



The effects of dry ageing period and subsequent culinary methods on the oral processing parameters of beef

Ivana D. Tomašević¹ , Igor Tomašević^{2*} , Nedim Turković², Đorđević Vesna¹ , Aristide Maggiolino³ , Volker Heinz⁴ and Ilija Djekić²

¹ Institute of Meat Hygiene and Technology, Kačanskog 13, Belgrade, 11040, Serbia

² University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Belgrade, Serbia

³ Università degli studi di Bari Aldo Moro, Piazza Umberto I, 1, 70121 Bari, Italy

⁴ German Institute of Food Technologies (DIL), Professor-von-Klitzing-Straße 7, 49610 Quackenbruck, Germany

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ABSTRACT

This study investigates the impact of dry aging duration and subsequent cooking methods on the oral processing parameters of beef. Dry aging is a traditional technique that enhances beef by controlled environmental and enzymatic changes. Two dry aging periods (21 and 42 days) were combined with two cooking methods (grilling and sous vide). A sensory panel evaluated the beef samples, assessing parameters such as particle size, chewing rate, and eating rate. The breakdown of food structures during oral processing influences the sensory perception of texture, flavor, and taste, thereby determining a food's overall acceptability and palatability. Results showed that shorter dry aging duration and cooking method significantly affected only some of the oral processing parameters. Shorter dry aging period (21 days) generally led to increased total number and share of smaller particle sizes. In these terms, sous vide cooking resulted in improved oral processing profiles compared to grilling. The longer period (42 days) of dry ageing was without an effect on beef oral processing, irrespective of culinary method applied. These findings contribute to a better understanding of how dry aging and cooking methods influence the sensory experience of beef, potentially aiding in the development of products tailored to consumer preferences.

1. Introduction

Dry aging is a traditional method that enhances beef by exposing it to controlled environmental and enzymatic changes. This technique improves tenderness, deepens flavor, and imparts distinctive texture characteristics. It involves storing large beef cuts, such as ribeye or strip loin, in a tightly regulated setting—typically maintained at low temperatures (2–4 °C), around 85% humidity, and with consistent airflow (Khan Muhammad *et al.*, 2016). Over a period of several weeks to months, natural enzymes in the meat, like calpains and cathepsins, break down complex proteins into smaller peptides and amino

acids. This enzymatic activity softens the meat and contributes to the development of rich, umami flavours (O'Quinn *et al.*, 2018).

The length of the aging period plays a crucial role in determining the final flavor and texture. Generally, longer aging enhances flavour intensity, but the ideal duration depends on factors such as the beef's original quality, the specific aging conditions, and the desired flavor profile (Cenci-Goga *et al.*, 2020). If not carefully monitored, the aging environment—particularly its heat and air circulation—can cause excessive water loss and protein denaturation, leading to a drier texture (Jadhav *et al.*, 2021). Sous vide—meaning “under vacuum”—uses a water bath

*Corresponding author: Igor Tomasević, tbigor@agrif.bg.ac.rs

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to cook meat at precisely controlled low temperatures, usually between 50 °C and 85 °C (Gómez and Beriain, 2019). This method ensures even heat distribution throughout the meat, minimizing temperature differences and allowing for accurate control of internal temperature and protein denaturation (Przybylski *et al.*, 2021).

Oral processing, a multifaceted and intricate initial stage of digestion, encompasses a series of actions within the oral cavity that prepare food for swallowing and subsequent breakdown in the gastrointestinal tract. This process integrates muscle activity, jaw movements, and tongue movements, all contributing to the transformation of food structure into a bolus suitable for ingestion (Koç *et al.*, 2013). The breakdown of food structures during oral processing directly influences the sensory perception of texture, flavor, and taste, thereby determining a food's overall acceptability and palatability (Foegeding *et al.*, 2015). The parameters of oral processing, including chewing rate, bolus formation time, and salivary flow rate, are highly variable and are influenced by an array of factors, such as individual physiology, food properties, and cognitive expectations (Campbell *et al.*, 2017). The way that food undergoes changes in the mouth has a big impact on how we experience its texture, which is a core feature that affects how much we enjoy eating (Devezeaux De Lavergne *et al.*, 2021). The idea of this research was to examine the effects of dry ageing duration (21 and 42 days) and subsequent culinary methods (grill and sous vide) on the oral processing parameters of beef.

2. Materials and Methods

2.1. Meat samples and ageing process

Beef hindlegs (shank and chump off, $n = 12$) were collected from six beef carcasses on the day of slaughter. Paired legs (left and right) from the same animal were randomly assigned to two ageing treatments: in-bag dry-ageing (21 days) or in-bag dry-ageing (42 days). Briefly, in-bag dry-ageing was carried out in water permeable ageing bags (TUBLIN® 10, 50 µm thick, polyamide mix with water vapor transmission rate 920 g/50 µm²/24 h at 7 °C, 50% RH, and oxygen transmission rate 660 g/m²/24 h at 7 °C, 50% RH, TUB-EX ApS, Denmark) at 2 ± 0.5 °C, 0.5 m.s⁻¹ air velocity and relative humidity of 75 ± 5 %. Samples without a period of dry ageing were investigated as control samples.

2.2. Food oral processing panel

The food oral processing (FOP) panel consisted of eight panellists (four male and four female members, normal body mass index 18–25 kg/m²) with previous experience in similar studies. They all confirmed two main pre-conditions for performing this type of research—good general health condition and no dental problems (Forde *et al.*, 2013). Before performing the planned FOP study, one 2-hour training session was organized to get the panellists familiar with the methods to be employed (Djekic *et al.*, 2021). During this initial session, all panellists signed written consent to participate voluntarily.

2.3. Oral processing analysis

The first task for the panellists was to consume cubical meat samples (2×2×2 cm). The chewing process was recorded using a digital video camera that was placed 30 cm from each panellist (Forde *et al.*, 2013). Video recordings were analysed using stopwatch. This enabled counting of the number of chews and total oral consumption time (Hennequin *et al.*, 2005). In parallel, panellists raised their hand when swallowing to enable counting of the number of swallows per sample (Djekic *et al.*, 2021). The mass of each sample before consumption was measured using a technical balance of 0.01 g accuracy. Based on recorded data, food oral processing parameters were calculated (Aguayo-Mendoza *et al.*, 2019). All panellists received two samples from each ageing period and another two samples from each culinary method.

2.4. Particle size analysis

To analyse particle distribution of the boluses, the same types of meat samples (2×2×2 cm) were collected from each panellist at the moment before swallowing by expectorating (Djekic *et al.*, 2021). Upon collection, they were: (i) rinsed using distilled water on filter paper; (ii) spread out on white plates and, (iii) photographed with a digital camera. The spreading of boluses was performed with care to prevent damage of the particles. Image analysis was conducted using ImageJ software. This enabled counting of the number of particles and calculation of their surface area (Rizo *et al.*, 2019). Bolus analysis was performed in two replicates.

2.5. Statistical analysis

Data from the texture profile analysis and food oral processing study were subjected to analysis of variance as follows: one-way ANOVA was employed for the effects of culinary method (C), aging days (D), and for the number of particles. The statistical significance of the factors C and D was determined using the Tukey HSD test ($p < 0.05$). The chi-square test for association was used in analysing possible relationships between particle size fragmentation and aging of meat ($p < 0.05$).

3. Results and Discussion

Understanding the relationship between the structure of solid foods and their oral processing is paramount for enhancing features such as texture and taste (Guo, 2021). The number of particles in food oral processing relates to the degree of food breakdown during chewing and bolus formation (van der Bilt, 2009). The “ideal” number of particles depends on the desired sensory experience and functionality of the food product and there isn’t a universally “better” option between a larger or smaller number of particles (Tyle et al., 1990). Our results clearly

demonstrated that the sous-vide cooking technique resulted in a notably larger number of particles compared to grilling the meat, both without and with the period of dry ageing (Figure 1). However, no significant differences were found in the number of particles between the samples dry aged for 21 and 42 days, irrespective of the cooking technique applied.

The oral processing of food involves the breakdown of food structure into a bolus suitable for swallowing, with particle size being a key characteristic of this bolus (Koç et al., 2013). Food particle size plays a critical role in food oral processing, influencing texture perception, taste, and digestion (Devezeaux De Lavergne et al., 2021). Smaller particle sizes within the bolus create a larger surface area for digestive enzymes to act upon. This increased surface area facilitates more efficient enzymatic breakdown of carbohydrates, proteins, and fats (Ramírez et al., 2019).

Our results demonstrate that the percentage of small particles in the boluses significantly decreased (by 18.41% in grilled and 11.75% in sous-vide beef samples) after the aging period of 21 days compared to day 0, irrespective of the culinary technique applied. Further ageing for the subsequent three weeks increased the number of small particles by only a relatively insignificant margin of only 2.4% on average for

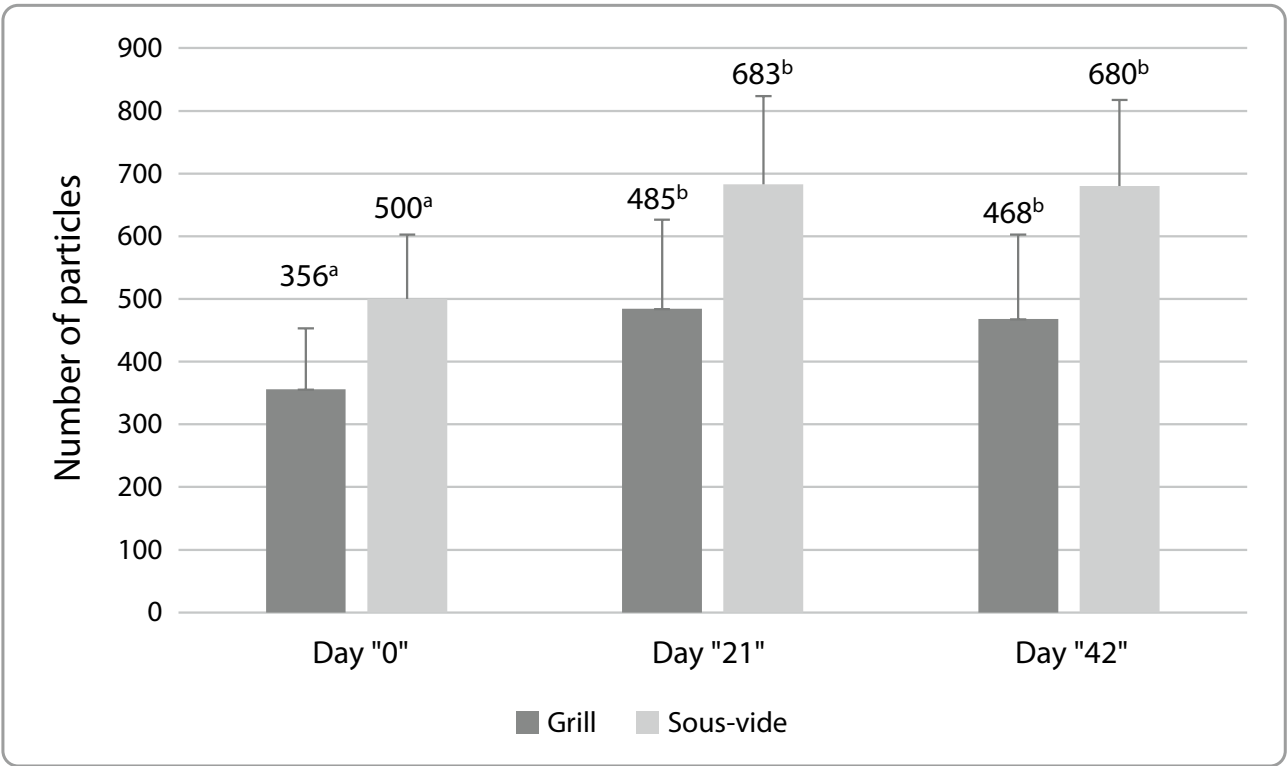


Figure 1. Number of particles of samples obtained in vivo during the aging time for grilled samples (dark grey bars) and sous-vide (light grey bars). Different letters indicate significant differences according to Tukey’s test ($\alpha=0.05$)

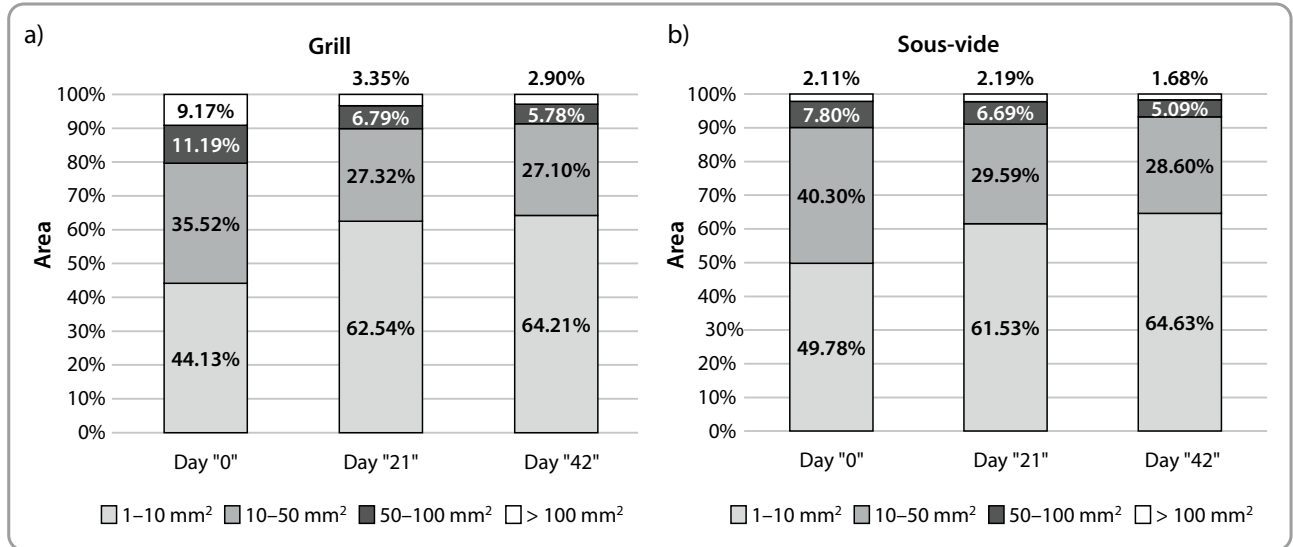


Figure 2. Percentage of area occupied by particles of size: 1–10 mm² (light grey), 10–50 mm² (dark grey), 50–100 mm² (black color), and >100 mm² (white color) depending on the aging time

grilled and sous-vide samples. The number of large particles (>100mm²) for grilled samples was greater than for sous-vide samples by 4-fold on day 0 and continued to remain on the lesser side during the whole period of dry ageing. We already know that a higher number of smaller particles in food samples may result in a smoother texture, while fewer, larger particles could create a coarser or chunkier sensation (Guo, 2021).

Eating rate, or how quickly one consumes food, plays a significant role in food oral processing, influencing both sensory perception and overall food intake (Wee et al., 2018). It affects the duration of oral exposure, the number of chews, and the bolus properties at the point of swallowing (Goh

et al., 2021). Chewing rate specifically measures how quickly someone chews their food and focuses solely on the mastication process, regardless of the amount of food consumed (Sánchez-Ayala et al., 2013). Surprisingly, our results did not reveal a statistically significant influence of either dry ageing or the cooking technique applied on any of the food oral processing parameters presented in Table 1. Chewing cycle duration, chewing and rate remained almost a constant throughout the study. Consumption time for one bite and the number of chews were altered by the duration of dry ageing and cooking method, but never to an extent where the differences could be perceived as statistically significant.

Table 1. Food oral processing parameters of beef subjected to grilling and sous-vide cooking methods.

Meat cooking method	Number of chews	Consumption time for one bite [s]	Number of swallows	Chewing cycle duration [s/chew]	Chewing rate [chew/s]	Eating rate [g/s]
Grilling						
Day 0	43.5 ± 12.4	31.2 ± 9.5	2.9 ± 1.3	0.7 ± 0.2	1.4 ± 0.3	0.4 ± 0.1
Day 21	39.0 ± 6.7	26.3 ± 4.7	2.4 ± 1.2	0.7 ± 0.1	1.5 ± 0.1	0.4 ± 0.1
Day 42	39.6 ± 11.7	26.9 ± 6.9	2.4 ± 1.0	0.7 ± 0.1	1.5 ± 0.1	0.4 ± 0.1
Sous-vide						
Day 0	40.9 ± 15.1	31.3 ± 20.5	2.9 ± 1.2	0.7 ± 0.2	1.4 ± 0.3	0.4 ± 0.1
Day 21	53.1 ± 13.5	37.9 ± 8.5	3.4 ± 0.9	0.7 ± 0.1	1.4 ± 0.2	0.3 ± 0.1
Day 42	41.4 ± 23.3	31.2 ± 20.2	2.8 ± 1.1	0.7 ± 0.1	1.4 ± 0.2	0.4 ± 0.2

Testing was performed in two replicates. Data are mean values ± standard deviation.

4. Conclusion

Three weeks of dry ageing resulted in partly improved oral processing of beef, but only in terms of the increased total number of particles and percentage of area occupied by particles of smaller size, which might have an indirect positive effect on meats' texture, digestion and nutrient absorption. In the same terms, sous-vide was not perceived as a favourable culinary method compared to grilling. Dry ageing for a prolonged period of time, i.e., an additional three weeks,

had no effect on beef oral processing. However, a limitation of this study was the food oral processing panel that was not tested for reliability, repeatability, or consistency. Also, further research is needed where the difference between dry ageing periods would be smaller, which could lead to more statistically robust and reliable results; instrumental textural analysis is also needed to confirm the sensory findings. The results of these studies could also be compared with the results of sensory evaluation and textural characteristics.

Uticaj perioda suvog zrenja i naknadnih kulinarskih metoda na parametre oralne obrade govedine

Ivana D. Tomasević, Igor Tomašević, Nedim Turković, Djordjević Vesna, Aristide Maggiolino, Volker Heinz i Ilija Djekić

INFORMACIJE O RADU

Ključne reči:

Suvo zrenje
Roštilj
Sous-vide
Veličina čestica
Brzina žvakanja
Brzina jedenja
Oralna obrada
Tekstura go

APSTRAKT

Ova studija istražuje uticaj trajanja suvog zrenja i naknadnih metoda termičke obrade na parametre oralne obrade govedine. Suvo zrenje je tradicionalna tehnika koja poboljšava senzorni kvalitet govedine u kontrolisanim uslovima usled dejstva enzima. Dva perioda suvog zrenja (21 i 42 dana) kombinovana su sa dve metode termičke obrade (roštilj i su-vid). Senzorni panel je ocenio uzorke govedine, procenjujući parametre kao što su veličina čestica, brzina žvakanja i brzina jedenja. Razgradnja strukture hrane tokom oralne obrade utiče na senzornu percepciju teksture, ukusa i arome, čime određuje ukupnu prihvatljivost i ukus mesa. Rezultati su pokazali da kraće trajanje suvog zrenja i metod termičke obrade značajno utiču samo na neke od parametara oralne obrade. Kraći period suvog zrenja (21 dan) generalno je doveo do povećanja ukupnog broja i udela čestica manjih veličina. U tom smislu, su-vid kuvanje je rezultiralo poboljšanim profilima oralne obrade u poređenju sa roštiljanjem. Duži period (42 dana) suvog zrenja nije imao uticaja na oralnu obradu govedine, bez obzira na primenjeni kulinarski metod. Ovi nalazi doprinose boljem razumevanju kako suvo starenje i metode termičke obrade utiču na senzorno iskustvo govedine, što potencijalno pomaže u razvoju proizvoda prilagođenih željama potrošača.

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Authors info

Ivana D. Tomasević, <https://orcid.org/0009-0007-1448-6557>

Igor Tomašević, <https://orcid.org/0000-0002-1611-2264>

Nedim Turković /

Djordjević Vesna, <https://orcid.org/0009-0008-5187-4089>

Aristide Maggiolino, <https://orcid.org/0000-0001-7128-8556>

Volker Heinz, <https://orcid.org/0009-0001-7019-5400>

Ilija Djekić, <https://orcid.org/0000-0002-8132-8299>