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Impact of Various Types of Heat Processing on the Selenium Content of Goose Breast Meat

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Abstract: The purpose of this study was to 1) examine the impact of various types of heat processing used by consumers (water bath cooking WBC, oven convection roasting OCR, grilling G, pan frying PF) on the selenium content and its retention in goose breast meat (with and without skin); 2) Estimation of coverage of this element's daily requirement in adults after consuming 100 g of goose breast meat. The material used in the study comprised 36 breast muscles cut from carcasses of 17-week-old White Koluda geese. The moisture, ash, and selenium were determined in both raw and thermally processed muscles. It has been concluded that various methods of heat processing significantly impact cooking loss, moisture, ash and selenium content of meat. The heat processing increased the selenium content of the muscle regardless of the presence of skin, which affects the possibility of covering adults' Nutrient Reference Values-Requirements (NRV-R) for this element in the range of 33.3-44.8%. Goose breast meat can be a valuable component of a diversified diet. It provides many nutrients. It is also a safe source of selenium. It is unlikely that adult consumers, even those who eat goose regularly, will exceed this element's upper tolerable intake level.

Keywords: selenium; goose; meat; heat treatment; recommended dietary allowance; nutrient reference values-requirements

1. Introduction

Selenium (Se) is among the bio-elements that should be supplied to the human body with the diet because it performs many vital physiological functions. Selenium's crucial role in improving the immune system's functioning has become important in the prevention/treatment of COVID-19 caused by the SARS-CoV-2 virus [1,2]. The development of diseases can be caused by both dietary selenium deficiency (increased oxidative stress, Keshan disease, Kashin Beck, abnormalities in thyroid function, cardiovascular and/or neurodegenerative diseases, type 2 diabetes, asthma, cirrhosis, some malignancies) and excess (selenosis) [3]. Compared to other micronutrients, Se has one of the narrowest ranges between its toxic dose (> 400 μg/day) and dietary deficiency (< 40 μg/day) [4,5]. Therefore, the source of this component in the diet is essential. Selenium is found in both plant and animal products. The content of Se in plant foods can be affected by different uptake rates by plants, which can be related to plant type, soil, pH, microbial activity, rainfall and several other biogeochemical parameters [5]. For this reason, the selenium content of plant products is variable. On the other hand, animal tissues show less variation in this regard. Animal products containing selenium are mainly liver, kidney and skeletal muscles.

Goose are waterfowl mainly consumed in some regions of the world [6]. According to the Food and Agriculture Organization of the United Nations (years 1994-2021), the most significant goose meat production is found in China (95.1%), 3.4% in Europe, and 1.4% in Africa. The most significant amount of goose meat in European countries is produced in Hungary, Poland and Ukraine [7].

The meat obtained from geese can be a good source of minerals in the human diet. However, mineral content in meat is influenced by many factors, including species, breed, gender, age, muscle

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type, nutrition, genetics, and cooking methods [7–10]. The role of selenium in the diet and its occurrence in raw goose meat, including as a result of feed fortification, has already been devoted to a review article [11]. It shows that the Se content of goose meat depends on the origin (domestic, wild), breed, type of muscle, presence of skin and cooking treatment used. Fortification of feed with Se (organic and inorganic) increases its content in goose muscles.

The application of heat during household cooking of foodstuffs encompasses a variety of processes, such as boiling, frying, steaming, baking, stewing and roasting, in microwave, steam and traditional ovens. Key benefits of thermal processing include the inactivation of foodborne pathogens, natural toxins or other harmful components, extended shelf life, improved digestibility and bioavailability of nutrients, improved palatability, flavour, texture and aroma, and enhanced functional properties. However, heat processing can also be associated with unintended, undesirable consequences, such as loss of certain nutrients [12]. Despite the development of non-thermal processing technologies, such as irradiation and high-pressure processing, among others, heat continues to be the treatment of choice to enhance the characteristics of meat products, including safety and quality [13,14].

In addition, as part of cardiovascular disease prevention or weight reduction, consumers are encouraged to remove the skin and subcutaneous fat from carcass parts before cooking. The skin, occurring on the culinary elements, contains sulfur amino acids, collagen, elastin, fat, cholesterol, fat-soluble vitamins, and minerals [15]. Therefore, information about the selenium content of goose carcass parts with or without skin can be important for consumers when making dietary choices. Since there are few scientific reports on the selenium content of goose meat, the purpose of this study was to 1) determine the effect of popular heat treatment techniques on its concentration and retention in breast muscle and 2) estimate the coverage of AI (Adequate Intake), EAR (Estimated Average Requirement), RDA (Recommended Dietary Allowance), RI (Reference Intakes) and NRV-R (Nutrient Reference Values-Requirements) for selenium from 100 g servings of goose meat in adults.

2. Materials and Methods

2.1. Meat samples

The experimental material was the breast muscles (*Pectoralis major*) of 17-week-old White Koluda geese. After fattening, the geese are known as "Polish oat geese". Birds were reared on the same commercial farm and fed the same diet [16]. Before the slaughter, geese were subjected to feed withdrawal for 12 hours. Next, the birds were slaughtered in a poultry plant, according to the regulations applied in the Polish poultry industry. The eviscerated carcasses were placed in a 2°C to 4°C cooler for 24 hours, and then the breast muscles were cut out of the carcasses. Meat samples (N=36, 12 raw and 24 cooked breast muscles) were standardised for thickness and weight (average weight for breast muscles with skin and subcutaneous fat ≈ 384.7 g, without skin ≈ 286.4 g).

2.2. Heat processing

Heat treatment methods commonly used in the home processing of poultry meat (boiling in a water bath, grilling, pan-frying without fat, roasting in a convection oven) were selected for the study. No salt (NaCl), spices or food additives were added to the meat. After heat treatment, muscles were allowed to cool to room temperature for about two hours. Each raw and cooked breast muscle was ground separately (3 mm mesh diameter) in an electric mincer (model MM/1000/887 Zelmer, Poland).

Oven Convection Roasting (OCR). Each breast muscle was roasted in a forced-air convection oven (model EB7551B Fusion, Amica Ltd., Wronki, Poland) until a final internal temperature of 75°C inside the sample was reached. Before roasting, each muscle was wrapped in aluminium foil, and the oven was heated to T=200°C. The temperature inside each muscle was monitored using Teflon-coated thermocouples (Type T, Omega Engi-neering Inc., Stamford, CT, USA) connected to a Doric multichannel data logger (VAS Engineering Inc., San Diego, CA, USA).

Pan Frying (PF). Pan frying was performed using an electric pan (model 48155, Unold AG, Hockenheim, Germany). The muscles were fried on a preheated pan (at 160°C) and turned when they

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reached an internal temperature of 40°C. Processing was finished when the inside temperature of each sample was 75°C.

Water Bath Cooking (WBC). Each muscle, wrapped in a plastic bag, was immersed in water at 90°C (model SW 22, Julabo GmbH, Seelbach, Germany). Cooking continued until the temperature reached 75 °C inside the samples.

Grilling (G). Whole muscles were placed between two heating plates of an electric grill (model PD 2020R, Red Fox, Warszawa, Poland), preheated to 200°C. The samples were grilled until the temperature in the centre of each specimen reached 75°C.

2.3. Chemical analysis

The moisture and ash content (%) of raw breast muscles (n=6 with skin and n=6 without skin) and the muscles subjected to heat processing (n=12 with skin and n=12 without skin for each heat processing type) were analysed with the use of reference methods (EN ISO 9831:2004 and AOAC [17]). Moisture was measured by the oven-drying of 2 g samples at 102°C for 12 hrs to a constant weight in a SUP-4M laboratory dryer (Wawa-Med, Warsaw, Poland) (950.46B, p. 39.1.02). Ash, i.e. total mineral content, was determined by incineration at 550°C for ten hours in an FCE 7SHM muffle furnace Czylok (Jastrzębie Zdrój, Poland) (920.153, p.39.1.09).

Selenium (Se) concentrations were determined using Watkinson's spectrofluorometric method, modified by Grzebuła and Witkowski [18]. The samples were digested in HNO_3 (230°C/180 min) and $HClO_4$ (310°C/20 min). Then, 9% HCl was added to the samples to reduce selenates (Se VI) to selenites (Se IV). The Se was derivatized with 2,3-diaminonaphthalene (Sigma-Aldrich), and the complex was extracted into cyclohexane. The Se concentration was determined fluorometrically using a Shimadzu RF-5001 PC spectrofluorometer. The excitation wavelength was 376 nm, and the fluorescence emission wavelength was 518 nm. The accuracy of the analytical procedure was verified using Certified Reference Material ERM-BB185 (bovine liver). The mean recovery was 94% of the reference value.

2.4. Calculation indices

Cooking loss (CL) was calculated [19] from differences in the weights before (Wb) and after heat processing (Wt) of the samples cooled down to room temperature.

$$CL = (Wb - Wt) / Wb \cdot 100\%$$

The following equation was used to calculate the percentage of selenium retention after heat processing of meat [20]:

$$\%\ Retention = \frac{Se\ content/100\ g\ of\ heat\ processed\ meat}{Se\ content/100\ g\ of\ raw\ meat} \times \frac{meat\ weight\ (g)\ after\ heat\ processing}{meat\ weight\ (g)\ before\ heat\ processing} \times 100$$

2.5. Statistical Analysis

The obtained results were examined for normality of distribution with Shapiro-Wilk Test and variation of homogeneity with Laven's test. Two-way analysis of variance (ANOVA) was performed. Statistical significance of differences between the averages of the groups was calculated using Tukey's multiple comparisons test, on the level of significance $p \leq 0.05$ and $p \leq 0.01$, with the use of Statistica®13.1 software [21]. The tables show arithmetic means and standard errors of the mean (SEM). All data are reported as means (±SEM) of 2 parallel measurements.

3. Results and Discussion

Heat processing methods have been most commonly used to accomplish two main objectives: cooking food, i.e., making it flavourful and easier to chew and digest, and ensuring food safety by inactivating pathogen microorganisms and enzymes [22]. Heat processes can be classified into three primary groups: moist, dry, and microwave-based. The treatments we used are among the moist (water bath cooking WBC, where the source of heat is usually hot liquid media, such as water) and dry (oven convection roasting OCR, where the source of heat is hot air in ovens and hot surfaces in pan-fried PF or heating plates in grilled G). These are the conventional techniques used by consumers [13,22].

3.1. Cooking loss

Cooking loss is a combination of liquid and soluble matters lost from the meat during cooking. Total cooking losses rely on the temperature and rate of heating [8].

In our study (Table 1), both the type of muscle (with or without skin) and the type of heat processing used significantly ($p \leq 0.01$) affected cooking loss in goose breast muscles. Significantly higher CLs characterised muscles with skin than without skin (43.2 vs. 38.7%) in all heat processing methods. This is because goose meat, which belongs to waterfowl, contains significant amounts of subcutaneous and intramuscular fat lost during heat treatment. Similarly, other authors [9,19] found significantly ($p \leq 0.05$) greater CL in the pectoral muscles of White Koluda goose with skin than without skin. In our study, we also observed a significant ($p \leq 0.01$) effect of heat treatment on increasing cooking loss in muscle (G, OCR, PF > WBC), even though in our experiment, the final temperature inside the sample was the same (75°C). Evaporation, dripping and structural changes cause water loss during cooking, oven convection roasting, grilling, and pan-frying of meat. Shrinkage during cooking causes the most noteworthy water loss at 60–70°C, and it is assumed that water is removed by the pressure applied by the shrinking connective tissue on the aqueous solution in the extracellular void [10].

Similarly, Wołoszyn et al. [19] showed significant ($p \leq 0.05$) the least cooking loss in the pectoral muscles of White Koluda goose under water bath cooking, compared to the other methods: OCR, G and PF. In a study of other thermal treatments, Wereńska [9] showed the lowest value of cooking loss for sous-vide (27.16%) samples compared with microwave (40.16%) cooking and stewing (47.63%).

In our study, the interaction between the type of muscle (with or without skin) and the type of heat treatment used proved significant ($p \leq 0.01$). In contrast, Wołoszyn et al. 2020 [19] showed no interaction between the type of meat and heat treatment in White Koluda goose.

3.2. Moisture content

Both the type of muscle (with or without skin) and the type of heat treatment significantly ($p \leq 0.01$) affected the moisture content of White Koluda goose pectoral muscles (Table 1). The skinless muscles were characterised by significantly ($p \leq 0.01$) larger content of moisture than those with skin (61.5 vs. 58.6%). In contrast, significantly ($p \leq 0.01$) larger moisture content in White Koluda goose breast muscles without skin than with skin was found by Goluch et al. [16] and Wereńska et al. [23] (62.5 vs. 58.3% and 62.91 vs. 58.94 respectively).

The content of moisture in the raw muscles (68.9%) and WBC (63.9%) was significantly ($p \leq 0.01$) higher than in other heat-treated samples (PF, OR, G). Belinsky and Kuhnlein [24] found that heat processing influences the moisture content in Canada Goose breast muscles with skin: FR>B>OCR (56.1>51.4>50.6% respectively). Differently, Oz and Celik [25] have found no significant impact of 7 types of heat processing (boiling, grilling, pan frying without fat or oil, pan frying with oil, deep-fat frying, oven roasting, microwave cooking) on the fluctuations in moisture content of Turkish skinless geese breast muscles.

Unlike the study by Goluch et al. [16], in our study, the interaction between the type of muscle (with or without skin) and the method of heat treatment, in the case of water content, did not prove significant.

3.3. Ash content

There are no significant differences in ash content between muscle types (with or without skin) (Table 1). However, Goluch et al. [16] and Werenska et al. [23] found significantly ($p \leq 0.01$) higher ash content in White Koluda goose breast muscles without skin than with skin (1.40 vs. 1.25% and 1.47 vs. 1.12 respectively).

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These studies revealed significant ($p \leq 0.01$) changes in the ash content in the muscles depending on the type of heat processing used. The heat processing methods caused a significant general increase in ash content in muscles compared to raw muscles ($p \leq 0.01$). Raw meat had the lowest ash content (1.39%) compared to heat-treated meat. The highest ash content was found in OCR-treated meat (2.21%). Goluch et al. [16] also found significantly ($p \leq 0.01$) the lowest ash content in raw White Koluda goose muscles (1.10%) and the highest in grilled muscles (1.61%). In the case of ash content, the interaction between the type of meat and the heat processing method was insignificant. In contrast, Goluch et al. [16] found the highest ash content in grilled muscles without skin (1.74%), while in grilled and fried muscles with skin, the content was 1.47 and 1.48%, respectively.

3.4. Ash retention

Food contains many heat-sensitive nutrients, including minerals. Retention of these nutrients in food products requires innovative approaches for process design because of their sensitivity to various physical and chemical factors, which causes either loss of biological functionality, chemical degradation and premature or incomplete release. Maximum destruction during heat processes is of vitamins and minerals [26]. Retention of nutrients in food subjected to heat processing is vital for dietary reasons.

In our study, there was no significant effect of either the type of muscle (with or without skin), the heat treatments used or the interaction between them on ash retention. Similarly, Goluch et al. [16] and Wereńska et al. [23] found no significant differences in ash retention in White Koluda goose breast muscles between those without and with skin. In contrast, in studies with thermal treatments different from ours, Wereńska [9] found significantly ($p \leq 0.05$) higher ash retention in goose breast muscles treated with sous-vide (93.55%) compared with microwave (89.97%) cooking and stewing (67.16%).

3.5. Selenium content and retention

The primary dietary bioavailable forms of selenium (≥ 90% bioavailability) are selenomethionine (SeMet) and selenocysteine (SeC). The inorganic forms of selenium (selenate $[SeO_4]^{2-}$, selenite $[SeO_3]^{2-}$, etc.) also have good bioavailability (60–70% bioavailability) but less than SeMet and SeC. SeMet is absorbed from the intestine, whereas the inorganic forms of selenium (selenate, selenite, etc.) are absorbed by the simple diffusion process. The absorbed selenium sources are converted to selenide (HSe^{2-}) in the liver, which is utilised for the activation/generation of selenoenzymes. Glutathione peroxidase (GSH-Px), type I iodothyronine deiodinase and selenoprotein P were identified as specific selenium-containing Se-Cys proteins. The liver is the chief organ storing selenium and supplies selenium to other tissues on a need basis. Excretion of absorbed Se as methylated Se compounds, e.g. trimethylselenonium, occurs mainly through urine [2,5,27]. Retention of Se is inversely related to intake; low Se intake results in lower urinary excretion and increased body retention of Se.

Geese take up selenium with conventional feed in organic (SeMet and Se-Cys) or inorganic (sodium selenite) form. In regions of the world where this element is found to be deficient in the environment, geese can take it up from feed fortified with Se-enriched yeast, selenium chelate, nano-Se or algae such as *Scenedesmus quadricauda* and Chlorella. Drinking water is also a source of selenium in goose nutrition. Although the Se content in water is minimal (10-20 μg/L), there are regions of the world where the content of this element in water is high, including areas of the US, Venezuela and China [28,29].

Skeletal muscle is reported to be the major Se body pool, accounting for approximately half of the total body Se. Goose meat contains selenoproteins, of which the main biologically active form of selenium is the amino acid selenocysteine (SeC), 81% of which is absorbed mainly in the small intestine [30].

During heat treatment, culinary losses due to mass transfer depend not only on cooking conditions such as cooking method, cooking surface, cooking temperature and cooking time but also on meat properties such as moisture, fat and protein content, pH value of raw meat and meat size [31]. Losses of minerals during heat treatment of meat also depend on the form in which they occur.

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Minerals in the form of soluble dissociated salts (part of Na, small amounts of P, Ca and K) end up in the leakage. Ingredients such as Fe, which combine with proteins, remain in the meat. Several research papers [16,24,25,27,32] have been devoted to the effect of heat treatment on the content of minerals (Ca, K, Mg, Na, Fe, Cu, Zn, Mn, P, B, Al) in goose meat, but they did not address selenium.

In our study, muscle type (with or without skin) had no significant effect on the selenium content of White Koluda goose breast muscles. However, a significant ($p \leq 0.01$) effect of heat processing on the value of this element in muscles was observed. Raw muscles (15.3 µg/100g FM) had the lowest selenium content, compared to heat-treated ones: R< OCR, G, PF, WBC (25.8; 25.6; 24.3; 21.8 3 µg/100g FM respectively). The Se content found in raw breast muscles was higher than that determined by Boawei et al. [28], Horak et al. [29], Łukaszewicz et al.[30] and Sobolev et al. [33] (14; 0.035; 13.1; 9.25 µg/100g respectively). The differences in the values obtained are due to the origin of goose meat (commercial sales, experimental studies), different breeds (White Koluda, Canada goose, Gray, Gorki breed), sex and diet. There was also a significant ($p \leq 0.01$) interaction between the type of muscle (with or without skin) and the heat processing used. Significantly, the highest selenium content was found in OCR-treated skinless muscle (26.7 µg/100g) compared to raw muscle (17.4 µg/100g). Grilling and pan-frying also significantly ($p \leq 0.05$) increased selenium content in skinless muscles, compared to raw muscles (24.9 and 24.3 vs. 17.4 µg/100g). In the case of muscle with skin, all the thermal treatments applied significantly ($p \leq 0.01$) increased selenium concentration, compared to raw muscle: OCR, G, PF, WBC > R.

The higher Se content of roasted meat is due to its retention, which occurs when high temperature acts on muscle proteins. During roasting, when the temperature is between 100 and 140°C, proteins' digestibility is reduced by forming intramolecular and intermolecular covalent bonds [34]. In another study, it was shown [19] that a crust is formed during roasting of goose meat, which prevents the escape of water and thus minerals, which explains their higher concentration in cooked muscles.

Since no studies adequate to ours have been found in the literature, it is impossible to compare the results obtained of the selenium content of breast meat after applying various thermal treatments to the results of other researchers. For example, according to data from the U.S. Department of Agriculture database [35], the Se content of raw goose meat with skin is 14.4 µg/100g and 16.8 µg/100g without skin, but these values apply to the whole carcass, not just the breast muscles. Similarly, Chen et al. [36] reported a Se content of 34.6 (22.1-49. 8) µg/100g FM in goose meat bought in commercial stores in Taiwan, but the type of muscle, sex of the birds, and presence of skin were not given. It is well known that muscles differ in their histological structure and the nature of their metabolic transformations, which may affect their mineral content, including selenium [37].

Considering the calculated selenium retention (Table 2), the study showed no significant differences between the type of meat (with or without skin), the heat processing used, and the interaction between the two.

3.6. Coverage of selenium intake standards

Recommendations for the amount of selenium intake (Table 3) by adults vary according to gender, age and level of the standard (AI Adequate Intake, EAR Estima-ted Average Requirement RDA Recommended Dietary Allowance, RI Reference Inta-kes). Recommendations for Se intake range from 25 to 70 µg/d. For example, WHO/FAO (2005) recommends, for women aged 19-65 (at the RI level), an intake of 26 µg/d, and over 66 years of age, 25 µg/d. Similarly, these recommendations for men are 34 and 33 µg/d. Consumption of 100 g of goose meat (raw or heat-treated) will therefore cover the recommended Se intake for men and women in different countries in different percentages, depending on the adopted level of the AI, RI, EAR or RDA standard.

Our calculations show that, theoretically, a serving of 100 g of raw goose breast meat without skin will cover the daily Se requirement for women in the range of 24.9-69.6% and for men from 24.9-52.7%, depending on the level of standards (Table 3). The same serving of raw goose breast meat with skin will cover the daily Se requirement in a lower percentage: similarly for women 18.9-52.8% and men 18.9-40.0%. However, the consumption of raw goose meat is not widespread, and in most regions of the world, it is subject to various culinary treatments.

Breast meat grilled with skin and OCR without skin (78.5-107.6%) will cover the highest percentage of daily selenium requirements for both men and women. In general, depending on the accepted standard, goose meat (without skin) subjected to various heat treatments will cover the daily selenium requirements of adults in the range of 28.6-106.8%, while with skin in the range of 33.3-99.6%.

It is understood that the above-physiological intake of Se by humans can cause the phenomenon of hyperalimentation and pose a risk of exceeding the Upper Level (UL). In 2006, EFSA proposed the upper level (UL) of selenium consumption of 300 µg/day for adults [28], which took into account this element from both diet and supplements (EFSA 2006). However, due to the increase in the consumption of dietary supplements in 2022, EFSA lowered the UL to 255 (µg/day), including for pregnant and breastfeeding women [29]The range of selenium intake sufficient and still non-toxic for the organism is very narrow, depending, however, on the chemical form of Se. Selenosis most often occurs in regions with high selenium levels in soil and drinking water. It can also be a consequence of consuming dietary supplements [30].

Taking into account our determined selenium content of raw meat and meat subjected to various heat processing, and considering the reference daily intake in different countries, the consumption of a serving of 100g of goose covers the needs of an adult human (depending on gender) from 18.9% to 107.6%. Ingestion of goose breast muscle could exceed the UL if consumed in its raw state in a portion 14-19 times higher than 100 g but after heat treatment in an amount 10 times larger.

In addition, it should be noted that selenium bioavailability can be affected by other dietary factors such as dietary methionine (Met) content, thiols, heavy metals and vitamin C [28]. Dietary Met deficiency results in using Se-Met for protein synthesis (to replace Met), contributing to increased Se content in tissues and thus reduced incorporation into the enzyme glutathione peroxidase (GSH-Px). Glutathione peroxidase transforms the toxic and carcinogenic hydrogen peroxide into harmless water and oxygen. Its activation requires small amounts of Se (selenocysteine), probably substituting sulfur in the glutathione molecule and causing the development of the modified enzyme GPx4 [29]. In contrast, with a diet rich in Met, there is competition in intestinal absorption with Se-Met, leading to a lower state of Se saturation in the body. Some thiols in the gastrointestinal tract increase selenite absorption, probably due to the formation of selenocomplexes with thiol compounds, which are more rapidly absorbed by the intestinal Na+-dependent and independent mechanisms. High vitamin C intake (1 g/d) may result in higher absorption and increased selenium retention, possibly due to vitamin C's protection of key sulfhydryl groups involved in selenium uptake from the gastrointestinal tract. The interaction of Se with heavy metals reduces Se utilization in some foods by forming bonds between them. Various arsenic compounds and cysteine, methionine, copper, tungsten, mercury, cadmium, and silver have been reported to decrease the efficiency of inorganic Se absorption from the gut. The effect of a low-protein diet rich in phosphorus on the lowest Se retention was also observed. In addition, fractions of soluble fibre and guar gum increase faecal Se excretion in humans and reduce Se homeostasis in the body due to reduced absorption from the gastrointestinal tract [38,39].

From the consumer's point of view, the information placed by the manufacturer on the food packaging label is important because it helps consumers make nutritional choices. According to a European Parliament directive [40], the label includes information on energy and nutritional value. This information should also include the daily intake (NRV) reference value. These recommendations are based on the best available scientific knowledge of the daily energy or nutrients needed for good health. In 2014, the Codex Committee on Nutrition and Foods for Special Dietary Uses determined that the NRV-R for selenium is 60 µg [41]. In contrast, in Annex XIII of Regulation (EU) No. 1169/2011 of the European Parliament and of the Council of October 25, 2011, on providing food information to consumers, the NRV-R is 55 µg [40].

Our calculations show that raw meat without skin covers the NRV-R (60 µg) of the consumer (regardless of gender) at 29% and with skin at 22% (Table 3). Goose breast meat subjected to various

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heat processing covers NRV-R in the 33.3-44.8% range, although OCR without skin and grilled with skin cover the highest percentage (44.8 vs. 44.5%).

In summary, in our opinion, goose meat, both with and without skin, heat processed in a 100g portion can be part of a varied diet for adults. Placing information on the label of food products regarding the value of minerals is voluntary for food manufacturers, so it seems reasonable to encourage them to do so. Then, the consumers can consciously include these compounds in their diet, and the products will thus become competitive in a wide assortment.

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Table 1. Cooking loos, moisture, ash content and retention of raw and heat-processed White Kołuda® goose muscles (Mean, SEM).

Item	Meat	Raw	Heat processing: Water bath cooking (WBC)	Grilled (G)	Oven convection roasting (OCR)	Pan-fried (PF)	Total	SEM	Level of significance: Meat (M)	Heat processing (HP)	M x HP
Cooking loss (%)	without skin	-	27.2^{b}	42.5^{a}	40.6^{a}	34.9^{b}	36.3^{Y}	1.84	0.001	0.001	0.032
	with skin	-	40.4^{b}	51.7^{a}	43.6^{ab}	45.7^{ab}	45.4^{X}	1.52			
	Total	-	33.8^{B}	47.1^{A}	42.1^{A}	40.3^{A}	40.8	1.50			
	SEM		3.43	2.15	0.82	2.50					
Moisture (%)	without skin	73.3	65.3	54.0	56.9	58.0	61.5^{X}	1.88	0.018	0.001	0.084
	with skin	64.5	62.5	56.2	55.1	54.5	58.6^{Y}	1.41			
	Total	68.9^{A}	63.9^{A}	55.1^{B}	56.0^{B}	56.2^{B}	60.0	1.19			
	SEM	2.66	1.30	0.68	0.78	1.21					
Ash (%)	without skin	1.41	1.34	1.63	2.45	1.56	1.48	0.19	0.102	0.001	0.727
	with skin	1.38	1.06	1.63	1.96	1.23	1.25	0.16			
	Total	1.39^{C}	1.20^{B}	1.63^{AB}	2.21^{A}	1.39^{B}	1.36	0.12			
	SEM	0.07	0.18	0.07	0.20	0.13					
Ash retention (%)	without skin	-	108.4	113.8	147.7	118.4	122.1	8.20	0.046	0.205	0.410
	with skin	-	112.1	96.5	111.2	81.4	100.3	5.96			
	Total	-	110.2	105.1	129.4	99.9	111.2	5.45			
	SEM		11.87	7.89	11.5	10.6					

Means within a row followed by different superscript letters differ significantly; ^{A,B,C} $p \leq 0.01$; ^{a,b} $p \leq 0.05$ Means within a column followed by different superscript letters differ significantly ^{X,Y} $p \leq 0.01$; ^{x,y} $p \leq 0.05$.

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Table 2. Selenium content and its retention of raw and heat-processed White Kołuda® geese breast meat (Mean, SEM).

Item	Meat	Raw	Heat processing: Water bath cooking (WBC)	Heat processing: Grilled (G)	Heat processing: Oven convection roasting (OCR)	Heat processing: Pan-fried (PF)	Heat processing: Total	SEM	Level of significance: Meat (M)	Level of significance: Heat processing (HP)	Level of significance: M x HP
Se (µg/100g FM)	without skin	17.4[Bb]	20.2	24.3[a]	26.7[A]	24.9[a]	21.8	1.01	0.559	0.001	0.001
	with skin	13.2[B]	23.3[A]	26.9[A]	24.9[A]	23.7[A]	20.9	1.46			
	Total	15.3[B]	21.8[A]	25.6[A]	25.8[A]	24.3[A]	21.3	0.89			
	SEM	0.99	1.22	1.29	0.96	1.12					
Se retention (%)	without skin	-	85.1	79.9	91.1	93.0	87.3	3.28	0.082	0.087	0.913
	with skin	-	113.4	101.5	111.4	99.2	106.4	8.61			
	Total	-	99.3	90.7	101.3	96.1	96.8	4.92			
	SEM	-	15.4	7.78	10.7	4.78					

Means within a row followed by different superscript letters differ significantly; [A,B,C] $p \leq 0.01$; [a,b] $p \leq 0.05$ Means within a column followed by different superscript letters differ significantly [X,Y] $p \leq 0.01$; [x,y] $p \leq 0.05$.

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Table 3. Fulfilment of the demand (%) for selenium of adults by the consumption of 100g of breast goose raw or after heat processing meat (without skin or with skin), concerning the recommendation, standards and Nutrient Reference Values-Requirements.

Meat	Se [μg /100g]	DACH (2015) AI (μg)		EFSA (2014) AI (μg)	HCNL (2014) NCM (2014) RI (μg)		WHO/FAO (2004) RI (μg)		NIPH-NIH (2020) IOM (2000) EAR (μg)	NIPH-NIH (2020) IOM (2000) RDA (μg)	NRV-R (μg)
		60♀	70♂	70 ♀♂	50♀	60♂	25-26♀	33-34♂	45♀♂	55♀♂	60♀♂
Raw meat without skin	17.4	29.0	24.9	24.9	34.8	29.0	69.6-66.9	52.7-51.2	38.7	31.6	29.0
Raw meat with skin	13.2	22.0	18.9	18.9	26.4	22.0	52.8-50.8	40.0-38.8	29.3	24.0	22.0
Water bath cooking without skin	20.0	33.3	28.6	28.6	40.0	33.3	80.0-76.9	60.6-58,8	44.4	36.4	33.3
Water bath cooking with skin	23.3	38.8	33.3	33.3	46.6	38.8	93.2-89.6	70.6-68.5	51.8	51,8	38.3
Grilled without skin	24.3	40.5	34.7	34.7	48.6	40.5	97.2-93.5	73.6-71.5	54.0	44.2	40.5
Grilled with skin	26.9	44.8	38.4	38.4	53.8	44.8	107.6-103,5	81.5-79.1	59.8	48.9	44.8
Oven convection roasting without skin	26.7	44.5	38.1	38.1	53.4	44.5	106.8-102.7	80.9-78.5	59.3	48.5	44.5
Oven convection roasting with skin	24.9	41.5	35.6	35.6	49.8	41.5	99.6-95.8	75.5-73.2	55.3	45.3	41.5
Pan-fried without skin	24.9	41.5	35.6	35.6	49.8	41.5	99.6-95.8	75.5-73.2	55.3	45.3	41.5
Pan-fried with skin	23.7	39.5	33.9	33.9	47.4	39.5	94.8-91.1	71.8-69.7	52.7	43.1	39.5

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 (Poland); IOM - Institute of Medicine (USA); NRV-R - Nutrient Reference Values-Requirements.

4. Conclusions

Based on the study, it can be concluded that the applied heat processing methods significantly affected cooking loss, moisture, ash and selenium content in goose breast muscles, compared to raw muscles. The heat treatments used increased the selenium content of the muscles regardless of the presence of skin, which affects the possibility of covering the NRV-R of adults for this element in the range of 33.3-44.8%. Therefore, we believe goose breast meat can be a valuable component of a diversified diet, as it provides selenium and essential nutrients. It is unlikely that adult consumers, even those who consume it regularly, will exceed the upper tolerable intake level for the element.

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