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REVIEW PAPER

GEESE FOR SLAUGHTER AND WILD GEESE AS A SOURCE OF SELECTED MINERAL ELEMENTS IN A DIET*

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Abstract

To source geese for slaughter and commercial sale, domesticated geese (*Anser anser domesticus*) of various breeds and varieties are used all over the world. Moreover, the meat of wild geese, for instance, Egyptian goose (*Alopochen aegyptiacus*) or Canada goose (*Branta canadensis),* is also consumed in some parts of the globe. So far, the research conducted on geese for slaughter has focused on their slaughter efficiency, carcass composition, histochemical composition of muscle fibres, and its chemical composition or sensory characteristics. Research concerning wild geese is concentrated on the content of pollutants in their meat, and not on its mineral elements. Therefore, the purpose of this project is to make an analysis of the existing local and international literature from 1986 until 2017 concerning the content of mineral elements in raw and culinarily and thermally processed meat of geese for slaughter and wild geese. On the basis of the existing literature, it has been calculated that for people aged 10 and over an occasional consumption of 100 g of cooked or roasted goose meet (skinless) significantly covers the Recommended Dietary Allowances or Adequate Intake of Se, P, Zn, Cu and Fe, and to a smaller extent, of K, Na Mg, Ca and Mn. Culinarily and thermally processed breast muscle fibres (100 g) are a better choice to provide P, Na, Ca, Mg, Fe and Cu, while K, Zn and Mn are found in the leg muscle fibres. The meat of wild geese, culinarily and thermally processed, will provide more Fe, Zn, Cu and Ca than meat of geese for slaughter. The findings reported in the literature were not methodologically complete. Considering the changes that have taken in the last thirty years in the intensity of agricultural production, progress in stock raising, breeding and feeding geese, feed supplementation, and an increased interest in goose meat, it is evident that conducting new research concerning mineral content and/or updating the previous research findings is necessary.

Keywords: geese, meat, mineral elements.

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INTRODUCTION

The meat of waterfowl poultry (geese and ducks), due to its specific nutritional and culinary value and a high price, is less popular than the meat of the gallinaceous poultry. However, according to the data provided by FAO (2016), between 2003 and 2013 there was an increase in the goose meat production in the world, including Poland, which is the leader in this respect among other countries of the European Union (EUROSTAT 2016, MOLNAR 2016). According to the statistical data gathered in December 2016, the production of poultry livestock for slaughter in Poland was higher by 11.5% than it was in 2015. Meanwhile, the production of geese for slaughter constituted 1.39% of general production of poultry livestock for slaughter, and was higher by 1.9% in comparison to 2015. For consumers, it is also important to note that the price of 1 kg of poultry in 2016 was lower than in the previous year (Concise Statistical Yearbook of Poland 2017).

To source goose for slaughter and commercial sale, domesticated geese (*Anser anser domesticus*) of various breeds and varieties are used all over the world. Goose meat is produced in Poland mainly (95%) using the white Koluda goose® (W-31 cross-breed made of ♂ W-33 x ♀ W-11), which has been considered a separate breed since 2012 (WENCEK et al. 2015). A small amount of White Gosling G-35 geese is also produced; there are also geese coming from populations involved in the animal genetic preservation programme, where 14 breeds of geese are included. These geese are characterised by high slaughter and meat quality appreciated by consumers, therefore they may be a very good source of non-industrial production of meat for regional, organic products to be used in agritourism.

So far, the research conducted on geese for slaughter has focused on their slaughter efficiency, carcass composition, histochemical composition of muscle fibres and its chemical composition. Particularly in the recent years, attention has been paid to the cholesterol and fatty acids content in muscles, liver and depot fat of both male and female geese (BIESIADA-DRZAZGA 2006, GUMUŁKA et al. 2006, GARDZIELEWSKA et al. 2009, KAPKOWSKA et al. 2011, LIU et al. 2011, OKRUSZEK et al. 2013, KOKOSZYŃSKI et al. 2014, ADAMSKI et al. 2016, LEWKO et al. 2017).

Wild geese hunted during spring and autumn are a source of energy and nutrients for people in many regions of the world, for instance the Egyptian goose (*Alopochen aegyptiacus*) consumed in South Africa, or the Canada goose (*Branta canadensis*), traditionally consumed by local, rural communities, such as Eastern James Bay Cree of Quebec in Canada. In the USA, there are programmes such as "Hunters for the Hungry" and "Sportsmen Against Hunger", where fresh wild game is given to the needy. The USDA Wildlife Services donates more than 60 tons of wild game (e.g. *Branta canadensis*) to a variety of charitable organizations each year. However, the environmental factors might cause an excessive accumulation of heavy metals, *inter alia*, in the fibres of wild geese, which might have a negative impact on consumers' health and therefore needs to be constantly monitored. Moreover, the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service and the U.S. Food and Drug Administration monitor commercially produced poultry and livestock for chemical contaminants.

Therefore, the objective of this project is to make an analysis of the existing local and international literature from 1986 until 2017 concerning the content of selected mineral elements in raw and culinarily processed meat of livestock and wild geese.

THE ASH AND MINERAL CONTENT IN THE MEAT OF GEESE FOR SLAUGHTER AND WILD GEESE

The fundamental examination to determine the general mineral content in the meat of animals for slaughter is to determine the ash content. Existing literature suggests that the ash content of goose meat constitutes from 10 to 15 g kg^{-1}. Its amount depends on the breed/variety of the goose, its sex, its feeding system, the age at which it was slaughtered, the season, the type of muscles, the packaging of the meat, the conditions in which it was stored and the culinary processes which were used (Biesiada-Drzazga, Górski 1998, Belinski, Kuhnlein 2000, Biesiada-Drzazga 2006, Gumułka et al. 2006, Okruszek et al. 2008, Geldenhuys et al., 2013, Pietrzak et al. 2013, Uhliřova, Tůmova 2014, Damaziak et al. 2016, Łukaszewicz et al. 2016).

The results of an analysis of the mineral content in the goose meat may be affected by various factors, which is particularly important if those factors persist for many years. First of all, it should be noted that the use of mineral, chemical and calcium fertilizers in the agriculture has increased in various parts of the world since the 1960s. In Poland, the use of the nitrogen, potassium and calcium fertilizers increased between 2009 and 2016, and the use of phosphorus fertilizers decreased (Concise Statistical Yearbook of Poland 2017). This fact may affect the content of the feeds used in goose fattening (López-Alonso 2012). The demand for nutrients in young geese for slaughter changes rather quickly and requires at least three optimized complete compound feeds to be used in intensive breeding: a starter, a grower and a finisher. They include full grains, which, especially in the final period of fattening, may be supplemented by roughage (green forage and/or bulb and root plants).

Secondly, the feeds are supplemented, as premixes, by compounds of Ca, Na, Fe, Mn, Cu, Zn, J, Co and Sn, which may modify their content in the goose meat (NRC 1994).

Moreover, throughout the years the recommendations of energetic and nutrient values of feed used in fattening of geese have changed. The recommendations of the National Research Council in 1984 suggested a larger supply of Ca and P during 0-4 weeks of fatting than they did in 1994 (Applegate, Angel 2014). At the moment, the tenth edition of dietary recommendations for poultry is being developed.

Finally, water is also a source of mineral elements in feeding geese. Geese must have access to adequate and appropriate water for their age, stage of production and weather conditions (Berger 2006).

Major elements content in raw muscle of geese for slaughter and wild geese

Phosphorus (P)

According to Usda (2016), the phosphorus content in a raw goose carcass is 3120 mg kg^{-1}, and its amount is smaller when skin is removed (2340 mg kg^{-1} of tissue). Nevertheless, The Food and Nutrition Institute in Poland claims (Kunachowicz et al. 2017) that the content of this element in carcasses of Polish geese for slaughter with skin (available commercially) is smaller by a half (Table 1).

Taking into account the type of muscles, Oz and Celik (2015) demonstrated a larger content of P in raw leg muscles of a Turkish goose, slaughtered at the age of 16 weeks, than in its chest muscles (7940 vs. 5580 mg kg^{-1} of tissue). Yet, Geldenhuys et al. (2015) researched raw muscle of wild Egyptian geese and concluded that neither the hunting season (winter and summer) nor the sex of geese affected the phosphorus contents. The content of P in these wild geese is smaller than in geese for slaughter (Table 2).

Sodium (Na)

The content of sodium established by Usda (2016) in a raw, skinless goose carcass is larger than that in a carcass with skin (Table 1), but it is also larger than in Polish geese for slaughter, as demonstrated by Kunachowicz et al. (2017). Taking into account the type of muscle, Oz and Celik (2015) determined a larger content of Na in the chest muscle of the Turkish geese than in the leg muscle (3510 vs. 1350 mg kg^{-1} of tissue). No significant correlation between the hunting season or the sex of geese and Na content in the muscles of wild Egyptian geese was found (Geldenhuys et al. 2015), and the amount of Na is smaller in the muscles of wild geese than in geese for slaughter (Table 2).

Calcium (Ca)

Data established by Usda (2016) shows that the Ca content in a raw goose carcass is similar between those with or without skin, yet it is much higher than that determined by Kunachowicz et al. (2017) in Polish geese for slaughter (50 mg kg^{-1} of tissue) (Table 1). Considering the type of the muscle, the research conducted in the 1980s by Bielińska et al. (1984) determined

Table 1

Selected macroelement content in raw carcasses of geese and in meat submitted to thermal culinary processing

Carcass	Country	N	Ash ($g\ kg^{-1}$)	Major elements ($mg\ kg^{-1}$)					Reference
				P	Na	Ca	K	Mg	
Meat only, raw	-	-	11.0	3120.0	870.0	130.0	4200.0	240.0	USDA (2016)
Meat and skin, raw	-	-	8.7 8.0	2340.0 1520.0	730.0 480.0	120.0 50.0	3080.0 2430.0	180.0 180.0	USDA (2016) KUNACHOWICZ et al. (2017)
Meat only, cooked, roasted	-	-	11.4	3090.0	760.0	140.0	3880.0	250.0	USDA (2016)
Meat and skin, cooked, roasted	-	-	9.7 10.0	2700.0 1920.0	700.0 610.0	130.0 70.0	3290.0 3250.0	220.0 230.0	USDA (2016) KUNACHOWICZ et al. (2017)
Flesh only oven-roasted	Canada	8	11.2	-	-	69.1	-	-	BELINSKY, KUHNLEIN (2000)
Flesh only boiled		2	7.7	-	-	49.1	-	-	

Table 2

Selected macroelement content in raw breast muscle (B) and leg/thigh (L/T) of geese and submitted to thermal culinary processing

Meat	Country	*N*	Ash ($g\ kg^{-1}$)	Major elements ($mg\ kg^{-1}$)										Reference
				P		Na		Ca		K		Mg		
				B	L/T	B	L/T	B	L/T	B	L/T	B	L/T	
Raw	- Turkey	16 16	- -	- 5580	- 7940	- 3510	- 1350	155 1680	230 2400	- 612	- 681	- 611	- 883	Bielińska et al. (1984) Oz, Celik (2015)
Raw	Canada	194	-	-	-	-	-	46.1	-	-	-	266	-	Horak et al. (2014)
Raw, winter season	Egypt	18 (9♂ 9♀)	-	1730	-	211	-	70	-	1657	-	313	-	Geldenhuys et al. (2015)
Raw, summer season		18 (9♂ 9♀)	-	1677	-	233	-	74	-	1564	-	310	-	
Cooked		6	17.0	1925	-	220	-	123	-	1801	-	325	-	Geldenhuys et al. (2013)
Boilled	Turkey	16	-	9280	7039	3960	3873	2597	1865	524	630	1020	768	Oz, Celik (2015)
Grilled		16	-	5858	3010	3072	2896	1784	821	990	1310	638	332	
Pan-fried without fat or oil		16	-	9390	7940	4530	1360	2860	2150	524	1480	1040	864	
Pan-fried with oil		16	-	5853	7786	2703	1219	1784	2215	650	1300	640	833	
Deep-fat fried		16	-	7141	8482	2776	1120	2065	2460	900	1270	779	921.5	
Oven cooked		16	-	6497	5336	3409	2566	1955	1590	955	964.6	716	581.8	
Microwave		16	-	6380	6780	2509	1980	1885	2050	800	800	700.3	736	
With skin oven-roasted	Canada	8	8.9	-	-	-	-	74.4	96.2	-	-	-	-	Belinsky, Kuhnlein (2000)
With skin fire-roasted		1	12.0	-	-	-	-	65.3	85.9	-	-	-	-	
With skin boiled		2	7.0	-	-	-	-	58.3	75.4	-	-	-	-	

that there is a smaller amount of Ca in the raw muscle of chest than in legs (155. vs. 230 mg kg^{-1} of tissue) of pasture-raised geese for slaughter, slaughtered at the age of 16 weeks (Table 2).

The research conducted by Oz and Celik (2015) demonstrated a larger content of Ca in raw leg muscles of Turkish geese than in their chest muscles (2400 vs. 1680 mg kg^{-1} g of tissues). The amounts of Ca established by these authors were many times larger than those presented by Usda (2016) and over 20 times larger than those of James Bay Cree of Quebec Canada geese (49.1-275.9 mg kg^{-1}), as reported by Belinsky and Kuhnlein (2000). No significant correlation between the hunting season or the sex of geese and Ca content in the muscles of wild Egyptian geese was found (Geldenhuys et al. 2015), and its amount was similar to that found in the muscles of geese for slaughter.

Potassium (K)

The K content in a raw, skinless goose carcass (Table 1) is larger than that in a carcass with skin, according to USDA (2016). A smaller amount of potassium was found in carcasses of Polish geese for slaughter (3250 mg kg^{-1} of tissue) (Kunachowicz et al. 2017). Oz and Celik (2015) demonstrated a larger amount of K in raw leg muscles of Turkish geese for slaughter than in their chest muscles (681. vs. 612 mg kg^{-1} of tissue) and these were much smaller amounts than those described in the research above (Table 2). Considering the hunting season and the sex of geese, Geldenhuys et al. (2015) found no significant differences in the muscles of Egyptian wild geese. Yet, the potassium content in this meat was higher than in the relevant muscles of Turkish geese (Oz, Celik 2015).

Magnesium (Mg)

The content of Mg (Table 1) in a raw, skinless goose carcass, according to USDA (2016), is higher than in a carcass with skin, and it is similar to the content established by Kunachowicz et al. (2017) in Polish carcasses of geese for slaughter. Considering the type of muscle, Oz and Celik (2015) demonstrated a higher content of Mg in the leg muscles of Turkish geese for slaughter than in their chest muscles (883 vs. 611 mg kg^{-1} of tissue) (Table 2). Nevertheless, Geldenhuys et al. (2015) has not established a significant impact of the hunting season and the sex of geese on the Mg content in the chest muscles of wild Egyptian geese. These amounts, however, were smaller by half than in the muscles of geese for slaughter, as well as in the muscles of wild Canada geese, as established by Horak et al. (2014).

Minor element content in the raw muscle of geese for slaughter and wild geese

Iron (Fe)

The research conducted in the 1970s and 1980s by Falandysz et al. (1986, 1989, 1991) and Kopczewski et al. (1987) on raw carcasses of geese for slaughter from northern Poland showed that there was a wide range in the iron content, from 15 mg to 55 mg kg^{-1} of tissue (Table 3). A smaller amount (24 mg kg^{-1} of tissue) of Fe in raw carcasses of Polish geese for slaughter was found by Kunachowicz et al. (2017), and this amount was similar (25 mg kg^{-1} of tissue) to the amount presented by USDA (2016).

In the 1980s, the research conducted by Bielińska et al. (1984) established that the amount of Fe found in raw chest muscles is larger than that found in leg muscles (55 mg vs. 50 mg kg^{-1} of tissue) in pasture-raised geese for slaughter (Table 4). Furthermore, taking into account the feed type and the muscle type, Borys et al. (2001) determined that there is a significant correlation between intensive feeding of male geese for slaughter of the white Koluda® breed (slaughtered at the age of 24 weeks) and the Fe content in their muscles, compared to those submitted to extensive feeding; the Fe content amounted to 15.85 vs. 13.29 mg kg^{-1} of tissue, respectively. The difference between the Fe content in the chest and in the leg muscles was not statistically significant.

The research conducted by Oz and Celik (2015) on Turkish geese for slaughter showed that there is a larger amount of Fe in raw chest muscles than in leg muscles (10.1 mg vs. 7.6 mg kg^{-1}). The findings of the research conducted by Horak et al. (2014) on the chest muscles of wild Canada geese determined that the Fe content is higher (79.6 mg kg^{-1} of tissue) than in the muscles of livestock geese, as presented above, because muscles from migratory birds contain high proportions of type I fibres, rich in myoglobin. On the other hand, Geldenhuys et al. (2015) found that neither the hunting season nor the sex of the geese significantly affected the Fe content in raw muscles of wild Egyptian geese of both sexes (Table 4).

Zinc (Zn)

The research conducted by Falandysz et al. (1986, 1989, 1991) and Kopczewski et al. (1987) suggests that the Zn content in raw muscles of carcases of geese coming from northern Poland in the 1970s and 1980s ranged from 6.3 mg to 43 mg kg^{-1} of tissue (Table 3). More recent research done by Kunachowicz et al. (2017) showed that the Zn content in raw carcasses of Polish geese for slaughter is 16.6 mg kg^{-1} of tissue. A slightly larger amount of Zn (17.2 mg kg^{-1} of tissue) in the raw meat and skin of geese of various breeds and varieties is presented in the data provided by USDA (2016).

Borys et al. (2001) determined a significant ($P \leq 0.01$) correlation between intensive feeding of male geese for slaughter of white Koluda® breed and Zn content higher by 21.4% in comparison to geese submitted to exten-

Table 3

Selected microelement content in raw chest and leg muscles submitted to thermal culinary processing

Carcass	Country	N	Ash ($g\ kg^{-1}$)	Minor elements ($mg\ kg^{-1}$)						Reference
				Fe	Zn	Cu	Mn	Se	J	
Meat and skin, raw	-	29	-	31.0-54.0	15.0-30.0	0.86-4.0	0.12-0.24	-	-	Falandysz et.al (1986)
Meat and skin, raw	-	18	-	22.0-55.0	6.3-43.0	1.1-15.0	0.14-2.4	-	-	Kopczewski et al. (1987)
Meat and skin, raw	-	18	-	15.0-46.0	8.4-19.0	0.85-7.7	0.17-0.31	-	-	Falandysz et al. (1989)
Meat and skin, raw	-	400	-	26.0-35.0	13.0-16.0	3.6-7.3	0.26-0.27	-	-	Falandysz (1991)
Meat only, raw	-	-	11.0	25.7	23.4	3.06	0.24	0.168	-	USDA (2016)
Meat and skin, raw	-	- -	8.7 8.0	25.0 24.0	17.2 16.6	2.70 1.7	0.20 0.20	0.144 -	- 0.007	USDA (2016) Kunachowicz et al. (2017)
Meat only, cooked, roasted	-	-	11.4	28.7	31.7	2.76	0.24	0.255	-	USDA (2016)
Meat and skin, cooked, roasted	- -	- -	9.7 10.0	28.3 34.0	26.2 22.2	2.64 2.2	0.23 0.30	0.218 -	- -	USDA (2016) Kunachowicz et al. (2017)
Flesh only oven-roasted	Canada	8	11.2	98.1	31.5	6.4	-	-	-	Belinsky, Kuhnlein (2000)
Flesh only boiled		2	7.7	11.7	3.69	0.75	-	-	-	

Table 4

Selected microelement content in raw breast muscle (B) and leg/thigh (L/T) of geese and submitted to thermal culinary processing

Meat	Country	*N*	Ash (g kg^{-1})	Minor elements (mg kg^{-1})								Reference
				Zn		Cu		Mn		Se		
				B	L/T	B	L/T	B	L/T	B	L/T	
1	2	3	4	5	6	7	8	9	10	11	12	13
Raw	Poland (White Kołuda®) Turkey	20 (♂) 16	- -	13.95 15.0	29.12 58.7	2.67 1.5	1.47 1.2	- 0.2	- 0.5	- -	- -	Borys et al. (2001) Oz, Celik (2015)
Raw	Poland (White Koluda®)	20 (10♂10♀)	10.4	-	-	-	-	-	-	0.0925	0.0745	Łukaszewicz et al. (2016)
Raw	Canada	194	-	13.6	-	8.2	-	0.3	-	0.00035	-	Horak et al. (2014)
Raw	Gray	24	10.5	-	-	-	-	-	-	0.14	-	Boawei et al. (2011)
Raw, winter season	Egypt	18 (9♂ 9♀)	-	15.0	-	4.0	-	0.6	-	-	-	Geldenhuys et al. (2015)
Raw, summer season		18 (9♂ 9♀)	-	15.0	-	4.0	-	0.6	-	-	-	
Cooked		6	17.0	21.0	-	5.0	-	1.0	-	-	-	Geldenhuys et al. (2013)

cont. Table 4

1	2	3	4	5	6	7	8	9	10	11	12	13
Boilled	Turkey	16	-	25.6	60.3	2.0	10.0	0.7	8.0	-	-	Oz, Celik (2015)
Grilled		16	-	25.4	64.5	1.8	1.1	0.4	0.5	-	-	
Pan-fried without fat or oil		16	-	25.0	47.0	2.5	20.0	4.5	3.4	-	-	
Pan-fried with oil		16	-	15.6	68.9	1.3	1.6	0.5	16.3	-	-	
Deep-fat fried		16	-	23.0	74.5	1.6	1.4	0.6	2.1	-	-	
Oven cooked		16	-	25.1	63.6	1.6	0.9	0.3	2.4	-	-	
Microwave		16	-	24.0	91.	2.0	1.5	0.1	1.5	-	-	
With skin oven-roasted	Canada	8	8.9	30.5	41.2	4.0	2.2	-	-	-	-	Belinsky, Kuhnlein (2000)
With skin fire-roasted		1	12.0	29.0	41.0	4.5	2.6	-	-	-	-	
With skin boiled		2	7.0	32.5	48.1	5.0	2.7	-	-	-	-	

sive feeding. Considering the type of muscles, the Zn content were 108.7% higher in leg muscles than in chest muscles (29.12 mg vs 13.95 mg kg^{-1}). A larger amount of Zn in raw leg muscles and chest muscles of Turkish geese for slaughter (58.7 vs. 15 mg kg^{-1} of tissue) was determined by Oz and Celik (2015), while a similar amount of Zn was found in chest muscles of wild Canada geese by Horak et al. (2014). The research conducted by Geldenhuys et al. (2015) on raw muscles of wild Egyptian geese of both sexes did not show a significant impact of the hunting season and the sex of geese on the content of this element (Table 4).

Copper (Cu)

In the 1970s and 1980s, the content of Cu (Table 3) in raw carcasses of Polish geese for slaughter was from 0.85 to 15 mg kg^{-1} of tissue (Falandysz et al. 1986, 1989, 1991, Kopczewski et al. 1987). On the other hand, the research conducted by Kunachowicz et al. (2017) on the raw carcasses of Polish geese for slaughter showed that the average content of Cu amounts to 15 mg kg^{-1} of tissue and is lower (0.270 mg 100 g^{-1} of tissue) than that suggested by USDA (2016).

Borys et al. (2001) determined that the Cu content was significantly ($P \leq 0.01$) dissimilar depending on the type of muscles (chest: 2.67 vs. legs: 1.47 mg kg^{-1}) in male geese of white Koluda® breed. Yet the feeding type (intensive vs. extensive) did not significantly affect the amount of this element in their muscles. The research conducted by Oz and Celik (2015) showed that the Cu content in raw chest muscles of Turkish geese for slaughter was higher than in their leg muscles (15 mg vs. 12 mg kg^{-1} of tissue), and these findings were similar to those obtained during research on Polish geese for slaughter. A larger amount of Cu was noted by Horak et al. (2014) in raw chest muscles of wild Canada geese (8.2 mg kg^{-1} of tissue). Moreover, the research conducted by Geldenhuys et al. (2015) on raw muscles of wild Egyptian geese determined that the hunting season and the sex of the geese did not significantly affect the Cu content (Table 4).

Manganese (Mn)

In the 1970s and 1980s, the Mn content (Table 3) in raw carcasses of Polish geese for slaughter was from 0.12 to 0.24 mg kg^{-1} of tissue (Falandysz et al. 1986, 1989, 1991, Kopczewski et al. 1987). The analysis of the more recent data provided by USDA (2016) and published by Kunachowicz et al. (2017) suggests that the amount of Mn in raw carcasses of geese internationally and in Poland is similar (0.2 mg kg^{-1} of tissue). A slightly higher Mn content in raw muscles of Canada wide geese (0.3 mg kg^{-1} of tissue) was established by Horak et al. (2014). On the other hand, Geldenhuys et al. (2015) did not find a significant correlation between the hunting season and the sex of the geese and the Mn content in the muscles of wild Egyptian geese of both sexes (Table 4).

Selenium (Se)

Very little research was found on the Se content in geese muscles (Table 3). The data gathered by USDA (2016) suggest that raw carcasses of geese with skin contain 0.144 mg kg^{-1} of tissue of selenium, and this amount is similar to that determined by Baowei et al. (2011) in the chest muscles of 9-week-old broiler chickens QAU gray geese. The research concerning 16-week-old white Koluda geese® conducted by Łukaszewicz et al. (2016) determined that a larger amount of Se may be found in the raw chest and leg muscles of male geese than female ones (0.098-0.087 vs. 0.082-0.067 mg kg^{-1}), although these differences were not statistically significant. However, the research conducted by Horak et al. (2014) on the raw chest muscles of wild Canada geese showed that the Se content was much lower (0.00035 mg kg^{-1} of tissue) than established in the aforementioned research concerning geese for slaughter (Table 4).

Iodine (J) and boron (B)

The amount of iodine and boron has not been the subject of much research. The iodine content in raw carcasses of geese for slaughter according to Souci et al. (2000) is 0.407 mg kg^{-1} of tissue. Yet, the research conducted by Kunachowicz et al. (2017) on the raw carcasses of Polish geese for slaughter concludes that the average iodine content is even smaller and amounts to 0.007 mg kg^{-1}.

In the case of wild geese, the research conducted by Geldenhuys et al. (2015) on raw muscles of Egyptian geese of both sexes determined that the hunting season did not affect the content of this element significantly. On the other hand, it was established that the chest muscles of female geese contain a significantly ($P \leq 0.05$) larger amount of boron than male geese (0.0003 vs. 0.00026 mg kg^{-1} of tissue).

MINERAL CONTENT IN CULINARILY AND THERMALLY PROCESSED MEAT OF GEESE FOR SLAUGHTER AND WILD GEESE

It is important to consider the influence of cooking techniques and conditions on trace element content, considering that humans rarely eat raw meat. Belinsky and Kuhnlein (2000) determined that a larger amount of Ca in carcasses of wild Canada geese is found in oven-roasted meat (176ºC) than in tmeat which was only boiled. A higher Ca content was also found in leg muscles than in chest muscles which were thermally processed in different ways: oven-roasted, fire-roasted and boiled (Table 1). During the heat treatment, cooking losses due to mass transfer depend on not only the cooking conditions such as a cooking method, cooking surface, cooking temperature and time, but also on meat properties such as the water content, fat content, protein content, pH value of the raw meat and the meat size (Gerber et al. 2009). Losses of minerals during thermal treatment of meat depend on the form in which they occur. Mineral elements which can be found in the form of soluble dissociated salts (part of sodium, small amounts of phosphorus, calcium and potassium) pass to the leakage. Elements, such as iron, that combine with proteins remain in the meat.

The analysis of the data provided by USDA (2016) suggests that cooked and roasted carcasses, with or without skin, contain less P, Na, Cu than raw carcasses with and without skin. When it comes to Ca, Fe, Zn and Se, an opposite situation is observed. On the other hand, the K content in raw skinless carcasses was higher than in cooked and roasted ones without skin. In the raw carcasses with skin the amount of K and Mg was smaller than in cooked and roasted carcasses with skin. The Mn content in raw and cooked skinless carcasses was identical, while in cooked carcasses with skin it was higher than in raw carcasses with skin (Tables 1, 3).

The research conducted by Kunachowicz et al. (2017) showed a higher content of P, Na, Ca, K, Mg, Fe, Zn, Cu, and Mn in cooked and roasted carcasses with skin than in raw carcasses with skin, while Belinsky and Kuhnlein (2000) found that the Ca content is higher in oven-roasted carcasses than in only boiled ones (Tables 1, 3). Geldenhuys et al. (2013) determined a higher amount of Fe, P, Na, Ca, K and Mg in the chest muscles of Egyptian geese which were cooked in a preheated oven (160°), in comparison to raw muscles. Yet, the boron content did not change when submitted to thermal culinary processing (Tables 2,4).

Oz and Celik (2015) conducted research on chest and leg muscles of Turkish geese slaughtered at the age of circa 24 weeks. Their estimates of mineral elements content were made both in raw meat as well as that submitted to boiling (<100C°), grilling (180C°), pan-frying without fat or oil (180C°), pan-frying with oil (180C°), deep-fat frying (180C°), oven roasting (200C°) and automatic microwave cooking; these various methods of cooking were applied for 5 to 35 min, depending on the method of cooking and type of muscle. The authors concluded that in terms of cooking, cooking methods had only a significant effect ($P < 0.05$) on the K content of breast meat and Fe content of both breast and leg meat samples. A smaller amount of potassium was noted after the meat was boiled. This situation indicates that the liquid phase of the meat contains most of the minerals. However, a significant increase in the Fe content both in chest and in leg muscles was established during pan-frying without fat and/oil. Yet, even though the content of P, Na, Ca, Mg Zn, Cu and Mn in chest and leg muscles of geese changed under the influence of various types of thermal processing, these changes were not statistically significant (Tables 2, 4).

GOOSE MEAT SATYSFYING THE DEMAND OF THE HUMAN BODY FOR MINERAL ELEMENTS

It is generally acknowledged that only a varied diet may cover the demands of the human body for all kinds of nutrients. Considering the mineral content per 100 g of cooked or roasted goose carcass without skin (suggested by USDA 2016), according to Recommended Dietary Allowances or Adequate Intake for people over 10 years old (Jarosz et al. 2017), it may be concluded that even small and occasional consumption of goose meat may provide the body with significant amount of these elements.

Consuming goose meat (100g of cooked/ roasted goose carcass without skin) will provide, depending on the age and sex, the largest amount of Se (46.4-63.8%), P (27.5-44.1%), Zn (28.8-39.6%), Cu (20.7-39.4%) and Fe (19.1-28.7%). It will also provide small amounts of K (11.1-16.25%), Mg (6.1-10.4%), Na (5.8-6.3%), Ca (1.1-1.45) and Mn (0.9-1.5%) in relation to RDA or AI standards. However, no such calculation was made for iodine, because its content in cooked/roasted goose carcass or muscles was not analytically established (it was only done in a raw carcass).

The parts of a goose carcass that are most often and most willingly consumed are chest and leg muscles submitted to thermal culinary processing (boiled, grilled, pan-fried without fat or oil, oven cooked). On the basis of the research concerning Turkish geese for slaughter (Oz, Celik 2015) it may be concluded that the largest amount of P, Na, Ca, Mg, Fe and Cu will be provided by a consumption of 100 g of chest muscles (Tables 2, 4), while 100 g of leg muscle of a goose will provide more K, Zn and Mn. In the case of Mn, its amount in muscles is not significantly different depending on the applied thermal process, and there has been no such research done for J and Se.

In many countries around the world wild goose meat is also consumed after being culinarily and thermally processed, hence this type of meat will provide the human body with larger amounts of Fe, Zn, Cu and Ca than the meat of geese for slaughter. As in the case of geese for slaughter, the chest muscles of wild geese provide larger amounts of Fa and Cu, while the leg muscles provide more Zn and Ca (Belinsky, Kuhnlein 2000). However, due to migration of wild geese and the risk of accumulation of elements to amounts beyond the level considered to be safe for humans, the content of their meat should be constantly monitored.

CONCLUSIONS

The data presented above shows that according to available local and international literature, there is a shortage of contemporary research concerning mineral element content in goose meet, which hinders further discussion on the issue. The findings reported since 1980s have been methodologically incomplete due to insufficient information concerning the breed/ variety of geese, their sex, raising conditions, feeding types and notification of mineral elements content in the feed, age at slaughter, the number of researched subjects/samples and the variety of analytical methods. Moreover, the research concerning the influence of thermal culinary processing on the mineral elements content was conducted on a small number of samples, which may affect its findings. The question concerning the bioavailability of mineral contents in carcasses/ muscles submitted to thermal processing remains open.

Considering the changes that took place in the last thirty years in in the intensity of agricultural production, progress in stock raising, breeding and feeding geese, feed supplementation, and increased interest in goose meat, it is evident that conducting new research concerning mineral content and/or updating the previous research findings is necessary.

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