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EFFECTS OF HIGH HYDROSTATIC PRESSURE ON THE TEXTURAL PROPERTIES OF COOKED WILD RED DEER MEAT

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Abstract: Game meat could be considered a good alternative for red meat for human consumption. Meat sourced from wild animals raised under natural environment become increasingly popular with consumers in recent years. This study aimed to assess the effect of high hydrostatic pressure (HHP) on the textural properties of cooked wild red deer (*Cervus elaphus)* meat. Samples of raw deer meat were treated with different pressures ranging from 150 to 600 MPa for 5 min and stored at 4°C. The samples were cooked on day 1 and 7, and after cooking drip loss and the textural properties were measured. The textural properties were determined using Texture Profile Analysis (TPA) and the Warner–Bratzler (WB) methods. The decision to measure cooked samples is based on the fact that the product will be consumed by the consumers in a cooked form. The results of this study showed that the significant changes in texture attributes, including hardness, springiness, cohesiveness, chewiness, and shear force, in response to HHP treatment and storage duration. These results provide valuable information about the influence of HHP on the textural quality of cooked wild red deer meat, informing food processing practices aimed at increasing consumer satisfaction and product acceptability.

Keywords: deer meat, game meat, HHP, texture profile analysis, Warner–Bratzler

1. Introduction

The consumption of game meat, particularly wild red deer, has emerged as a popular choice among consumers seeking natural and sustainable alternatives to traditional red meats. Renowned for its lean profile, high protein content, and potential for reduced environmental impact, wild game meat holds significant appeal for health-conscious and environmentally conscious individuals (Lorenzo et al., 2019). Moreover, the allure of wild game meat often stems from its sourcing, with animals typically raised in natural environments, further enhancing its appeal among consumers.

Despite the growing demand for wild game meat, there remains a notable gap in our understanding of the factors influencing its quality, particularly regarding post-slaughter handling and processing techniques. While research on various aspects of venison and game meat has advanced in recent years, information regarding the intricate interactions between production systems, pre-slaughter handling, post-slaughter processing, and the ultimate quality of deer meat remains limited (Kudrnáčová et al., 2018). Addressing this knowledge gap is essential for ensuring the continued production of high-quality wild game meat that meets consumer expectations.

In light of these considerations, this study aims to investigate the impact of high hydrostatic pressure on the textural properties of cooked wild red deer meat. High hydrostatic pressure, a non-thermal food processing method, has garnered attention as a promising technique for enhancing the quality of meat products, offering potential improvements in texture, flavor, and shelf life. By subjecting meat to elevated pressures in a controlled environment, high hydrostatic pressure processing achieves microbial inactivation without the need for high temperatures, thereby preserving the nutritional integrity and sensory characteristics of the meat (Garriga et al., 2004; Garriga & Aymerich, 2009; Jofré et al., 2009; Tassou et al., 2007).

This research seeks to contribute to the existing body of knowledge by examining how high hydrostatic pressure treatment influences the texture of cooked wild red deer meat. Through a comprehensive analysis of textural attributes, this study aims to provide valuable insights into the optimization of meat processing practices, ultimately enhancing the quality and consumer appeal of wild game meat products.

2. Materials and methods

2.1. Pressure treatment

Fresh wild red deer meat samples were obtained from a local processing plant in Hungary. The samples were transported to the laboratory in polyethylene bags, maintaining a chilled temperature of 4 ± 1°C. The samples were then uniformly sized and vacuum-packed in polyethylene bags, using a C200 vacuum packer (Multivac Ltd., Geprüfte Scherhert, AGW, Wolfertschwenden, Germany). High Hydrostatic Pressure (HHP) processing was conducted with a Resato FPU-100-2000 system (Resato Int. B.V., Roden, Netherlands), applying pressures of 150, 200, 250, 300, 350, 400, 450, 500, 550, and 600 MPa for 5 minutes at 22°C. In total, 11 samples, including a non-treated control sample, were used in the study. After treatment, samples were stored at 4 ± 1°C for 7 days, and quality parameters were assessed on days 1 and 7 of storage.

2.2. Drip loss measurement

Drip losses were assessed by measuring the difference in meat weight before and after cooking in vacuum-packed conditions. Prior to treatment, the weight of each meat sample was recorded. Following cooking, the samples were removed from the vacuum bags, dried by blotting, and then reweighed. Drip loss was determined using the following formula:

$$Drip\ loss = \frac{Initial\ weight - Drip\ weight}{Initial\ weight} \times 100$$

2.3. Instrumental texture measurement

Instrumental texture measurements were conducted using the SMS TA.XT Plus texture analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK).

2.3.1. Texture profile analysis

The wild red deer meat samples utilized for texture profile analysis (TPA) samples were shaped into cylindrical forms with dimensions of 12 mm in diameter and 12 mm in height. Each meat sample was then positioned under a cylindrical probe with a diameter of 35 mm, specifically designed for the TPA measurement. The probe descended at a consistent speed, following a predetermined pattern: 3.0 mm/s for the pre-test phase, 1.0 mm/s during the main test phase, and again 3.0 mm/s for the post-test phase. As the probe descended, it penetrated the meat sample until reaching a depth equivalent to 75% of the sample's height. Subsequently, the probe retracted to its initial point of contact with the sample and paused for a set period of 2 seconds before initiating the second compression cycle. Throughout the test, the resistance of the meat sample to compression was continuously measured, with data recorded every 0.01 seconds. These resistance values were then plotted on a force-time plot, allowing for the visualization of the sample's response to the applied force over time (de Huidobro et al., 2005; Jonas et al., 2017). This TPA methodology provided valuable insights into the textural characteristics of the wild red deer meat samples.

2.3.2. Warner-Bratzler shear test

The Warner-Bratzler shear test (WBS) is utilized to measure the force (in Newtons) required to shear a piece of meat. For the wild red deer meat samples, this test involved opening them from vacuum packaging and slicing them to a thickness of 20 mm. The prepared meat sample was then positioned on the table beneath a V-shaped blade. As the blade descended with a consistent speed through the slit in the table, it cut through the meat sample. The downward stroke had 30 mm.

During the test, the resistance of the meat sample to shearing was continuously recorded at intervals of 0.01 seconds. These data points were then plotted by a computer to generate a force-deformation plot. The primary parameter measured in this test was the maximum shear force, which corresponds to the highest peak observed on the curve and represents the maximum shear resistance of the sample.

2.4. Statistical analysis

To evaluate the impact of the HHP treatment on the quality parameters of the wild red deer meat samples, including texture and drip loss, a one-way analysis of variance (ANOVA) was conducted using IBM SPSS27 (Armonk, NY 2020). For texture analysis, the ANOVA examined the differences in textural attributes among the various treatment groups. Similarly, for drip loss, the ANOVA assessed the variations in moisture loss across the different treatment conditions. Following the ANOVA analyses, post hoc tests, such as Tukey's HSD, could be applied to determine specific differences between individual treatment groups, if applicable. A significance level of $P < 0.05$ was employed for all statistical tests, indicating significant differences in texture and drip loss among the treatment groups.

3. Results

3.1. Drip loss

Figure 1 illustrates the impact of HHP treatment on the drip loss of red deer meat samples. On day 1 of storage, the analysis of drip loss indicated that the treatment group subjected to 250 MPa exhibited significantly lower drip loss compared to the control sample. Conversely, the samples treated at 550 MPa showed significantly higher drip loss than the control sample.

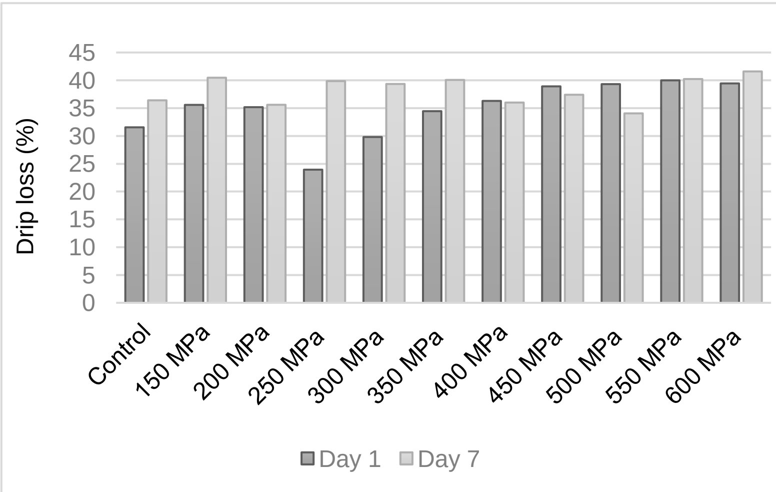

Figure 1.: Effects of HHP processing on drip loss values of deer meat samples after cooking.

However, by day 7 of storage, the pattern of drip loss had shifted. The sample treated at 500 MPa displayed a significant reduction in drip loss compared to day 1. In contrast, the drip loss for the other treatment groups either remained significantly higher or remained similar to the levels observed on day 1.

3.2. Texture analysis

Table 1 provides a comprehensive overview of the effects of HHP treatment on the textural properties of cooked wild red deer meat samples on day 1. On day 1, the highest shear force was observed in the sample treated at 200 MPa, while the lowest shear force was recorded for the sample treated at 400 MPa. Regarding hardness, the sample treated at 300 MPa exhibited the highest hardness, whereas the lowest hardness was observed in the sample treated at 200 MPa.

Table 1.: Effects of HHP treatment on the textural properties of cooked wild red deer meat samples on day 1.

Treatment	**Day 1**				
	Shear force WB (N)	Hardness TPA (N)	Cohesive-ness TPA (-)	Springiness TPA (mm)	Chewiness TPA (mJ)
Control	544.34±12.22^{b}	128.24±11.56^{b}	0.41±0.01^{bc}	0.80±0.07^{a}	42.14±4.01^{a}
150 MPa	508.41±32.44^{b}	132.59±10.23^{ab}	0.47±0.02^{a}	0.73±0.06^{ab}	45.37±3.56^{a}
200 MPa	785.42±29.76^{a}	100.18±9.45^{d}	0.44±0.01^{b}	0.46±0.04^{c}	20.52±2.01^{d}
250 MPa	451.77±32.12^{c}	125.71±11.49^{bc}	0.43±0.02^{b}	0.59±0.04^{b}	32.13±3.12^{bc}
300 MPa	389.71±18.54^{c}	143.84±10.72^{a}	0.39±0.03^{c}	0.54±0.02^{bc}	30.45±2.05^{c}
350 MPa	352.17±23.26^{cd}	126.86±8.99^{b}	0.42±0.01^{b}	0.49±0.03^{c}	26.69±2.78^{c}
400 MPa	303.04±23.65^{d}	111.97±10.42^{c}	0.41±0.02^{bc}	0.62±0.06^{b}	28.66±19.23^{c}
450 MPa	380.77±21.98^{cd}	129.01±11.23^{b}	0.44±0.04^{b}	0.60±0.02^{b}	34.54±3.12^{b}
500 MPa	371.01±29.12^{c}	131.31±13.11^{ab}	0.45±0.04^{ab}	0.59±0.03^{b}	35.53±2.13^{b}
550 MPa	399.09±32.94^{c}	129.28±9.65^{b}	0.44±0.03^{b}	0.67±0.05^{b}	38.38±2.65^{b}
600 MPa	464.06±37.91^{bc}	114.79±10.34^{c}	0.47±0.04^{a}	0.84±0.08^{a}	45.82±4.15^{a}

Table 2 presents a detailed analysis of the impact of HHP treatment on the textural properties of cooked wild red deer meat samples on day 7. On day 7, the highest shear force was observed in the sample treated at 600 MPa, while the lowest shear force was recorded for the sample treated at 400 MPa. Similarly, the highest hardness was observed in the sample treated at 600 MPa, while the lowest hardness was recorded for the sample treated at 300 MPa.

Table 2.: Effects of HHP treatment on the textural properties of cooked wild red deer meat samples on day 7.

Treatment	**Day 7**				
	Shear force WB (N)	Hardness TPA (N)	Cohesive-ness TPA (-)	Springiness TPA (mm)	Chewiness TPA (mJ)
Control	476.06±23.14^{c}	170.25±11.22^{a}	0.42±0.01^{a}	0.67±0.05^{a}	48.50±3.43^{a}
150 MPa	459.07±42.12^{c}	148.43±13.10^{b}	0.41±0.03^{ab}	0.62±0.06^{ab}	37.39±2.87^{b}
200 MPa	504.28±29.99^{b}	138.44±10.23^{c}	0.44±0.02^{a}	0.69±0.05^{a}	41.86±1.23^{ab}
250 MPa	362.03±26.14^{d}	157.08±12.34^{b}	0.38±0.03^{b}	0.51±0.03^{b}	30.71±2.54^{c}

300 MPa	410.12±39.12[cd]	110.45±10.29[d]	0.36±0.02[c]	0.70±0.06[a]	28.35±2.22[c]
350 MPa	398.17±23.55[d]	136.99±11.87[c]	0.35±0.02[c]	0.56±0.05[b]	27.20±1.76[c]
400 MPa	334.24±23.59[d]	111.00±10.56[d]	0.37±0.01[bc]	0.72±0.06[a]	30.01±3.03[c]
450 MPa	409.47±41.33[cd]	142.88±11.15[bc]	0.42±0.04[a]	0.59±0.04[b]	35.56±3.34[b]
500 MPa	464.87±23.97[c]	134.91±12.13[c]	0.43±0.03[a]	0.55±0.05[b]	31.89±3.11[c]
550 MPa	336.66±31.54[d]	161.06±12.22[ab]	0.38±0.02[b]	0.66±0.06[a]	41.01±4.07[ab]
600 MPa	638.52±58.12[a]	172.96±15.98[a]	0.44±0.04[a]	0.37±0.02[c]	28.58±1.99[c]

4. Discussion

In conclusion, the findings of this study provide valuable insights into the effects of high hydrostatic pressure (HHP) treatment on the quality attributes of cooked wild red deer meat. The results revealed significant variations in both texture and drip loss among the different treatment groups, highlighting the influence of pressure levels on the meat's properties.

The texture analysis results demonstrated that HHP treatment had a pronounced effect on the shear force and hardness of the wild red deer meat samples. Specifically, the samples treated at higher pressure levels exhibited increased shear force and hardness, indicating enhanced textural attributes compared to untreated samples. Additionally, the observed differences between day 1 and day 7 results underscore the importance of considering the duration of storage when evaluating the impact of HHP treatment on meat quality.

Furthermore, the analysis of drip loss revealed that HHP treatment could effectively reduce moisture loss in wild red deer meat samples, particularly at specific pressure levels. These findings suggest that HHP treatment has the potential to improve both textural properties and moisture retention in cooked wild red deer meat, thereby enhancing its overall quality and consumer satisfaction.

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