

## Article

# The Quality of Goose Breast Muscle Products Depending on the Cooking Method Used

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**Featured Application:** The presented research results can be used to improve the thermal processing methods of goose meat to obtain products with optimal quality characteristics and nutritional value, both in gastronomic practice and in the industrial production of convenient foods.

**Abstract:** This study was conducted to compare the quality characteristics of White Kofuda goose breast muscle products, heated using the sous vide (SV) and the convection–steam oven (OV) methods. The qualitative analysis included instrumental evaluation of texture and colour parameters and the content of histidine dipeptide anserine. The research material consisted of breast muscles without skin, heated using the sous vide (SV) method at 65 °C for 4 h and 10 h and in a convection–steam oven (OV) in a steam environment at 80 °C and 90 °C (to obtain the final temperature of 65 °C in the geometric centre of meat pieces). Extending the heating time using the SV method and increasing the temperature in OV resulted in increased hardness, cohesiveness and chewiness. The use of heat treatment resulted in a significant reduction in the initial anserine content. A greater anserine reduction was found in SV samples compared to OV. The SV processing time did not significantly differentiate the dipeptide content, nor did the temperature used in OV processing. Pectoral muscles heated using the sous vide method were characterised by higher values of the parameters L\* and b\* and the hue angle (h) compared to OV processing, in which the value of the a\* parameter was higher. The low-temperature processing methods (SV 65 °C/4 h and OV 80 °C) of goose breast meat allowed for obtaining products with similar textural characteristics: hardness, adhesiveness, elasticity and chewiness.

**Keywords:** goose; meat; anserine; colour; TPA; sous vide; thermal treatment



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## 1. Introduction

Poultry meat, including goose meat, is an important element of the human diet. The nutritional value of products obtained from meat depends both on the quality of the raw material resulting from species characteristics and breeding conditions. Meat is a valuable source of high-quality protein, fats, B vitamins and minerals, including iron, phosphorus, selenium and zinc [1–4]. Although the share of waterfowl in the world production of poultry meat is small, there is an upward trend in production. The European leader in goose meat production is Poland, while on a global scale China and Egypt [FAO Database <http://faostat.fao.org>, accessed on 4 April 2020]. The basis of Polish goose production is White Kofuda geese, which constitute over 90% of the total production in commercial production. In the final stage of breeding (14–17 weeks), the birds are fed with oats, thanks to which they obtain valued sensory values [4,5]. The consumption of goose meat is not high compared to chicken or turkey meat, which is mainly due to the significantly higher price of goose meat. The increase in consumption may be facilitated by the promotion of goose meat as a product with attractive sensory values and high nutritional value. It should

be emphasised that goose meat is a source of fat with a high monounsaturated fatty acid (MUFA) content and is characterised by one of the highest unsaturated fatty acid/saturated fatty acid (UFA/SFA) ratios among various types of meat [6]. Growing consumer awareness means that meat is perceived not only as a source of high-quality protein and micro- and macroelements but also as a potentially important source of bioactive compounds. These compounds have significant physiological significance. The substances of this group are considered to be primarily bioactive peptides, L-carnitine, creatine, taurine, conjugated linoleic acid,  $\alpha$ -lipoic acid, coenzyme Q10,  $\gamma$ -aminobutyric acid and glutathione [7].

Bioactive compounds also include histidine dipeptides carnosine and anserine. These compounds have strong antioxidant properties comparable to synthetic antioxidants [8]. The antioxidant effect is attributed to blocking the products of free radical reactions by deactivating superoxide and hydroxyl radicals, blocking singlet oxygen, prooxynitrile radicals and chlorates [9,10]. Anserine and carnosine have chelating properties against heavy metals, in particular cobalt, zinc, iron and copper. The chelation of copper and zinc ions is particularly important in regulating zinc levels in the central nervous system. Anserine is of particular importance in this process, thus indicating a significant neuroprotective effect [11,12]. Histidine dipeptides in the protein–fat matrix contribute to the reduction in the formation of advanced lipooxidation end products and advanced glycosylation end products [10,13]. Carnosine is composed of L-histidine and beta-alanine, and anserine is its methyl derivative, produced as a result of metabolic processes [14–16]. Carnosine is identified in tissues where metabolic processes occur most effectively—the central nervous system, liver, kidneys, stomach and skeletal muscles [14,17]. The content of histidine dipeptides has been confirmed in beef [18,19], pork [20,21] and poultry [14,22] as well as in some fish and seafood [10,23]. Their content in tissues varies depending on the animal species, breed, sex, muscle activity and living conditions [10,14,19]. To the best of our knowledge, there is no information in the literature on the content of histidine dipeptides in goose meat, so this study fills this gap.

The choice of heat treatment method by consumers is mainly determined by the possibility of obtaining a product that has sensory attractiveness, mainly in terms of appearance, texture and palatability. In industrial production, an important factor determining the selection of heat treatment parameters and methods is also the economic analysis of the process, which determines obtaining a safe product that meets market expectations. Commonly used heat treatment methods, such as cooking, baking, frying, stewing and grilling, differentiate meat products in terms of textural and chemical characteristics. The scope of these differences is determined by the process conditions, usually described by the processing temperature, its duration and the heating environment. Heat treatment promotes a cascade of physicochemical changes that determine the final nutritional quality and functional properties of meat products. Moreover, high-temperature heat treatment may result in the formation of substances that are harmful or potentially harmful to humans [24,25]. At the same time, it is indicated that the heat treatment of meat in relatively mild conditions (temperature below 100 °C) allows obtaining products with minimal contamination with harmful compounds while maintaining nutritional value [26]. Therefore, there is an increasing interest of researchers in analysing the impact of low-temperature heat treatment methods on the quality of meat products. The sous vide technique allows us to obtain products of very good nutritional and sensory quality. The use of low temperature allows for minimizing the losses of thermolabile ingredients and limiting structural changes which affect other quality attributes (cooking loss, juiciness). At the same time, vacuum packaging used in heat treatment minimises potential losses resulting from the contact of the raw material with the heating medium, allows for more effective heat exchange and protects the product against contamination and undesirable changes during processing [27,28]. There is a constant increase in interest in minimally processed food, the high nutritional value of which results from properly conducted heat treatment. The sous vide technique is a commonly used method of meat processing, and heating at low temperatures in a convection–steam oven in a steam environment is much less common. The assessment of

the impact of various heat treatment methods on the quality of goose products is a current topic of study. It mainly concerns the comparison of the quality of products obtained using traditional methods in terms of sensory quality, textural characteristics and chemical composition analysis. These studies do not include an analysis of the variability of histidine dipeptide content, which prompted the authors to take up this topic.

Therefore, the aim of this research was to compare the quality characteristics of goose breast muscle products obtained using the sous vide method and in a convection–steam oven in a steam environment, taking into account the instrumental parameters of texture and colour and the content of histidine dipeptide anserine. As a result of the study, the most suitable method for the thermal treatment of goose breast will be indicated.

## 2. Materials and Methods

### 2.1. Sample Preparation and Thermal Treatment

The research material consisted of pectoral muscles (*Pectoralis major*) without skin from White Kofuda geese purchased in retail. According to the distributor's declaration, the birds came from one breeding farm and were slaughtered after 17 weeks of life. Meat samples obtained from cooled goose carcasses 24 h post-mortem were transported under refrigerated conditions (temperature below 4 °C) to the laboratory, where the meat was stored in a refrigerator at 4 °C until the 4th day post-mortem. The meat for heat treatment was standardised for weight—approximately 250 g ( $\pm 2$  g). The remaining part of the muscles was used to determine the water and anserine content and the pH value. Pectoral muscles intended for sous vide (SV) processing were vacuum-packed using vacuum sealing machine (Multivac, A 300/16, Wolfertschwenden, Germany) with extent of vacuum 99.6% in polyamide-polyethylene bags (PA/PE, thickness 70  $\mu$ m, Inter Arma sp. z o. o., Rudawa, Poland) and then heated in the SV device (Fusion Chef by Julabo, Diamond Z, Julabo GmbH, Seelbach, Germany). SV samples were heated at 65 °C for 4 ( $n = 6$ , SV4) and 10 h ( $n = 6$ , SV10) and in a convection–steam oven (OV) (Küppersbusch CPE 110, Küppersbusch Grobküchentechnik GmbH, Gelsenkirchen, Germany) in a 100% steam environment, at 80 °C ( $n = 6$ , OV80) and 90 °C ( $n = 6$ , OV90). The pectoral muscles were heated in an oven until a temperature of 65 °C was obtained in the geometric centre of the sample (OV80—approx. 60 min, OV90—approx. 40 min). After heat treatment, the products were cooled at 2 °C for 2 h and then packed in polyamide-polyethylene bags and stored at 4 °C for 24 h.

### 2.2. Moisture Content, pH and Cooking Loss Determination

The moisture content of the raw material and samples after heat treatment was determined by drying to constant weight at a temperature of  $103 \pm 2$  °C, and the final result was the mean values of 3 measurements [29]. Before drying to constant weight, pectoral muscles were individually ground in a grinder (ZMM4080, Zelmer SA, Rzeszów, Poland) through a 3 mm diameter mesh. To eliminate the potential impact of differences in the quality of the raw material on the results, the initial pH value was verified. pH values were measured directly in minced raw meat using an FC 200 combined electrode and an HI 8314 pH meter (Hanna Instruments Polska, Olsztyn, Poland). Three measurements were performed for each sample. Before measurements, the device was calibrated using pH 7 and pH 4 buffers. Cooking losses (CL) were calculated by the difference in weight before (W0) and after cooking (W1), according to the following equation:  $CL (\%) = (W0 - W1) / W0 \times 100$  [30]. The average value was determined based on the results of weighing all samples of a given experimental variant.

### 2.3. Colour Parameters

Meat colour was determined in the CIE L\*a\*b\* system (Commission Internationale l'Eclairage, CIE, [31]), with the Konica Minolta CR-400 (Sensing Inc., Osaka, Japan) (with a 10° view angle, D65 illuminant) calibrated with the use of a white tile standard before the analysis. The lightness ( $L^*$ ), redness ( $a^*$ ) and yellowness ( $b^*$ ) values were determined

during six measurements at randomly selected points in standardised samples before (raw meat) and after heat treatment (SV4, SV10, OV80, OV90). The changes in the colour parameters between the raw and cooked meat were determined by calculating the  $\Delta E$  coefficient according to the formula  $\Delta E = [(\Delta CIE L^*)^2 + (\Delta CIE a^*)^2 + (\Delta CIE b^*)^2]^{0.5}$ , where  $\Delta CIE L^*$ ,  $\Delta CIE a^*$  and  $\Delta CIE b^*$  denote differences in the values of lightness, redness and yellowness, respectively [32]. To relate the colour difference recorded by the chromameter to a food environment, the data were converted to National Bureau of Standards (NBS) units through the following equation:  $NBS \text{ unit} = \Delta E^* \times 0.92$ , where differences in colour were expressed in terms of NBS units. Based on values obtained, the changes were classified as negligible (0–0.5), minor (0.5–1.5), noticeable (1.5–3.0), moderate (3.0–6.0), considerable (6.0–12.0) or significant (>12.0) [31,32]. The chroma (C) was calculated from the following equation:  $C = (a^{*2} + b^{*2})^{0.5}$  and hue angle (h) according to the following equation:  $h = \arctan(b/a) \times 180/\pi$  [31].

#### 2.4. Texture Profile Analysis (TPA)

The texture profile analysis (TPA) was performed by Instron Universal Testing Machine (model 5942 Instron, Norwood, MA, USA). Texture analysis (TPA) was carried out using a piston with a diameter of 57 mm, compressing the meat twice to 50% of its original height, at a constant piston speed of 50 mm/min. The break between pressures was 5 s. For the determination of the texture profile analysis, portions of the cooked goose breast were cut into 1 cm<sup>3</sup> cubes. For each sample, six cubes were obtained and analysed [33–35]. From the resulting force–time curve, the following texture parameters were determined: hardness (maximum peak force during the first compression); springiness (the height that the sample recovers between the end of the first compression and the beginning of the second compression); cohesiveness (ratio of the force field during the second compression to that during the first compression); adhesiveness (work needed to overcome the attractive forces between the surface of the sample and the surface of other objects) and chewiness—a derivative of springiness, hardness and cohesiveness (Instron Bluehill® 2 Software) [33,36].

#### 2.5. Anserine Content Determination

The method described by Modzelewska-Kapituła et al. [19] was used to extract anserine. The anserine content of goose meat was determined by high-performance liquid chromatography (HPLC), derivatizing the extracts with phthalaldehyde (OPA, Sigma Aldrich Chemie GmbH, Stainheim, Germany) working solution. The derivatised samples were analysed on the Thermo Scientific ACCELA chromatograph using Thermo Scientific ChromQuest 5.0 software (Thermo Fisher Scientific, Waltham, MA, USA). The separation was carried out on a Venusil SCX column, 3 µm, 4.6 × 150 mm (Agela Technologies, Tianjin, China) under isocratic elution conditions at an eluent flow velocity of 750 µL/min at 25 °C. The eluent consisted of 0.5 M acetate buffer adjusted to pH 4.6, acetonitrile and methanol in a volume ratio of 85:5:10. Anserine was detected with the ACCELA PDA detector at  $\lambda = 332$  nm. The calibration curve was determined by the external standard method for anserine (Sigma-Aldrich Inc., St. Louis, MO, USA). In the concentration range of 0.16–1.50 µg/25 µL, the determination coefficient  $R^2$  was greater than or equal to 0.99. The content of anserine in goose meat samples was determined using a component of the ChromQuest 5.0 Concentration Calculator program. Two replicates were prepared from each muscle, and two sub-samples of each extract were analysed by HPLC [19,23]. The limit of detection (LOD) and the limit of quantification (LOQ) of the method used were, respectively, 0.05 and 0.16. The retention time of anserine was 5.60 min.

#### 2.6. Statistical Analysis

The results were analysed using Statistica 12 (StatSoft. Inc., Tulsa, OK, USA) at a significance level of  $p < 0.05$ . Experimental data showed normal distribution as indicated by Shapiro–Wilk’s test and variance homogeneity assessed by Leven’s test. The significance of

differences resulting from the applied heat treatment method on the anserine content, colour and texture parameters and other characteristics was assessed using one-way ANOVA.

### 3. Results and Discussion

#### 3.1. Colour Parameters and pH

The pH value may significantly determine the technological properties of meat. Therefore, the initial pH value of goose breast meat was tested. The samples did not differ significantly in the initial value of this characteristic, and the pH value of meat was in the range of 5.76–5.82. The indicated values are consistent with the results presented by Haraf et al. [4].

Table 1 summarises the results of the instrumental measurement of the colour parameters lightness ( $L^*$ ), redness ( $a^*$ ) and yellowness ( $b^*$ ), as well as calculated values determining the hue angle ( $h$ ) and chroma ( $C$ ) of goose breast meat processed in various experimental conditions. Instrumental colour parameters were differentiated by the heat treatment method, with significant differences identified between products heated using the SV method and those heated using the OV method. The lightness ( $L^*$ ) of samples heated using the SV method, regardless of the heating time, was significantly higher than that of samples heated using the OV method. A similar relationship was found for  $b^*$  values. However, in meat heated using the OV method, significantly higher values of  $a^*$  were found compared to samples heated using the SV method, regardless of the heating temperature used. Pectoral muscles heated using the SV method were also characterised by higher values of the hue angle ( $h$ ). It was also found that the value of the  $h$  parameter of meat heated at OV90 was significantly lower compared to those heated at a lower temperature (OV80). The heating time of goose breasts using the SV method did not significantly differentiate the chroma value ( $C$ ) of the products, although it was significantly higher compared to the OV samples. Based on the  $\Delta E$  and NBS unit values, the changes in the analysed colour parameters were classified as considerable in the case of OV samples (NBS OV80 = 9.21 and NBS OV90 = 6.58) and as significant in SV samples (NBS SV4 = 16.47 and NBS SV10 = 19.49).

**Table 1.** Effects of heat treatment on CIE Lab colour parameters (mean values  $\pm$  standard error).

Parameters	Raw Meat	Heat Treatment			
		SV4	SV10	OV80	OV90
$L^*$	34.54 <sup>b</sup> $\pm$ 2.36	47.72 <sup>a</sup> $\pm$ 2.79	51.17 <sup>a</sup> $\pm$ 2.18	38.54 <sup>b</sup> $\pm$ 0.71	34.51 <sup>b</sup> $\pm$ 0.67
$a^*$	15.89 <sup>c</sup> $\pm$ 1.59	6.54 <sup>b</sup> $\pm$ 0.11	6.48 <sup>b</sup> $\pm$ 0.87	7.90 <sup>a</sup> $\pm$ 0.69	9.58 <sup>a</sup> $\pm$ 0.88
$b^*$	3.45 <sup>c</sup> $\pm$ 1.87	10.80 <sup>a</sup> $\pm$ 0.26	12.05 <sup>a</sup> $\pm$ 0.39	7.76 <sup>b</sup> $\pm$ 0.75	6.61 <sup>b</sup> $\pm$ 0.78
$h$	13.08 <sup>d</sup> $\pm$ 3.78	58.83 <sup>a</sup> $\pm$ 3.89	61.74 <sup>a</sup> $\pm$ 1.46	44.50 <sup>b</sup> $\pm$ 3.27	34.61 <sup>c</sup> $\pm$ 0.79
$C$	19.34 <sup>a</sup> $\pm$ 3.04	17.35 <sup>a</sup> $\pm$ 0.68	18.53 <sup>a</sup> $\pm$ 0.62	15.66 <sup>b</sup> $\pm$ 0.84	16.19 <sup>b</sup> $\pm$ 0.52
$\Delta E$	-	17.90 <sup>b</sup> $\pm$ 0.38	21.19 <sup>a</sup> $\pm$ 1.77	10.01 <sup>c</sup> $\pm$ 0.32	7.16 <sup>d</sup> $\pm$ 0.88
NBS unit	-	16.47 <sup>b</sup> $\pm$ 0.38	19.49 <sup>a</sup> $\pm$ 1.77	9.21 <sup>c</sup> $\pm$ 0.32	6.58 <sup>d</sup> $\pm$ 0.88

<sup>a–d</sup> Values in rows with different upper case letters differ at  $p < 0.05$ . SV4—sous vide at 65 °C for 4 h. SV10—sous vide at 65 °C for 10 h. OV80—convection–steam oven at 80 °C to obtain 65 °C in the core. OV90—convection–steam oven at 90 °C to obtain 65 °C in the core.  $\Delta E$ —calculated with respect to the raw meat colour. NBS—National Bureau of Standards.

The CIE Lab colour parameters determined for raw goose breast meat in this study were similar to the values indicated by Orkusz et al. [37] and Wołoszyn et al. [30]. In the indicated studies, the value of the  $L^*$  in the breast muscle of the White Kofuda goose ranged from 37.87 to 40.25. At the same time, the values of parameters  $a^*$  and  $b^*$  were in the ranges of 19.30–20.02 and 1.33–3.23, respectively. The colour of fresh meat depends mainly on the content of heme pigments and the share of individual myoglobin fractions: oxymyoglobin ( $MbO_2$ ), myoglobin ( $Mb$ ) and metmyoglobin ( $MetMb$ ). The share of individual myoglobin fractions in goose meat may vary depending on the bird variety [4].



The changes in meat lightness resulting from heat treatment presented in this study were consistent with Wереńska's results [38]. The author showed a significant increase in the lightness ( $L^*$ ) of goose meat heated using the SV method compared to raw meat, and at the same time, there was no significant difference in the value of this parameter between products heated in a microwave oven and stewed [38]. The increase in meat lightness after heat treatment is attributed to the denaturation and aggregation of sarcoplasmic and myofibrillar proteins, associated with an increase in light reflectance and scattering [39,40]. The lighter colour of meat products increases consumer acceptance [41]. The studies by both Wереńska [38] and Wołoszyn et al. [30] showed a decrease in the intensity of the red colour (parameter  $a^*$ ) and an increase in the yellow colour (parameter  $b^*$ ), resulting from the heat treatment of goose meat, but the scope of these changes was different for individual culinary methods. Similarly to Wереńska [38], the smallest reduction in the colour parameter  $a^*$  was found in meat heated using the SV method. At the same time, the results presented in this study indicate that extending the SV heating time did not significantly affect the value of this parameter. According to King and Whyte [42], the value of the  $a^*$  parameter in cooked meat decreases with the increase in the degree of myoglobin denaturation. Higher values of the colour parameter  $b^*$  in meat subjected to heat treatment are attributed to the denaturation of the MetM fraction leading to a brown colour [35,43]. Heating meat denatures and unfolds the globin molecule, resulting in the formation of globin-hemichrome or ferrihemochrome, known as a dull brown pigment formed during heating [35,44]. The applied heat treatment significantly changed the hue angle ( $h$ ) of meat compared to raw meat, with the lowest value found in the OV90 sample. The hue angle ( $h$ ) is determined by the chemical state of myoglobin and is inversely proportional to the value of the  $a^*$  parameter [38]. The chroma parameter ( $C$ ) of goose heated using the SV method, regardless of the heating time used, did not differ significantly from the values determined for raw meat and was significantly higher than the values determined for meat heated using the OV method. Lower values of the  $C$  parameter of the OV80 and OV90 samples showed that they were lighter (smaller distance from the  $L^*$  axis in the CIE Lab system) than those heated using the SV method. The colour saturation of meat depends on the concentration of myoglobin and the degree of its denaturation. This relationship is particularly clear at high myoglobin concentrations and a low degree of myoglobin denaturation [45].

### 3.2. Texture Profile Analysis (TPA)

The obtained values of the texture parameters taken into account in the TPA analysis of heated goose breast muscle are summarised in Table 2. As a result of the use of SV4 and OV80, meat samples of similar hardness were obtained (15.99 N and 17.84 N, respectively). Increasing the heating time in the SV method from 4 to 10 h significantly increased the hardness of the samples from 15.99 N to 19.89 N. The OV90 meat was characterised by the highest hardness. The heat treatment method used and its conditions did not significantly differentiate adhesiveness and springiness. The heat treatment methods used significantly differentiated the cohesiveness of the products. Cooked pectoral muscles with the highest cohesiveness were obtained by the SV10 method, and those with the lowest cohesiveness were obtained by OV80. The cohesiveness of the SV4 and OV90 samples was 0.52 and 0.50, respectively ( $p < 0.05$ ). Both SV4 and OV80 heating allowed obtaining meat with comparable chewiness ( $p > 0.05$ ). Heated meat SV10 and OV90 were characterised by significantly higher values of these texture parameters compared to the SV4 and OV80 samples.

**Table 2.** Texture profile analysis (TPA) of culinary heated goose breast muscle (mean values  $\pm$  standard error).

Parameters	Heat Treatment			
	SV4	SV10	OV80	OV90
Hardness (N)	15.99 <sup>c</sup> $\pm$ 1.55	19.89 <sup>b</sup> $\pm$ 2.68	17.84 <sup>c</sup> $\pm$ 2.08	23.27 <sup>a</sup> $\pm$ 3.06
Adhesiveness (J)	−0.03 <sup>a</sup> $\pm$ 0.01	−0.03 <sup>a</sup> $\pm$ 0.01	−0.03 <sup>a</sup> $\pm$ 0.01	−0.03 <sup>a</sup> $\pm$ 0.01
Springiness (cm)	0.57 <sup>a</sup> $\pm$ 0.07	0.72 <sup>a</sup> $\pm$ 0.15	0.61 <sup>a</sup> $\pm$ 0.18	0.64 <sup>a</sup> $\pm$ 0.22
Cohesiveness (-)	0.52 <sup>b</sup> $\pm$ 0.03	0.61 <sup>a</sup> $\pm$ 0.09	0.48 <sup>d</sup> $\pm$ 0.04	0.50 <sup>c</sup> $\pm$ 0.04
Chewiness (J)	4.28 <sup>b</sup> $\pm$ 0.52	7.17 <sup>a</sup> $\pm$ 1.26	5.35 <sup>b</sup> $\pm$ 1.03	7.81 <sup>a</sup> $\pm$ 1.17

<sup>a–d</sup> Values in rows with different upper case letters differ at  $p < 0.05$ . SV4—sous vide at 65 °C for 4 h. SV10—sous vide at 65 °C for 10 h. OV80—convection–steam oven at 80 °C to obtain 65 °C in the core. OV90—convection–steam oven at 90 °C to obtain 65 °C in the core.

The TPA results presented in this study are consistent with the texture profile characteristics presented by Haraf et al. [4] regarding the breast muscles of geese heated to an internal temperature of 75 °C. The significantly higher hardness values presented by the authors are probably due to the adoption of different methodological assumptions regarding differences in the adopted compression range in the instrumental texture analysis. The research presented in this paper used the procedure described by Roldán et al. [35], in which the tests used cuboids with a side length of 10 mm, and the assumed compression ratio was 50%. According to Wołoszyn et al. [30], the texture parameters of goose breast muscles subjected to heat treatment using various methods are determined by the processing method used. The authors showed that goose meat cooked in a water bath was characterised by the lowest values of hardness and chewiness. Wereńska [38] also analysed the influence of the cooking method (sous vide, microwave and stewing) of goose meat and showed a significant influence of the method used on texture parameters such as hardness, chewiness, cohesiveness and elasticity. The author showed the lowest values of the indicated parameters for meat cooked using the sous vide method at a temperature of 70 °C. These findings are consistent with those presented in this study, where SV4 products were characterised by the lowest values of hardness, elasticity and chewiness. At the same time, extending the SV heating time from 4 to 10 h significantly increased the values of texture parameters. Roldán et al. [35], by analysing the effect of different sous vide processing temperatures (60 °C, 70 °C and 80 °C) at different times (6 h, 12 h and 24 h), showed that prolonged heating at a given temperature resulted in a decrease in the texture parameters of cooked lamb loin. In our case, this relationship was not confirmed. The authors justify the demonstrated relationship by collagen solubilisation and gel formation with extended cooking time, with a comparable degree of denaturation of myofibrillar proteins and a lower degree of aggregation.

The mechanical properties of cooked meat products result from the characteristics of the structural components of meat, i.e., myofibrillar proteins and connective tissue. As a result of heat treatment, meat proteins are gradually denatured, which determines their structural characteristics. The denaturation of myofibrillar proteins at temperatures above 65 °C increases the hardness of meat because the elastic modulus increases and requires larger tensile stress to extend fractures [27]. However, heating the connective tissue may result in a reduction in the cross-linking of connective tissue proteins, its partial breakdown and interaction with other components, including water. These changes may result in a reduction in meat hardness and a change in texture characteristics. The denaturation of myofibrillar proteins occurs in the temperature range from 40 °C to 60 °C, and further heating to 80 °C results in further structural changes, increasing the strength of muscle fibres. At temperatures above 60 °C, the gelation of collagen fibres and other changes in connective tissue proteins, including actin denaturation, also occur. Taking into account various literature sources, it is assumed that both temperature and cooking time influence the tenderness of meat, with a greater share attributed to temperature in

shaping the texture of products through a greater influence on the contraction of muscle fibres [27,28,46]. The influence of the heat treatment temperature and not only the value of the final heating temperature was noticed based on the differences shown between OV80 and OV90. Products heated to the same final temperature were characterised by partially different mechanical characteristics. Samples with higher hardness, cohesiveness and chewiness were obtained by heating the meat at 90 °C. As indicated by Wołoszyn et al. [30], faster heating resulting from the use of a higher heating temperature results in a greater temperature gradient between the temperature of the centre of the sample and the outer surface, which may affect the course of protein denaturation. This was noted in this study, where a higher temperature in the OV heating resulted in higher hardness, indicating a greater denaturation of myofibrillar proteins and connective tissue. At the same time, Tornberg [47] indicates that saturated water vapor, as a result of better heat transfer, may increase the degree of the unfolding structure of proteins and their denaturation, mainly sarcoplasmic proteins and myosin. It can also increase the effectiveness of collagen solubilisation by breaking the thermolabile bonds of the fibrous structure.

### 3.3. Anserine, Moisture Content and Cooking Loss

The applied methods and heat treatment conditions resulted in different cooking losses and obtained meat samples with different water and anserine contents (Table 3). The highest cooking loss was found in OV90 samples. In the remaining samples, the average values obtained did not significantly differentiate the cooking loss values. As a result of the heat treatment methods used, the cooking loss values ranged from 17 to 27%. The initial water content of raw goose breasts was reduced as a result of the processing methods used, ranging from 7 to 11%. The highest moisture content was found in samples SV10 and OV90 and the lowest in SV4. The moisture content in OV80 was higher than that of SV4 and lower than that of SV10.

**Table 3.** Moisture content, cooking loss and anserine content of culinary heated goose breast muscle (mean values  $\pm$  standard error).

Parameters	Raw Meat	Heat Treatment			
		SV4	SV10	OV80	OV90
Moisture (%)	73.36 <sup>a</sup> $\pm$ 1.93	62.92 <sup>d</sup> $\pm$ 1.26	65.02 <sup>b</sup> $\pm$ 0.17	64.38 <sup>c</sup> $\pm$ 0.10	64.90 <sup>b</sup> $\pm$ 0.46
Cooking loss (%)	-	19.44 <sup>b</sup> $\pm$ 1.24	17.73 <sup>b</sup> $\pm$ 0.31	18.26 <sup>b</sup> $\pm$ 0.10	27.35 <sup>a</sup> $\pm$ 0.17
Anserine (mg/100 g)	237.97 <sup>b</sup> $\pm$ 7.75	248.55 <sup>a</sup> $\pm$ 3.58	229.28 <sup>c</sup> $\pm$ 0.91	251.95 <sup>a</sup> $\pm$ 1.93	249.03 <sup>a</sup> $\pm$ 8.77
Anserine (mg/100 g dry matter)	881.66 <sup>a</sup> $\pm$ 16.86	670.37 <sup>c</sup> $\pm$ 9.65	655.47 <sup>c</sup> $\pm$ 4.75	707.34 <sup>b</sup> $\pm$ 5.42	709.55 <sup>b</sup> $\pm$ 24.99

<sup>a–d</sup> Values in rows with different upper case letters differ at  $p < 0.05$ . SV4—sous vide at 65 °C for 4 h. SV10—sous vide at 65 °C for 10 h. OV80—convection—steam oven at 80 °C to obtain 65 °C in the core. OV90—convection—steam oven at 90 °C to obtain 65 °C in the core.

Wereńska [38] showed a significant impact of the applied heat treatment of skinless goose breast muscles (sous vide, microwave and stewing) on the cooking loss value, which ranged from 22% (SV) to 43% (stewing). The higher cooking loss that results from SV treatment may result from the use of a higher final temperature compared to our experiment (70 °C vs. 65 °C). Wołoszyn et al. [30] showed the cooking loss of goose meat resulting from various heat treatments (water bath cooking, grilling, oven convection roasting, pan frying) ranging from 35% to nearly 41%. The authors showed the lowest cooking loss in fried samples (35.71%) and the highest in grilled meat (40.80%) and oven convection roasting (40.50%). Gumułka and Połtowicz [48] showed differences in the value of cooking loss of breast muscles of Zatorska goose and White Koluda goose at the level of 35.08% and 34.13%, respectively. At the same time, Haraf et al. [4] showed that the goose genotype does not significantly differentiate the values of thermal leakage of the breast muscles, but they showed significant differences in the values determining roasting losses.



Culinary losses resulting from the heat treatment of meat largely determine the sensory quality of products, mainly in the area of texture and the feeling of juiciness. The amount of heat loss is determined by the processing temperature used and the final heating temperature. As the temperature increases, collagen and actin denaturise more, resulting in fibre contraction and causing water to be present between the fibres. Offer et al. [49] indicate that the thermal contraction of muscle fibres is associated with two phases. The authors indicate that at a heating temperature from 45 °C to 60 °C, the fibre shrinks mainly transversely, while at a temperature from 60 °C to 90 °C, longitudinal shrinkage occurs. Both types of fibre shrinkage reduce the water-holding capacity (WHC) of the meat and reduce its juiciness. The highest cooking loss of meat samples heated at the highest temperature (90 °C) shown in this study is consistent with the findings of Becker et al. [40]. The authors of the study showed that samples heated at the highest temperature (baking temperature of 180 °C, core temperature of 80 °C) were characterised by the highest cooking loss and longitudinal shrinkage. Significantly lower cooking loss values were found in samples heated at low temperatures (53–60 °C); at the same time, a clear transverse shrinkage was observed, while longitudinal shrinkage occurred to a lesser extent. Modzelewska-Kapituła et al. [50] showed that the heat treatment of beef using the steaming method results in greater cooking loss compared to the sous vide method (34.2% vs. 30%, respectively), and this difference results from the difference in the final heating temperature. Lepetit et al. [51] indicate the involvement of connective tissue surrounding muscle fibres in the contraction mechanism and its significant role in shaping cooking loss. However, the gelation of collagen fibres at temperatures above 60 °C and the impact of this process on cooking loss value should be taken into account. Becker et al. [40] showed that the long-time (20 h) cooking of pork at low temperatures (53 °C and 58 °C) results in greater cooking loss (28.4% and 33.6%, respectively) than shorter heating (2 h) at 60 °C (17.4%). Importantly, the authors point out that the indicated differences in the value of cooking loss were not fully reflected in the sensory assessment of juiciness. Similarly to our studies, the samples heated at the highest temperature had the lowest moisture content, and the processing method used and its conditions significantly differentiated the final moisture content.

As a result of heating the meat using the SV4, OV80 and OV90 methods, the anserine content increased compared to the content determined in raw meat (Table 3). Only in the SV10 sample was there a decrease in the initial anserine content from 237.97 mg/100 g of meat to 229.28 mg/100 g of meat. The obtained increase in anserine content should be attributed to the increased concentration of dry matter components and the detected cooking loss. All meat samples were heated to obtain the same final temperature in the geometric centre (temp. 65 °C), which resulted in products with similar final anserine content. The observed reduction in anserine content in the SV10 sample is probably due to the longest heating time used (10 h). The demonstrated cooking loss of heated meat was similar (except for the OV90), while the final moisture content in the samples varied. Therefore, the anserine content determined in wet samples was related to the dry matter content. Based on the amount of anserine in the dry matter, a significant reduction in its initial content was found as a result of the methods and processing conditions used. A greater reduction in anserine was found in SV samples compared to OV, and the SV processing time did not significantly differentiate the dipeptide content, nor did the temperature used in OV processing.

The content of histidine dipeptides and their proportions in meat differs depending on the animal species, the type of muscle and its vital activity, as well as the method of breeding, including the method of feeding. In beef, pork and horse meat, the dominant histidine dipeptide is carnosine, while in bird meat, anserine is the dominant one [1,18,19,21]. The initial content of histidine dipeptides identified in meat may change as a result of heat treatment. There are few studies on goose meat that quantitatively characterise the content of histidine peptides and the effect of heat treatment on their content. Kim et al. [1] showed a higher content of anserine than carnosine in the breast muscle of chickens from conventional and animal welfare farms. Changes in endogenous bioactive compounds, including

carnosine and anserine, in the meat of indigenous Korean chicken varieties, depending on the age of the bird and the cooking process used, were analysed by Jayasena et al. [52]. The authors demonstrated the predominant share of anserine in chicken meat, both in the breast muscle and leg meat. The authors showed that the average content of carnosine in the meat (taking into account the breast muscle and leg meat) was 127.24 mg/100 g, while the average content of anserine was 427.00 mg/100 g. As a result of cooking the meat to a core temperature of 72 °C, the content of carnosine and anserine decreased to 99.43 mg/100 g and 334.85 mg/100 g, respectively. The main reason for the loss of dipeptides during heat treatment is the high solubility of dipeptides in water, in particular carnosine. Peiretti et al. [18], after analysing the impact of various heat treatment methods on the content of dipeptides in beef and turkey products, showed that the final amount of dipeptides in the products may be lower than the initial content by up to 70%, with the highest losses of carnosine and anserine found in cooked products. Jayasen et al. [52], using boiling in water, showed much lower losses of carnosine and anserine. In this case, the retention of anserine was 82%, while the retention of carnosine was 78% in the breast muscle and 86% in the leg meat. Also, Simonetti et al. [21] showed a decrease in the content of carnosine and anserine as a result of the heat treatment of pork meat in a combi-steam oven, heating the samples to a final temperature of 73 °C. Modzelewska-Kapituła et al. [23], by analysing the processing conditions (temperature and time) using the sous vide method on the nutritional characteristics of pikeperch fillets, showed that the initial anserine content in pikeperch tissue did not change significantly as a result of heating SV65 (time 45 min) and SV75 (time 20 min). A significant reduction in the anserine content was observed only when SV90 was used (time 10 min). The indicated heat treatment conditions resulted in a significant reduction in the carnosine content in the samples. In this study, a decrease in the content of anserine was determined for a sample of wet goose breast heated at 65 °C for 10 h (SV10), and an increase in the content of SV4, OV80 and OV90 was found, compared to raw meat. At the same time, in relation to dry matter, it was shown that sous vide samples had a lower anserine content compared to samples heated by steam in a combi-steamer oven. Taking into account the high solubility of anserine and relatively high thermal resistance indicated in the literature, it can be assumed that the reduction in anserine results from cooking loss. The cooking loss in the SV method was contained in a hermetic package, creating an extraction environment for further leaching of anserine, which was facilitated by the long processing time. In the OV, the cooking loss that formed did not have direct contact with the heated product. At the same time, the product was heated at a higher temperature, and the temperature gradient created on the surface could result in stronger denaturation of surface proteins, resulting in reduced mass transfer. This assumption is consistent with the findings of Peiretti et al. [18], who indicated that microwave heating resulted in obtaining a surface layer on the meat that limited the losses of carnosine and anserine.

#### 4. Conclusions

The method of thermal treatment and its parameters (temperature and time) affected the quality of products obtained from pectoral goose muscles. SV cooked meat was lighter and less red and had more yellow hues than OV. When compared to raw meat, the OV samples differed in terms of colour considerably, whereas SV was significantly more cooked. Low-temperature processing (temp. 65 °C, time 4 h) of goose breast meat using the SV method and a convection–steam oven in a steam environment (processing temperature 80 °C, final temperature 65 °C) allowed for obtaining products with similar textural characteristics. Both extending the heating time in the SV and increasing the heating temperature in the OV increased the hardness, cohesiveness and chewiness of products. As a result of the heat treatment, a significant reduction in the anserine content related to dry matter was found. A greater reduction in anserine was found in SV samples compared to OV; however, neither SV processing time nor OV temperature significantly differentiated the dipeptide content. Taking into account the possibility of obtaining goose

meat products heated in a convection–steam oven in a steam environment with textural characteristics similar to sous vide products while reducing anserine losses during heat treatment, this method should be considered a rational alternative to the SV method.

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