of an aqueous extract, acidity, oxygen index number, and fat content).

Acidity is a valuable indicator for processing plants; textiles, fabrics, and raw materials that come into contact with human skin should be subject to an assessment of acidity. Chemicals that may change the pH of the treated raw material are added during the process of cleaning and washing the feathers. Feathers with an alkaline pH (above pH 10) may be subject to the microbial degradation of keratin (Onuoha and Chukwura,
2011). Moreover, if the pH of the down is too high or too low, it may be damaged during storage.

According to the European standard (PN-EN, 12935:2002), the pH of the feathers should be between 6.6 and 8.0. The pH values obtained in the present study were slightly lower. This was probably because the laboratory analyses were conducted before cleaning the feathers.

The high proportion of down and the low amounts of residual matter suggest that Zatorska geese should be classified in group A. In conclusion, feathers obtained from geese antemortem constitute a valuable resource for the industry.

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Figure Legend

Figure 1. Percentages (mean ± SE) of abnormal forms of down obtained during successive collections of feathers from Zatorska geese (n = 10/group).

1 y.o. ♀, one-year-old geese; 2 y.o. ♀, two-year-old geese; 3 y.o. ♀, three-year-old geese,
3 y.o. ♂, three-year-old ganders

a,b: indicate that the values within the same evaluated trait (nestling, tangled, and coupled down) and age-group were significantly different (P < 0.05)
Table 1. Weight, composition, and size of feathers obtained from successive gatherings from Zatorska geese (n = 10/group) (mean ± SE).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Gathering</th>
<th>1 y.o. ♀</th>
<th>2 y.o. ♀</th>
<th>3 y.o. ♀</th>
<th>3 y.o. ♂</th>
<th>Mean</th>
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<tr>
<td>Feather weight (g)</td>
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<tr>
<td>1st</td>
<td></td>
<td>73.1 ± 5.6a</td>
<td>80.5 ± 5.9a</td>
<td>86.0 ± 5.7</td>
<td>104.8 ± 8.9</td>
<td>79.9 ± 3.8a</td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td>91.9 ± 6.2ab</td>
<td>77.4 ± 6.6a</td>
<td>86.1 ± 6.2</td>
<td>107.1 ± 3.5</td>
<td>85.1 ± 3.2a</td>
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<tr>
<td>3rd</td>
<td></td>
<td>98.5 ± 3.9b</td>
<td>108.8 ± 4.2b</td>
<td>94.9 ± 3.9</td>
<td>103.5 ± 2.8</td>
<td>100.7 ± 2.0b</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>87.8 ± 3.6</td>
<td>87.7 ± 3.6</td>
<td>89.0 ± 3.6a</td>
<td>105.1 ± 3.6</td>
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<tr>
<td>Down mature (%)</td>
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<tr>
<td>1st</td>
<td></td>
<td>36.4 ± 1.6a</td>
<td>39.8 ± 1.7a</td>
<td>38.4 ± 1.6ax</td>
<td>30.3 ± 1.7y</td>
<td>38.2 ± 1.0a</td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td>28.4 ± 1.3b</td>
<td>27.9 ± 1.4b</td>
<td>31.0 ± 1.3b</td>
<td>26.2 ± 1.3b</td>
<td>28.8 ± 0.7b</td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td>28.1 ± 1.2b</td>
<td>28.1 ± 1.3b</td>
<td>27.1 ± 1.2b</td>
<td>23.8 ± 1.1b</td>
<td>27.7 ± 0.6b</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>30.9 ± 1.0</td>
<td>32.1 ± 1.0</td>
<td>32.2 ± 1.0b</td>
<td>26.8 ± 1.0b</td>
<td></td>
</tr>
<tr>
<td>Feathers (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td></td>
<td>60.0 ± 1.7a</td>
<td>55.9 ± 1.9a</td>
<td>57.1 ± 1.7ax</td>
<td>65.4 ± 1.8ay</td>
<td>57.7 ± 1.0a</td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td>67.1 ± 1.1b</td>
<td>67.6 ± 1.3b</td>
<td>63.9 ± 1.1bx</td>
<td>69.4 ± 1.4by</td>
<td>66.2 ± 0.7b</td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td>68.3 ± 1.7b</td>
<td>66.3 ± 1.3b</td>
<td>69.3 ± 1.2ax</td>
<td>71.9 ± 1.3by</td>
<td>67.9 ± 0.7c</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>65.1 ± 1.0</td>
<td>62.9 ± 1.0</td>
<td>63.4 ± 1.0y</td>
<td>68.9 ± 1.0y</td>
<td></td>
</tr>
<tr>
<td>Size of down (pcs./0.10 g)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td></td>
<td>82.6 ± 1.9a</td>
<td>80.0 ± 2.0a</td>
<td>81.1 ± 1.9a</td>
<td>81.4 ± 2.1a</td>
<td>81.2 ± 1.0a</td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td>79.1 ± 2.0ab</td>
<td>74.6 ± 2.1ab</td>
<td>74.2 ± 2.0b</td>
<td>75.7 ± 2.0a</td>
<td>75.9 ± 1.0b</td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td>71.6 ± 2.0a</td>
<td>70.9 ± 2.2a</td>
<td>73.7 ± 2.1b</td>
<td>68.1 ± 1.5b</td>
<td>72.1 ± 1.0c</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>77.8 ± 1.1</td>
<td>75.3 ± 1.1</td>
<td>76.3 ± 1.1b</td>
<td>75.1 ± 1.1b</td>
<td></td>
</tr>
<tr>
<td>Residual matter (%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td></td>
<td>0.9 ± 0.1a</td>
<td>1.1 ± 0.1</td>
<td>1.3 ± 0.1a</td>
<td>0.9 ± 0.1a</td>
<td>1.1 ± 0.1a</td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td>1.3 ± 0.3a</td>
<td>1.5 ± 0.3</td>
<td>1.9 ± 0.3a</td>
<td>1.6 ± 0.1b</td>
<td>1.6 ± 0.1b</td>
</tr>
<tr>
<td>3rd</td>
<td></td>
<td>1.1 ± 0.1a</td>
<td>1.0 ± 0.1</td>
<td>1.0 ± 0.1b</td>
<td>1.2 ± 0.1ab</td>
<td>1.0 ± 0.03a</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.1 ± 0.1</td>
<td>1.2 ± 0.1</td>
<td>1.4 ± 0.1</td>
<td>1.2 ± 0.1</td>
<td></td>
</tr>
</tbody>
</table>

1 y.o. ♀, one-year-old goose; 2 y.o. ♀, two-year-old goose; 3 y.o. ♀, three-year-old goose, 3 y.o. ♂, three-year-old ganders.

Values in columns within successive gatherings with superscripted letters differ significantly (a,b,c: P < 0.05).

Values in rows within 3 y.o. ♀ and 3 y.o. ♂ with superscripted letters differ significantly (x,y: P < 0.05).
Table 2. Physical features of feathers obtained from successive gatherings from Zatorska geese (n = 10/group) (mean ± SE).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Gathering</th>
<th>1 y.o. ♀</th>
<th>2 y.o. ♀</th>
<th>3 y.o. ♀</th>
<th>3 y.o. ♂</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>49.1 ± 3.1a</td>
<td>43.6 ± 3.3a</td>
<td>35.8 ± 3.1a</td>
<td>45.7 ± 5.7a</td>
<td>42.8 ± 2.1a</td>
<td>42.8 ± 2.1a</td>
</tr>
<tr>
<td>2nd</td>
<td>31.8 ± 4.8b</td>
<td>35.5 ± 5.0b</td>
<td>37.0 ± 4.8ab</td>
<td>37.8 ± 4.2a</td>
<td>34.8 ± 2.3b</td>
<td>34.8 ± 2.3b</td>
</tr>
<tr>
<td>3rd</td>
<td>25.1 ± 2.0b</td>
<td>26.0 ± 2.1b</td>
<td>25.8 ± 2.0b</td>
<td>22.8 ± 1.0b</td>
<td>25.6 ± 0.9c</td>
<td>25.6 ± 0.9c</td>
</tr>
<tr>
<td>Mean</td>
<td>35.3 ± 2.1</td>
<td>35.3 ± 2.1</td>
<td>32.9 ± 2.1</td>
<td>35.4 ± 2.1</td>
<td>35.4 ± 2.1</td>
<td></td>
</tr>
<tr>
<td>Turbidity (NTUs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>70.9 ± 16.5a</td>
<td>70.6 ± 17.3a</td>
<td>135.3 ± 16.5a</td>
<td>73.3 ± 17.4a</td>
<td>92.2 ± 9.3a</td>
<td>92.2 ± 9.3a</td>
</tr>
<tr>
<td>2nd</td>
<td>163.1 ± 32.2b</td>
<td>150.6 ± 33.4b</td>
<td>145.7 ± 32.2a</td>
<td>138.5 ± 32.9a</td>
<td>153.1 ± 15.8b</td>
<td>153.1 ± 15.8b</td>
</tr>
<tr>
<td>3rd</td>
<td>321.0 ± 38.0c</td>
<td>255.7 ± 40.1b</td>
<td>287.7 ± 38.0b</td>
<td>323.1 ± 37.4b</td>
<td>288.1 ± 18.9c</td>
<td>288.1 ± 18.9c</td>
</tr>
<tr>
<td>Mean</td>
<td>185.0 ± 19.5</td>
<td>154.3 ± 19.5</td>
<td>189.6 ± 19.5</td>
<td>178.3 ± 19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidity (pH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>6.9 ± 0.1</td>
<td>7.2 ± 0.1a</td>
<td>7.2 ± 0.1a</td>
<td>6.8 ± 0.1a</td>
<td>7.1 ± 0.1a</td>
<td>7.1 ± 0.1a</td>
</tr>
<tr>
<td>2nd</td>
<td>6.9 ± 0.5</td>
<td>6.1 ± 0.5ab</td>
<td>6.8 ± 0.5ab</td>
<td>6.8 ± 0.1a</td>
<td>6.6 ± 0.2ab</td>
<td>6.6 ± 0.2ab</td>
</tr>
<tr>
<td>3rd</td>
<td>6.4 ± 0.2</td>
<td>6.2 ± 0.2b</td>
<td>6.4 ± 0.2b</td>
<td>5.9 ± 0.1b</td>
<td>6.3 ± 0.1b</td>
<td>6.3 ± 0.1b</td>
</tr>
<tr>
<td>Mean</td>
<td>6.7 ± 0.1</td>
<td>6.5 ± 0.1</td>
<td>6.8 ± 0.1</td>
<td>5.9 ± 0.1</td>
<td>6.5 ± 0.1</td>
<td></td>
</tr>
</tbody>
</table>

1 y.o. ♀, one-year-old goose; 2 y.o. ♀, two-year-old goose; 3 y.o. ♀, three-year-old goose, 3 y.o. ♂, three-year-old ganders; NTUs: nephelometric turbidity units.

Values in columns within successive gatherings with superscripted letters differ significantly (a,b,c: P < 0.05).

Values in rows within 3 y.o. ♀ and 3 y.o. ♂ with superscripted letters differ significantly (x,y: P < 0.05).
Table 3. Fat content and oxygen number of feathers obtained from successive gatherings from Zatorska geese (n = 10/group) (mean ± SE).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Gathering</th>
<th>1 y.o. ♀</th>
<th>2 y.o. ♀</th>
<th>3 y.o. ♀</th>
<th>3 y.o. ♂</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>2.6 ± 0.2a</td>
<td>2.4 ± 0.2</td>
<td>2.7 ± 0.2a</td>
<td>2.5 ± 0.2</td>
<td>2.6 ± 0.1a</td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>2.6 ± 0.2d</td>
<td>2.6 ± 0.2d</td>
<td>3.4 ± 0.2be</td>
<td>2.9 ± 0.3</td>
<td>2.9 ± 0.1ab</td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>3.4 ± 0.3b</td>
<td>3.1 ± 0.3</td>
<td>3.1 ± 0.3ab</td>
<td>3.5 ± 0.6</td>
<td>3.2 ± 0.2b</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.8 ± 0.2</td>
<td>2.7 ± 0.2</td>
<td>3.1 ± 0.2</td>
<td>3.0 ± 0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen index number (mg of oxygen/100 g of feathers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>64.6 ± 1.9ad</td>
<td>68.2 ± 2.3ad</td>
<td>78.1 ± 1.1ex</td>
<td>70.4 ± 2.0y</td>
<td>70.3 ± 1.2a</td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>89.5 ± 1.6b</td>
<td>80.7 ± 7.6ab</td>
<td>86.9 ± 1.4</td>
<td>86.2 ± 2.3b</td>
<td>85.8 ± 2.0b</td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td>81.3 ± 1.1b</td>
<td>81.5 ± 1.5b</td>
<td>82.7 ± 2.3</td>
<td>80.9 ± 1.4b</td>
<td>81.6 ± 0.8b</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>78.5 ± 2.1</td>
<td>76.7 ± 2.9</td>
<td>82.6 ± 1.1</td>
<td>79.2 ± 1.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 y.o. ♀, one-year-old goose; 2 y.o. ♀, two-year-old goose; 3 y.o. ♀, three-year-old goose; 3 y.o. ♂, three-year-old ganders

Values in columns within successive gatherings with superscripted letters differ significantly (a,b,c: P < 0.05).
Values in rows within goose age-groups (columns 2–4) with superscripted letters differ significantly (d,e: P < 0.05).
Values in rows within 3 y.o. ♀ and 3 y.o. ♂ with superscripted letters differ significantly (x,y: P < 0.05).
Fig. 1.

[Graph showing data for nestling down, tangled down, and coupled down percentages for different ages and genders.]

- 1st gathering
- 2nd gathering
- 3rd gathering

- 1 y.o.
- 2 y.o.
- 3 y.o.

- ♂
- ♀

Legend:
- 1st gathering
- 2nd gathering
- 3rd gathering