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REVIEW PAPER

GOOSE MEAT AS A NUTRITIONAL SOURCE OF DIETARY SELENIUM*

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Abstract

Selenium (Se) has many important physiological functions in the human body, and its deficiency may lead to the development of diseases associated with oxidative stress or inflammation. As goose meat has been gaining popularity in many regions of the world, the aim of the work was to review the current state of knowledge regarding the Se content of raw and cooked goose meat, including that of birds raised on fortified feed, and to compare it with the recommended daily intake in humans. It was found that the Se content in goose meat depends on the breed, type of muscle, the presence of the skin and form of preparation. Fortification of feed with organic and inorganic Se increased its content in goose meat. Although adult Se intake recommendations vary by country, sex, age, and local norms, this amount ranges from 25 to 70 µg/day. Hence, even an occasional consumption of 100 g of roasted goose meat without skin fulfils 36.4 to 102.0% of the recommended daily consumption of Se, and meat with skin from 31.1 to 87.2%, depending on sex and the adopted local standard. Meat from wild geese fulfils 31.0 to 86.8% of the daily Se requirement. Based on the Nutrient Reference Values-Requirements (NRV-R) for selenium (60 µg 100 g^{-1}), on the label of the food product, 100g of meat roasted with and without skin, from both domestic and wild geese, covers 36.2 to 37.5% of the RDA. Our findings may be a useful guideline for consumers when making dietary choices. However, further research is needed on the influence of heat treatment on the concentration and retention of Se in goose meat.

Keywords: goose, meat, selenium, fortified, Recommended Dietary Allowance, Reference Values-Requirements.

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INTRODUCTION

Although goose meat can be a valuable source of minerals (Goluch, Haraf 2018), their levels depend on many factors such as age and sex of birds, rearing system, region, and fattening time, as well as their content in the feed, drinking water, premixes and even medication provided to the birds. One essential human bioelement is selenium (Se): an essential structural component of the mammalian enzyme, glutathione peroxidase (GPx) which is involved in the cellular defence system against reactive oxygen species (ROS). In poultry, the glutathione peroxidase family includes four Se-dependent forms of the enzyme; however only GSH-Px1 and GSH-Px4 are well characterised and have received substantial attention as important enzymes participating in chicken adaptation to commercially-relevant stresses (Surai et al. 2018). It is also needed by a second form of GPx that protects cell membrane lipids. Se is also present in the active site of type I iodothyronine deiodinase, which has an important function in thyroid hormone metabolism, and affects the conversion of tyroxine to triiodothyronine (Wang et al. 2018). In addition, it also stimulates various metabolic processes, and protects against cadmium, lead, thallium and silver toxicity by forming inactive and non-toxic complexes with them (Kiełczykowska et al. 2018).

Epidemiological studies indicate that low Se consumption may result in oxidative stress or inflammation and the development of various cardiovascular and neurodegenerative diseases known to be associated with aging (Alzheimer's disease), type 2 diabetes, asthma, cirrhosis and some forms of cancer. In addition, Se deficiency may reduce immunity and increase susceptibility to viral infections (Fairweather-Tait et al. 2011, Méplan, Hughes 2020). It has been estimated that the mean Se consumption varies considerably, from 10 μg in Se-deficient regions to 1400 μg in regions with excessive levels; nevertheless, in most countries, the level of consumption remains low (20-40 μg/day). Se consumption ranges from 100.5 μg/day to 158.5 μg/day among adults in the USA (aged 19-50 years) (Institute of Medicine, 2000), and from 31.0 to 65.6 μg/day among adults in European countries (≥18 years of age) – EFSA 2014. In contrast, Eastern European countries have a lower Se intake than Western European countries (Stolfaner, Morrse 2015), and the mean consumption of Se in Poland is only 37.9 μg/day in women and 62.2 μg/day in men (Flynn et al. 2009). Furthermore, inadequate Se consumption (70 μg/day) has also been noted in New Guinea, Nepal, India, Egypt, Belgium, Serbia, Slovenia, Turkey, England, Spain, Slovakia, Sweden, France, Portugal, Germany, Italy and Austria (Surai, 2006). In contrast, higher consumption of Se (over 200 μg/day) was recorded in Canada, Venezuela, the Philippines, Thailand and Japan (Sobolev et al. 2017). The upper appropriate (i.e. safe) level of Se consumption for adults from all sources i.e. both diet and supplements, is believed to be 300 μg/day (EFSA 2006).

Se intake can be improved by increasing the consumption of four key groups of foods: 1) natural sources such as fish, shellfish and nuts, 2) dietary supplements, 3) directly-enriched products, e.g. bread, beverages, and 4) indirectly-enriched products, i.e. foods of plant or animal origin produced with the use of selenium-fortified feed (Sobolev et al. 2017). One potential source of Se in the human diet is goose meat, a ready source of selenoproteins, i.e. proteins that include the amino acid selenocysteine (Sec). Hence, meat from geese raised with either natural fodder, or with feed supplemented with inorganic sodium selenite, or organic Se-methionine (Se-Met) or selenocysteine (Se-Cys), can be a source of Se in the human diet. Currently, a number of selenium-enriched feedstuffs are used for poultry nutrition, such as those enriched with algae (*Scenedesmus quadricauda*, *Chlorella*), Se-enriched yeast, selenium chelate or nano-Se (Suchý et al. 2014).

However, selenium is a heavy metal and excessive intake leads to chronic poisoning (Nuttal 2006). Most studies examining the content of Se in goose muscle tissue have done so in the context of its potential as a bioindicator of environmental pollution (Pilarczyk et al. 2019) rather than as a nutritional source. In addition, most studies of mineral content in poultry meat do not consider separate assays of the breast and leg meat, i.e. the parts most commonly eaten by humans. However, these muscles differ with regard to their histological structure and their metabolism, and this may affect their mineral content, including that of selenium (Wideman et al. 2016). Similarly, male and female geese differ in their growth rate, which affects the amount of feed, and thus selenium, consumed; this will influence its use in the body and its excretion. In addition, consumers commonly remove the skin, and subcutaneous fat, from the meat prior to cooking to reduce their fat intake, either as a precaution against cardiovascular disease or to lose weight. However, the skin is not only a source of fat and cholesterol, but also various sulfuric amino acids, collagen, elastin, fat-soluble vitamins and minerals (Marangoni et al. 2105, Stangierski, Lesnierowski 2015), and it may be of interest to the consumer to know the Se content of goose meat, with and without skin.

Therefore, the aim of the study was to review the present state of knowledge concerning the Se content in raw and cooked goose meat, including meat from geese raised on fortified fodder, and to compare it with the recommended daily intake for Se in humans.

SELENIUM CONTENT IN RAW GOOSE MEAT

Chen et al. (2013) report an Se content of 0.346 (0.221-0.498) mg kg^{-1} fresh mass in goose meat purchased in commercial stores in Taiwan. That study, however, did not take into account the muscle type, sex of the birds or the presence of skin. Data from the public and free the USDA database (2019) indicates a lower Se content in raw goose meat with skin (0.144 mg kg^{-1} of tissue) than without (0.168 mg kg^{-1}).

Higher Se content (0.14 mg kg^{-1} dry mass) has been noted in the pectoral muscle tissue of nine-week-old male grey geese (Mirande × Atiquere, purchased from Gaomi Hehong Goose Industry, Shandong, China) – Baowei et al. (2011) than in Canadian wild geese, *Branta canadensis* (0.00035 mg kg^{-1} of tissue) – Horak et al. (2014). In addition, in Polish 16-week-old Koluda geese, higher Se content has been reported in breast and leg muscles of male birds (0.098 and 0.082 mg kg^{-1} of tissue) compared to females (0.087 and 0.067 mg kg^{-1} of tissue); however, these differences were not statistically significant (Łukaszewicz et al. 2016).

SELENIUM CONTENT IN CULINARY GOOSE MEAT

The selenium content in heat-treated domestic and wild goose meat is presented in Table 1. The USDA database (2019) notes higher Se levels in roast goose meat without skin (0.255 mg kg^{-1} of tissue) than in meat with skin (0.218 mg kg^{-1}), which has a similar Se content to roast wild goose (0.2071 mg kg^{-1}). In addition, the type of culinary processing, e.g. boiling, baking, frying and grilling, also significantly affects the mineral content in goose meat, and their retention (Goluch et al. 2021).

Bratakos et al. (1988) found that Se loss during culinary processing ranges from 13 to 41% depending on the type of meat or processing (e.g. boiled under pressure in a pressure cooker, fried in oil, grilled). For meats, the degree of loss was found to depend on the kind of meat treated, irrespective of the cooking practice. Thus, despite the shorter cooking time, chicken lost more selenium than lamb, while beef and calf lost the least. The loss

Table 1

Selenium content of goose meat, both raw and cooked

Meat	Goose	Selenium (mg kg^{-1}) in meat			Reference
		carcass	breast	leg/thigh	
Raw					
Meat only, raw	-	0.168	-	-	USDA (2019)
Meat and skin, raw	-	0.144	-	-	USDA (2019)
Raw	White Koluda®	-	0.0925	0.0745	Łukaszewicz et al. (2016)
Raw	Canada	-	0.00035	-	Horak et al. (2014)
Raw	gray	-	0.14	-	Boawei et al. (2011)
Raw	Gorki breed	-	0.131	0.115	Sobolev et al. (2017)
Thermal culinary processing					
Meat only, cooked, roasted	-	0.255	-	-	USDA (2019)
Meat and skin, cooked, roasted	-	0.218	-	-	USDA (2019)
Goose, wild roasted	-	0.217	-	-	USDA (2019)

of selenium itself depends on the form of preparation: it can enter the aqueous (or oil) phase, where part of it can be absorbed on the walls of the utensils, and the rest can escape in the gaseous phase. Frying and grilling were found to cause the highest percentage of selenium loss; boiled meat, despite its reduction in content, can still be a valuable source of Se in the diet.

Unfortunately, due to the paucity of available literature on the effect of heat treatment on the Se content of goose breast and leg meat (with and without skin), any more in-depth discussion is impossible.

SELENIUM CONTENT IN GOOSE MEAT RAISED ON FORTIFIED FEED

It is possible to obtain raw goose meat products with high Se content, which is highly desirable in Se-deficient regions. The European Commission Regulation (2019) permits the use of poultry feed fortified with sodium selenite and zinc L-selenomethionine, as they appear to have no negative impact on animal health, human health or the environment. The maximum amounts of supplementation that can be fed to poultry are 0.3 mg kg^{-1} in most countries for inorganic selenium (sodium selenite) – Fda, 1987, and 0.3 mg kg^{-1} in North America (FDA, 2003) and 0.5 mg kg^{-1} in Europe for organic selenium (selenium-enriched yeast or selenomethionine) – Ibrahim et al. (2019).

Baowei et al. (2011) from Qingdao Agricultural University (QAU) examine the effect of nine-week feed supplementation of male gray geese with organic selenium (selenium-enriched yeast). After the course, the fortified groups demonstrated significantly (P<0.05) higher Se content in the breast tissue, *viz.* 0.40, 0.47 and 0.58 mg kg^{-1} dry mass of tissue following 0.1, 0.3 and 0.5 mg kg^{-1} supplementation, compared to control group (0.14 mg kg^{-1} dry mass). The greatest increases were all detected in the 0.5 mg kg^{-1} group (Table 2).

Łukaszewicz et al. (2016) found that fortification of fodder with organic selenium (selenium yeast Sel-PlexTM) at a dose of 0.3 mg kg^{-1}, with 100 mg kg^{-1} vitamin E, in male and female Koluda geese during rearing (week 1-13) resulted in increased Se values in the breast and leg muscles (♀ 0.162-0.170 vs. ♂ 0.190-0.161 mg kg^{-1} of tissue); these values were 1.88 to 2.25-times higher than control values. However, sex had no significant effect on selenium accumulation in muscles.

Sobolev et al. (2017) conducted a 75-day experiment on Gorki goslings, in which the feed was fortified with 0.4, 0.5 and 0.6 mg kg^{-1} sodium selenite. The controls demonstrated a significantly higher Se content in breast muscles (0.131 mg kg^{-1} of tissue) compared to leg muscles (0.115 mg kg^{-1}). Supplementation of the feed with selenium resulted in a significant (P≤0.001) increase in Se density in both types of muscles, compared to controls. Interestingly, following 0.4 and 0.5 mg kg^{-1} fortification, higher Se content was found in the leg muscles (0.181; 0.184 mg kg^{-1} of tissue) than in the pectoral muscles (0.177; 0.182 mg kg^{-1} of tissue), while 0.6 mg kg^{-1} Se fortification resulted

Table 2

Selenium content in raw meat from geese receiving selenium-fortified feed

Gesse	Fortified compound	Dose selenium (mg kg-1 feed)	Selenium (mg kg-1) in meat		Reference
			breast	leg/thigh	
Qingdao Agricultural University (QAU) gray geese	selenium-enriched yeast	0 0.1 0.3 0.5	0.140 ♂ 0.410 ♂ 0.410 ♂ 0.580 ♂	- - - -	Baowei et al. (2011)
White Koluda®	selenium yeast Sel-Plex™	0 0.3 + 100 mg vitamin E	0.087 ♀ 0.162 ♀ 0.190 ♀	0.098 ♂ 0.170 ♀ 0.161 ♂	Łukaszewicz et al. (2016)
Gorki breed	sodium selenite	0 0.4 0.5 0.6	0.131 0.177 0.182 0.186	0.115 0.181 0.184 0.186	Sobolev et al. (2017)

in similar Se content in both types of muscles (0.186 mg kg^{-1} of tissue). Se content increased by 35%, 38.9% and 42.0% after fortification in the pectoral muscles, depending on the level of fortification (i.e. 0.4, 0.5 and 0.6 mg kg^{-1}), and by 57.4%, 60.0% and 61.7% in the leg muscles, compared to the control group.

GOOSE MEAT AND MEETING THE DAILY INTAKE FOR SELENIUM

Recommendations regarding the amount of selenium consumption (Table 3) by adults vary according to sex, age, Se content in the blood and the type of norm: e.g. AI – Adequate Intake, EAR – Estimated Average Requirement, RDA – Recommended Dietary Allowance, RI – Reference Intake. Se intake recommendations range from 25 to 70 μg/day. For example, the WHO/FAO (2005) recommends an intake of 26 μg/day for women aged 19 to 65 years (the RI level), and 25 μg/day for those over 66 years of age, and 34 and 33 μg/day for these groups of men. For residents of Scandinavian countries, the RI values for Se are 50 μg/day for women and 60 μg/day for men (Nordic Nutrition... 2012). The EU Scientific Committee on Food (SCF) and the US Institute of Medicine recommend 55 μg/day for both men and women (the RDA). On the other hand, EFSA (2014) and DACH (2015) recommend an adequate intake (AI) in the range of 60-70 μg/day. Nevertheless, despite the different standards, the consumption of 100 g of goose meat (raw or heat-treated) will cover the recommended intake of Se for women and men in different countries, depending on the adopted level of the AI, RI, EAR or RDA standard.

Our calculations indicate that a 100 g portion of raw goose carcass without skin (without breakdown by muscle type) will cover 24.0-67.0% of the daily requirements of women, and 24.0-51.0% of men, depending on the standard (Table 3). The same portion of raw goose meat with skin will cover a smaller percentage of the daily requirement: 20.6-57.6% for women and 20.6-43.6% for men.

Table 3

Fulfilment of the demand (%) for selenium of adults by the consumption of 100 g of goose meat, with regard to the recommendation, standards and Nutrient Reference Values-Requirements

Meat	Selenium (µg 100 g^{-1})	DACH (2015) AI		EFSA (2014) AI	HCNL (2014) NCM (2014) RI		WHO/FAO (2004) RI		NIPH-NIH (2020) IOM (2000) EAR	NIPH-NIH (2020) IOM (2000) RDA	NRV-R
		60 ♀	70♂	70 ♀♂	50 ♀	60♂	25-26 ♀	33-34♂	45 ♀♂	55 ♀♂	60♀♂
Raw meat only	168.0	28.0	24.0	24.0	34.0	28.0	67.0-65.0	51.0-49.0	37.3	30.5	28.0
Raw meat and skin	144.0	24.0	20.6	20.6	28.8	24.0	57.6-55.4	43.6-42.4	32.0	26.2	24.0
Raw White Koluda® geese	92.5 breast 74.5 leg	15.4 12.4	13.2 10.6	13.2 10.6	18.5 14.9	15.4 12.4	37.0-35.6 29.8-28.7	28.0-27.2 22.6-21.9	20.6 16.6	16.8 13.5	15.4 12.4
Raw Canada geese	0.35 breast	0.06	0.05	0.05	0.07	0.06	0.14-0.13	0.11-0.10	0.08	0.06	0.06
Raw Gray geese	140.0 breast	23.3	20.0	20.0	28.0	23.3	56.0-53.8	42.4-41.2	31.1	25.5	23.3
Raw Gorki breed geese	131.0 breast 115.0 leg	21.8 19.2	18.7 16.4	18.7 16.4	26.2 23.04	21.8 19.2	52.4-50.4 46.0-44.2	39.7-38.5 34.8-33.8	29.1 25.5	23.8 20.9	21.8 19.2
Meat only, cooked, roasted	255.0	37.5	36.4	36.4	51.0	37.5	102.0-98.1	77.3-75.0	56.7	46.4	37.5
Meat and skin, cooked, roasted	218.0	36.3	31.1	31.1	43.6	36.3	87.2-83.8	66.1-64.1	48.4	39.6	36.3
Goose, wild roasted	217.0	36.2	31.0	31.0	43.4	36.2	86.8-83.5	65.8-63.8	48.2	39.5	36.2

AI – Adequate Intake, RI – Reference Intakes, EAR – Estimated Average Requirement, RDA – Recommended Dietary Allowance, DACH – Nutrition Societies in Germany and Austria and Switzerland (D-A-CH), EFSA – European Food Safety Authority, HNCL – Health Council of the Netherlands, NCM – Nordic Council of Ministers, NIPH-NIH – National Institute of Public Health-National Institute of Hygiene, IOM – Institute of Medicine, NRV-R – Nutrient Reference Values-Requirements

In addition, 100 g of raw goose pectoral muscles (depending on the breed) can provide between 0.05% and 56% of the daily dietary requirement of Se for women, and 0.05-42.4% for men. The same portion of raw goose leg muscle will provide 10.6 to 46.0% of the daily dietary Se intake for women, and 10.6 to 34.8% for men. However, eating raw goose meat is not popular, and in most regions of the world, it is subjected to various culinary treatments. Therefore, 100 g of roast domestic goose meat, without skin, will cover 36.4 to 102.0% the daily requirement for women, and 36.4-77.3% for men, while the same portion of domestic goose meat cooked with the skin will provide less Se, i.e. 31.1-87.2% for men and 31.1-66.1% for women. Similarly, 100 g of roast wild goose meat will provide 31.0-86.8% of the daily Se requirement in men and 31.0-65.8% in women.

The higher Se content in roasted meat is believed to result from its retention in muscle proteins during high temperature treatment. During roasting, when the temperature is between 100 and 140°C, the digestibility of proteins is reduced by the formation of intramolecular and intermolecular covalent bonds (Gomez et al. 2020). In addition, it has already been shown (Wołoszyn et al. 2020) that the crust formed when goose meat is roasted prevents the escape of water, and thus minerals; this explains their greater concentration in cooked meat.

GOOSE MEAT AND NUTRIENT REFERENCE VALUES--REQUIREMENTS

For a consumer, the information on the label concerning the energy and nutritional value is important when purchasing food products; this information should also include a reference value of the daily intake (NRV). These recommendations are based on best available knowledge of the daily amount of energy or nutrient needed to maintain good health (Levis 2019). The Codex Committee on Nutrition and Foods for Special Dietary Uses (2014) stipulates a Nutrient Reference Value – Requirement (NRV-R) value of 60 μg for selenium. Taking NRV-R into account, our calculations show that raw meat without skin constitutes 28% of the daily requirement (regardless of sex), and that goose with skin constitutes 24% (Table 3). In contrast, raw goose breast meat constitutes an NRV-R ranging from 0.06 to 23.3%, and leg muscles from 12.4 to 19.2%. Similarly, meat roasted with and without skin, from both domestic and wild geese, covers 36.2-37.5% of the Se requirement.

It is important, though, to consider that the availability of Se for humans ranges from 55-65%, with the exact value depending on the chemical form. The 2000 report of the US Food and Nutrition Board (Institute of Medicine 2000) suggests that most dietary selenium is highly bioavailable: >90% of selenomethionine is absorbed, selenocysteine appears to be absorbed very well, and 100% of selenate is absorbed but with a significant fraction lost in the urine. In addition, >50% of selenite is absorbed, depending on luminal interactions, and is better retained than selenate.

CONCLUSION

The literature regarding this subject is varied. Most findings apply to commercially-sold goose meat and have been derived from experimental research based on materials from different breeds of geese, of both sexes and receiving different diets. Although it has been found that the Se content of goose meat is increased by fortifying forage with organic and inorganic selenium, the exact amount of Se varies considerably between studies; this may result from differences in the methods used for its determination, such as fluorescence, atomic absorption spectrometry or ICP-MS. Little is known of the Se content in goose meat, and further studies are needed to determine the influence of various thermal treatments on its concentration and retention.

The information and calculations obtained from our literature review can provide useful guidance for consumers when making food choices. Depending on its type, the presence of the skin during consumption and the choice of culinary treatment, goose meat can be a valuable component of a varied diet, providing selenium in addition to basic nutrients.

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