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Research article

Marinating of bovine loin (*longissimus dorsi)* in split gill mushroom (*Schizophyllum commune*) raw water extracts

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Abstract
Meat tenderness is a factor that determines the palatability, acceptability, and consumer motivation to buy meat. This study evaluates the sensory, biochemical, and physicochemical properties of bovine loin ("longissimus dorsi") marinated in mushroom water extract of split gill (*Schizophyllum commune*). The study was conducted experimentally using a completely randomized experimental design with 4 concentrations (2.5, 5.0, 7.5, and 10.0%) of fruiting body *S. commune* raw water extracts in relation to negative control (0%) obtained by using distilled water, and positive control obtained by adding 0.2% papain. Each marination treatment was repeated 4 times. The results of the study showed that marination in *S. commune* water extract increased tenderness, water holding capacity, cooking loss, water content, protein, fat, digestibility protein content, total ash, selenium, colour, taste, aroma, and acceptability but did not affect the pH of bovine loin. The physicochemical, biochemical, and sensory characteristics of bovine loin marinated in 2.5% *S. commune* mushroom water extract as optimum concentration were better than 0.2% papain. This study recommends using *S. commune* mushroom water extract up to a concentration of 2.5% as a meat tenderizer.

Keywords
biochemical, bovine loin tenderness, marination, physicochemical, sensory, split gill mushrooms

Introduction

Beef is still a highly sought-after livestock commodity due to its distinctive and robust taste, even though many people nowadays eat vegetarian food or avoid beef. However, data shows that global beef consumption in 2020 reached 130 billion pounds (FAO, 2024). Tenderness is one of the factors that determines the palatability and acceptance of meat by consumers related to mouth feel, texture, and appearance (Zhang et al., 2017; Woinue et al., 2020), apart from taste and juiciness (O'Quinn et al., 2018). Tenderness is also a motivating factor for repeat consumer purchases, even at higher prices

(Madhusankha and Thilakarathna, 2021). Components involved in meat tenderness are connective tissue, sarcomere length, postmortem changes, proteolytic potential, and myofibrillar protein degradation (Gagaoua et al., 2021; Azmi et al., 2023). Recently, consumers have demanded that various products, including meat and meat products, be labeled "natural" and that their production does not use preservatives or synthetic components (Munekata et al., 2023). Changes in consumer behavior encourage food producers to design and produce foodstuffs with natural and health-beneficial labels.

Edible mushrooms have nutritional value, antioxidant activity, and health-beneficial properties and present one of the best natural sources of several functional ingredients such as ergosterol, polyphenols, terpenes, terpenoids, mannitol, and trehalose that have recently attracted consumers (Das et al., 2021; Kumar et al., 2021). They are categorized as healthy foods due to their low contents of calories and fat, but rich in protein, dietary fiber (e.g., chitin, hemicellulose, mannan, and β-glucan), and diverse minerals (Zhang et al., 2021). Thus, their taste and texture properties have recently attracted the industry's attention to use mushrooms as a substitute for several ingredients and additives in processed foods, including meat (Patinho et al., 2021; Singh et al., 2023).

Proteolytic enzymes from edible mushrooms can be meat tenderizers (Lee et al., 2017). Numerous studies have documented the use of mushrooms as meat tenderizers; e.g., *Pleurotus ostreatus* (Jacq.) P. Kumm. is used to tenderize beef and pork (Chung and An, 2012), *Sarcodon aspratus* (Fr.) P. Karst., *Lentinus edodes* (Berk.) Pegler, and *Grifola frondosa* (Dicks.) Gray to tenderize bovine loin (Lee et al., 2017), *Cordyceps militaris* L. to tenderize chicken meat (Barido and Lee, 2021), and *Agaricus bisporus* (J.E. Lange) Imbach to tenderize culling chicken breast meat (Wardah et al., 2023). However, the umami taste is one of the best candidates because it has a unique taste (flavor) and aroma (Mau et al., 2018; Prabsangob and Sittiketgorn, 2023).

Split gill mushroom [*Schizophyllum commune* (Fr.) Pilát] is popularly consumed in Asia due to its umami taste associated with meat (Prabsangob and Sittiketgorn, 2023). In addition, *S. commune* contains bioactive compounds, especially phenolics that have antioxidant and antidiabetic activities, glucans with antiradical activity, and schizophyllans with antimicrobial, anticancer, antitumor, and immunomodulating activities (Singh et al., 2021). Moreover, *S. commune* has been reported to produce ethanol from lignocellulosic biomass (Horisawa et al., 2019) and produce several enzymes such as cellulases (Sornlake et al., 2017; Kumar et al., 2018), xylanases (Gautam et al., 2018), pectinases (Zhu et al., 2016; Mehmood et al., 2018), lipases (Kam et al., 2016), laccases (Kumar et al., 2015), manganese peroxidase, and lignin peroxidase (Asgher et al., 2016). However, the profile of umami-related compounds and bioactive agents of mushrooms depends on several factors, such as species and maturity, as well as storage conditions and processing methods (Prabsangob and Sittiketgorn, 2023). Since no publications exist on *S. commune* mushroom water extract for bovine loin tenderization, this study evaluated bovine loin physicochemical, biochemical, and sensory characteristics marinated in split gill mushroom water extract (w.e.).

Materials and Methods

In this completely randomized study, four concentrations of *S. commune* w.e. (2.5%, 5.0%, 7.5%, and 10.0% w/w), together with a negative control (0%), and a positive control of 0.2% papain enzyme (CAS No. 9001-73-4, Sigma) were analyzed four times.

Preparation of S. commune mushroom water extract

The cultivated mushroom species *S. commune* was obtained from a mushroom farmer in Bandar Lampung (Rafadit, Indonesia). Freshly picked *S. commune* samples were cleaned of debris and then air-dried. After washing, they were sliced into tiny pieces and allowed to air dry without being exposed to sunlight. Twenty liters of distilled water were used to dry, grind, and macerate 2 kg of mushrooms, which were then shaken for 24 h at 150 rpm. The filter paper was used to filter the macerate. The filtrate was evaporated for 2 h at ~ 60 °C in a rotary evaporator to create a concentrated mushroom w.e. and then dried at ~ 60 °C in an oven until a constant mass.

Bovine loin marination

The bovine loin ("longissimus dorsi") section from 3-year-old Bali cattle (*Bos javanicus domesticus*) was purchased from Ternak Mart, Surabaya, Indonesia. After 48 h postmortem, 576 g of bovine loin was cut into cubes measuring 2 cm^3, divided into 6 portions of meat for each treatment (negative control, papain 0.2%, 2.5%, 5.0%, 7.5%, and 10.0% w.e.). Furthermore, the meat was marinated with mushroom w.e. for 48 h at ~ 4 °C. Tenderness, water-holding capacity, cooking loss, pH level, and organoleptic qualities like colour, taste, and aroma were all evaluated in the marinated meat. The marinated bovine loin was dried in an oven at 60 °C to observe biochemical characteristics until it was weighed and ground into flour.

Physicochemical characteristics of bovine loin

The physicochemical features considered by this study included pH, cooking loss, water-holding capacity (WHC), and tenderness. A penetrometer assessed meat tenderness as Wardah et al. (2023) outlined. The Honikel and Hamm (1994) approach, as outlined by Wardah et al. (2023), was used to measure the water holding capacity (WHC). The cooking loss of marinated meat steamed for 15 min at ~ 80 °C was calculated using the Lee et al. (2017) technique. The pH of the tenderized bovine loin at ~ 25 °C was measured using a pH meter calibrated in phosphate buffers 4.0 and 7.0.

Biochemical content

Analysis of the biochemical content of bovine loin, namely protein, water content, fat, digestible protein (PDC), total ash, and selenium minerals, was carried out using the NIR spectroscopy method in the near-infrared wavelength range (750-2500 nm) using the FOSS NIRS DS2500 grain analyzer tool (Denmark). After being turned on and reaching stable operating conditions, the FOSS NIRS DS2500 was calibrated. The marinated bovine loin was dried and ground. A total of 5 g of bovine loin flour was put into the NIRS DS2500 cuvette and tightly closed, after which the sample port of the FOSS NIRS DS2500 tool was inserted, scanned, measured, and displayed as an NIR spectrum. Data analysis was carried out by software that complies with the FOSS NIRS DS2500 specifications to extract information on the nutritional content of bovine loin flour from the spectrum.

Sensory characteristics

Twenty inexperienced panellists (lecturers and students) from the Faculty of Science and Technology at Universitas PGRI Adi Buana Surabaya, Indonesia, performed the meat sensory evaluation. Panellists were asked to assess the coded meat samples for colour, taste, aroma, and acceptability. Panellists were asked to give a score on a scale of 1 to 9 (Stone and Sidel, 1985) with a description

of each scale: 1 = dislike immensely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.

Statistical analysis

A Completely Randomized Design (CRD) was used to do a one-way analysis of variance in the data about meat's tenderness, WHC, cooking loss, pH value, biochemical properties, and sensory qualities. Before the analysis of variance, data from sensory characteristic assessment results were first transformed into log numbers + 0.5. Each treatment's differences were examined using a statistical Tukey's test at a significance of $P < 0.05$.

Results

Physicochemical characteristics

The results of this investigation (Fig. 1) demonstrated that the tenderness of bovine loin marinated in 10% *S. commune* w.e. concentration was significantly higher than that of all other treatments. The same was for 7.5% w.e. of *S. commune* extract concerning 0.2% papain, 2.5%, and 5% w.e. treatments and the negative control. The tenderness of bovine loin marinated in 5% *S. commune* w.e. was significantly higher than 0.2% papain and 2.5% *S. commune* w.e. while the tenderness of bovine loin marinated in 2.5% *S. commune* extract was significantly higher than that of negative control but not significantly different from the treatment with papain 0.2%. The results of this study (Fig. 1) demonstrated that the pH of bovine loin was not significantly affected by marinating in *S. commune* w.e. The pH of bovine loin in *S. commune* w.e. at all tested concentrations did not significantly change concerning the controls.

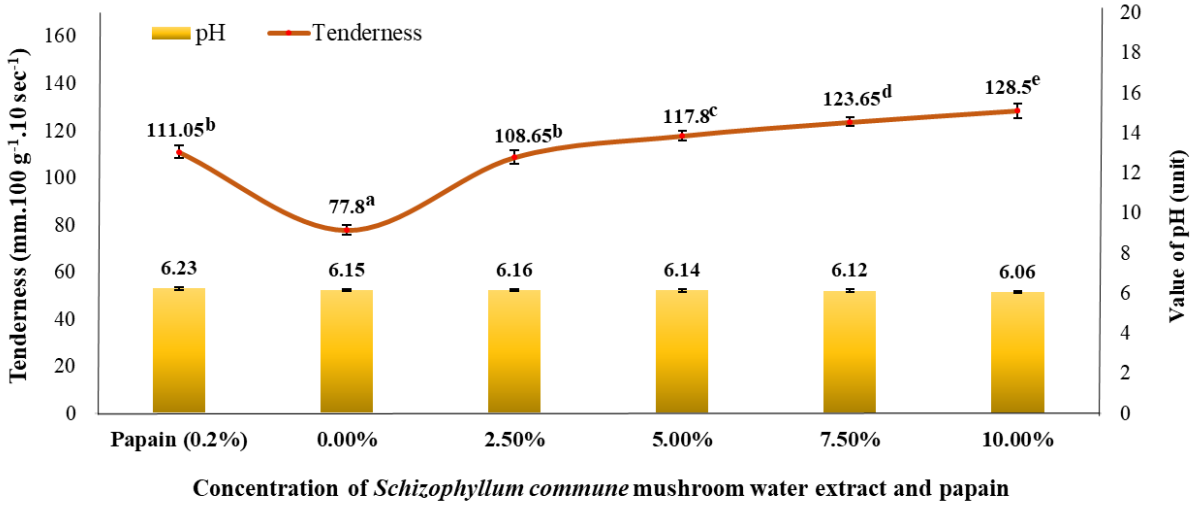

Fig. 1-Tenderness and pH of bovine loin marinated in *S. commune* w.e. and 0.2% papain. The average value with error bars marked with the same letter superscript shows no significant difference ($P > 0.05$).

The WHC of bovine loin marinated in 2.5% *S.commune* w.e. was significantly lower than that of papain 0.2%, *S.commune* 5.0%, 7.5%, and 10% w.e., but not significantly different from the negative control (Fig. 2). While the WHC of bovine loin marinated in 10.0% *S. commune* w.e. was

not significantly different from papain 0.2%, it was significantly greater than that of bovine loin marinated in 5.0% and 7.5% w.e. The findings of this investigation (Fig. 2) demonstrated that the cooking loss of bovine loin marinated in 2.5% *S. commune* w.e. was not significantly different from the negative control, but it was significantly lower than all other treatments. The cooking loss of bovine loin marinated in 10% *S. commune* w.e. was not significantly different from 7.5% and papain 0.2%, but it was significantly higher than that of 5%.

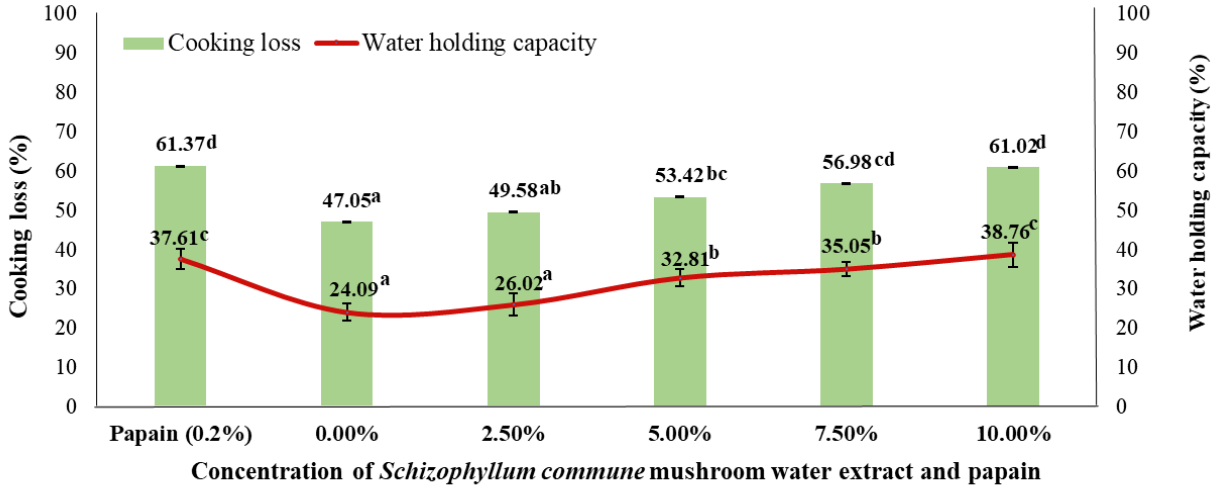

Fig. 2 - The cooking loss and water-holding capacity of bovine loin marinated in *S. commune* w.e. There is no discernible difference ($P > 0.05$) between the average value and the error bars superscripted with the same letter.

Biochemical content

The moisture content (Table 1) between bovine loin marinated in papain 0.2%, negative control, and *S. commune* w.e. at a concentration of 2.5% was not significantly different, but all three were significantly lower than *S. commune* w.e. at concentrations of 7.5% and 10.0%. Meanwhile, the moisture content of bovine loin marinated in *S. commune* at a concentration of 5% was not significantly different compared to all other treatments.

The protein content (dry basis matter) of bovine loin marinated in *S. commune* w.e. at concentrations of 5%, 7.5%, and 10.0% was significantly higher than that of the negative and positive (papain 0.2%) controls, but not significantly different from the *S.commune* w.e. at a concentration of 2.5%. The protein content of beef marinated in 2.5% *S. commune* w.e. did not differ significantly from all other treatments.

The PDC of bovine loin marinated in 10.0% *S. commune* w.e. was significantly higher than positive and negative controls and *S.commune* w.e. at concentrations of 2.5% and 5%, but not significantly different from 7.5% w.e. (Table 1). The PDC content of bovine loin marinated in *S. commune* w.e. at concentrations of 2.5%, 5.0%, 7.5%, and papain 0.2% was significantly greater than the negative control.

The fat content (Table 1) of bovine loin marinated in *S. commune* w.e. at a concentration of 10% was significantly higher than positive and negative controls and *S. commune* w.e. at concentrations of 2.5% and 5.0%, but did not significantly differ from 7.5% w.e. The fat content of bovine loin marinated in *S.commune* w.e. at a concentration of 5% was significantly higher than the negative and positive controls and *S. commune* w.e. at a concentration of 2.5%.

The total ash content of bovine loin marinated in *S. commune* w.e. at concentrations of 5.0%, 7.5%, and 10.0% was significantly higher than that of negative and positive controls but was not significantly different from *S.commune* w.e. at a concentration of 2.5% (Table 1). Selenium content of bovine loin marinated in *S. commune* w.e. at concentrations of 10.0% and 7.5% was significantly higher than that of *S.commune* w.e. at concentrations of 2.5%, 5%, positive and negative controls. Selenium content of bovine loin marinated in *S. commune* w.e. at a concentration of 5% was significantly higher than both controls, but not significantly different compared to *S.commune* w.e. at a concentration of 2.5%.

Table 1- Biochemical content of bovine loin marinated in w.e. of *S. commune*.

Biochemical components (w/w)	**Marinated in *S. commune* w.e. and papain**					
	0%	**0.2% papain**	**2.5%**	**5.0%**	**7.5%**	**10%**
Moisture (%) DM	5.10±0.02^{a}	5.61±0.02^{a}	5.81±0.03^{a}	6.13±0.83^{ab}	6.29±0.07^{b}	6.36±0.03^{b}
Protein (%) DM	54.92±1.46^{a}	55.04±2.23^{a}	57.06±1.83^{ab}	60.74±0.50^{b}	61.02±0.23^{b}	62.03±1.57^{b}
Fat (%) DM	10.48±0.50^{a}	10.69±0.51^{a}	11.70±0.49^{a}	12.75±0.88^{b}	13.54±1.37^{bc}	14.26±1.07^{c}
PDC (%) DM	72.57±0.02^{a}	77.92±0.07^{b}	77.97±0.02^{b}	78.30±0.07^{b}	79.05±1.22^{bc}	80.46±0.02^{c}
Total Ash (%) DM	0.53±0.02^{a}	0.55±0.04^{a}	0.58±0.07^{ab}	0.61±0.06^{b}	0.64±0.04^{b}	0.63±0.03^{b}
Selenium (µg g^{-1}) DM	0.068±0.007^{a}	0.067±0.008^{a}	0.071±0.003^{ab}	0.081±0.009^{b}	0.087±0.003^{c}	0.087±0.012^{c}

*The mean value and standard deviation are given the same notation in the row, indicating no significant difference ($P > 0.05$). DM: dry basis matter

Sensory characteristics

According to panellist evaluation (Fig. 3), the colour of bovine loin marinated in positive and negative controls was significantly lower than all *S. commune* w.e. By contrast to 2.5% and 5% w.e., the colour of the bovine loin marinated in *S. commune* w.e. at concentrations of 7.5% and 10% was significantly higher. Panellists rated the taste of bovine loin marinated in *S. commune* w.e. at the highest level (2.5% and 5.0%), with scores significantly higher than those at concentrations of 7.5% and 10% w.e., as well as both controls.

The panellists rated the bovine loin marinated in 2.5% and 5% *S. commune* w.e. significantly more acceptable (Fig. 3). *Schizophyllum commune* 10% w.e. used to marinate the bovine loin had a significantly lower aroma than that of other treatments. Panellists judged bovine loin marinated with *S. commune* w.e. at concentrations of 2.5% and 5% to be significantly more acceptable than controls and *S. commune* 7.5% and 10% w.e. The bovine loin marinated in 7.5% and 10% *S. commune* w.e. was significantly less acceptable than controls.

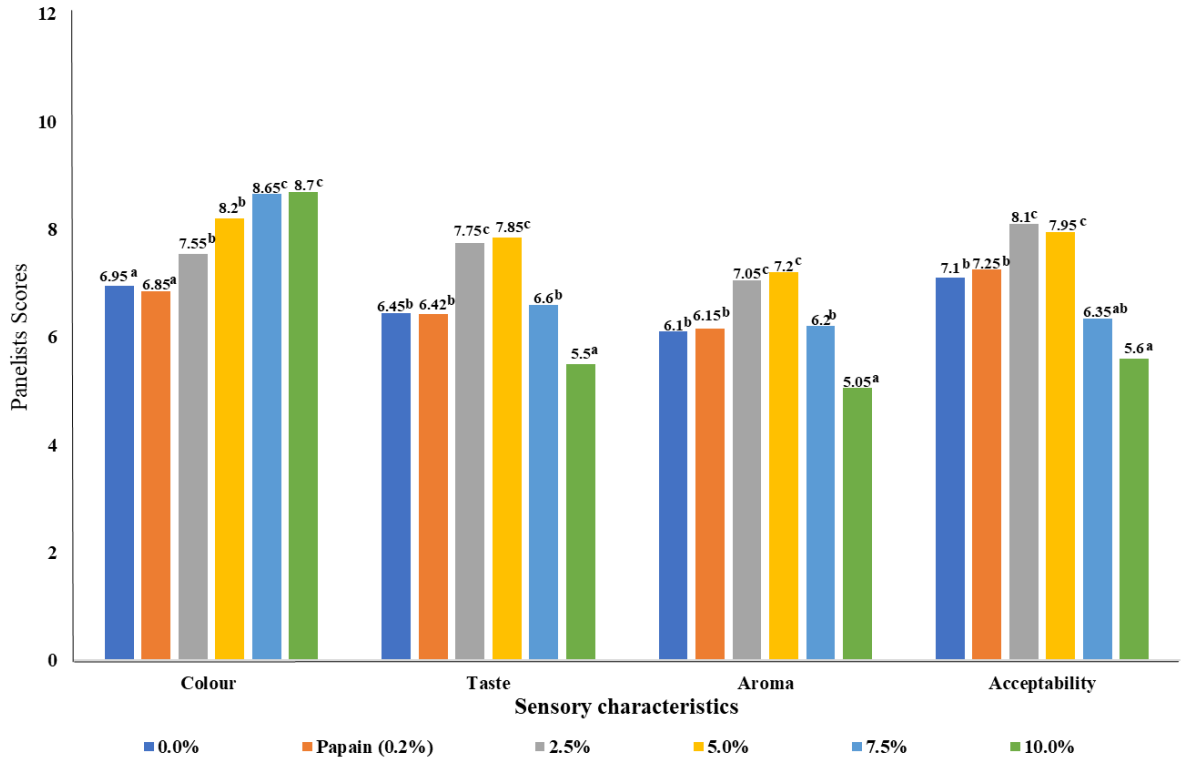

Fig. 3- Sensory characteristics (colour, taste, aroma, and acceptability) of bovine loin marinated in w.e. of *S. commune*. The average values are given the same letter superscript, indicating no significant difference ($P > 0.05$).

Discussion

The current study found that marinating bovine loin in *S. commune* w.e. improved its tenderness and rose as the mushroom extract concentration rose. The increase in bovine loin tenderness is believed to be due to the activity of the protease enzyme in the mushroom w.e. The current study is aligned with Lee et al. (2017) and Shin et al. (2008), who reported that adding extracts of *S. aspratus*, *A. bisporus*, and *L. edodes* mushrooms can increase meat tenderness through protein hydrolysis due to the presence of proteases contained in the mushrooms. Barido and Lee (2021) reported that marination with protease extracted from *C. militaris* mushroom at a concentration of 4% increased protein solubility and the myofibrillar fragmentation index in culled chicken breast meat. Wardah et al. (2023) reported that *A. bisporus* w.e. at a concentration of 5% showed protease and collagenase activity and could tenderize culled chicken breast meat. The difference in concentration for tenderizing beef is due to differences in the content and activity of protease enzymes from the mushroom species. The amount of bioactive chemicals (Angeloni et al., 2021), the sources of the enzyme (Meza-Espinoza et al., 2018), and the processing of raw materials (Lukin, 2020) are some of the factors that affect protease enzyme activity.

The current study indicated that marinating in *S. commune* w.e. up to a concentration of 10.0% can tenderize bovine loin without altering the pH levels. This study aligns with several studies that reported that marinating in mushroom extracts did not affect meat pH: *A. bisporus* w.e. at a concentration of 5% did not affect the pH value of bovine longissimus dorsi (Lee et al., 2017) and culled chicken breast meat (Wardah et al., 2023).

In this study, 10% concentration of marinating in *S. commune* w.e. increased WHC, which is thought to be due to changes in meat protein solubility for protease enzyme activity. The protease enzyme activity can affect protein solubility and changes in meat pH (Lee et al., 2017). Several studies reported that marinating in mushroom extract can increase meat WHC: e.g. *S. aspratus* for bovine longissimus dorsi (Shin et al., 2008) and *A. bisporus* for culled chicken breast meat (Wardah et al., 2023). The effect of marination in meat tenderizers on WHC varies among investigators. Maqsood et al. (2018) found that enzymes such as papain, ficin, or bromelain can lower the WHC of camel meat, while the WHC of rabbit meat can be raised by marinating it in papain, ginger extract, and kiwi fruit extract for 48 h (Naveena et al., 2004).

In our study, marinating bovine loin in highly concentrated *S. commune* w.e. increased cooking loss. The increase in bovine loin cooking loss is believed to be caused by the activity of protease enzymes derived from *S. commune*, which break down the collagen bonding tissue, causing the microstructure of the meat to be exposed and the myofibrils to be broken down. The peptide bonds are broken down into amino acids by protease enzymes, causing increased cooking loss in meat (Nowak, 2011). The number of damaged cell membranes and the beef longissimus dorsi's water content affected the cooking loss percentage (Shanks et al., 2002). The meat marinated in *S. aspratus* extract increased bovine longissimus dorsi cooking loss (Shin et al., 2008). The same results were obtained for culled chicken breast meat marinated in *A. bisporus* w.e. at concentrations higher than 5% (Wardah et al., 2023). The current study indicated an increase in water content in bovine loin marinated in *S. commune* w.e. at the highest concentrations (7.5% and 10%), which was probably caused by the activity of protease enzymes that degrade protein components, facilitating water absorption from the marinade liquid. The mushrooms have a high-water content and can cause an increase in the water content in beef burgers marinated in mushrooms (Patinho et al., 2019).

The protein content of bovine loin marinated in w.e. from *S. commune* increased, along with the increasing concentration of mushroom extract. Protease enzyme activity hydrolyzes protein and enhances its solubility, which is why bovine loin marinated in *S. commune* w.e. is thought to have more protein since nitrogen is absorbed from the mushroom. This study is aligned with the increase in solubility and total protein of chicken breast meat marinated in *C. militaris* extract (Barido and Lee, 2021). Mushrooms are a rich source of protein, essential amino acids, and other nutrients that can improve the nutritional quality of meat products (Singh et al., 2023).

Fat retention, fat emulsion, the creation of novel fatty acid compositions, and free fatty acids from the action of protease enzymes absorbed in the meat were the main causes of the rise in fat in bovine loin marinated with *S. commune* w.e. Mushrooms have a high β-glucan content that can help maintain moisture in meat products, so the meat retains more of its natural fat during the marinating process (Toh et al., 2023). Our results support the findings of Wardah et al. (2023), who found that marinating in *A. bisporus* w.e. raised the amount of fat in the meat from culled chicken breast meat. According to Wang et al. (2019), the combination of protein and fat is broken down, and fat are released by protease hydrolysis.

The current study indicated that marinating in w.e. of *S. commune* can increase the PDC of bovine loin. Increased PCD is thought to be due to an enzyme activity that breaks down crude protein to increase its digestibility and raise amino acid absorption. Several mushroom proteases and peptidase enzymes can break down proteins into smaller peptides and amino acids (Park et al., 2020).

Additionally, the chitinase enzyme present in fungal cell walls may aid in the digestion of crude proteins attached to chitin (Park et al., 2020).

The rise in ash content of bovine loin marinated in w.e. from *S. commune* at concentrations of 5–10% is believed to be caused by the meat's absorption of the mushroom's mineral content. According to Herawati et al. (2016), the ash content of wild and cultivated *S. commune* was 2.0% and 1.94%, respectively. This study supports the findings of Botella-Martínez et al. (2023), who pointed out that adding mushroom extract to beef burgers can raise their ash content.

The absorption of selenium from the *S. commune* w.e. is thought to be the reason for the rise in the selenium content of bovine loin. *Schizophyllum commune* contains around 2.1 ± 0.13 µg/100 g of selenium (Kabuyi et al., 2017). Mushrooms could convert inorganic selenium into bioactive forms such as selenium-polysaccharides, selenium-proteins, and selenoamino acids that can be absorbed by beef during the marinating process (Nie et al., 2023). The presence of selenium nanoparticles in mushroom extracts led to a rise in selenium content in beef, which could absorb it more efficiently (LeBlanc et al., 2023).

The current study indicates that *S. commune* w.e. can maintain the colour of bovine loin, which is thought to be due to the effect of antioxidant components in the mushroom. *Schizophyllum commune* contains schizophilans and polysaccharides consisting of β-glucan, which have high levels of antioxidant activity (Saetang et al., 2022; Nuinamwong et al., 2024). Gutiérrez et al. (2013) stated that myoglobin and lipid oxidation reduced fresh meat's colour and flavor acceptance during cold storage. The addition of fruiting body extracts of *Flammulina velutipes* (Curtis) Singer, *L. edodes*, *Pleurotus cornucopiae* (Paulet) Rolland, and *Pleurotus eryngii* (DC.) Quél maintains the bright red colour of bigeye tuna and chopped yellow tail meat stored in ice (Bao et al., 2010) while bovine longissimus dorsi marinated in *S. aspratus*, *A. bisporus*, and *L. edodes* extracts increased brightness, reddish, and yellowish (Lee et al., 2017).

Marination in *S. commune* w.e., up to concentrations of 2.5% and 5%, enriched the taste of bovine loin. Mushroom extract concentrations higher than 5% caused a decrease in the preference for the taste of meat. The increase in bovine loin taste due to marination in *S. commune* w.e. is thought to be due to the enrichment of the umami taste from the mushrooms. *Schizophyllum commune* has an umami taste because it contains several compounds similar to monosodium glutamates (Prabsangob and Sittiketgorn, 2023), such as aspartic acid, glutamic acid, adenosine-5‘-monophosphate, inosine-5‘-monophosphate, and guanosine-5'-monophosphate (Laplamool et al., 2023).

This study indicated low panellist acceptance of beef marinated in w.e. of *S. commune* at high concentrations (7.5% and 10%). The dislike was thought to be due to undesirable changes in taste and aroma, as well as the soft structure of the meat due to the high water content. In particular, the panellists did not like the change in bovine loin aroma due to marinating in high concentrations of *S. commune* w.e., which was thought to be due to the presence of volatile components in the *S. commune* w.e. that penetrated the meat. The mycelium of the *S. commune* contains the volatile components methyl 2-methyl butanoate, ethyl 2-methyl butanoate, and methyl 2-methyl propanoate (Freihorst et al., 2018).

Conclusion

Marination in *S. commune* mushroom w.e. has been proven to increase tenderness, WHC, cooking loss, water content, protein, fat, PDC, ash, selenium, colour, taste, and aroma, but does not affect the pH of bovine loin. Bovine loin marinated in *S. commune* w.e. at a concentration of 2.5% exhibited optimum physicochemical, biochemical, and sensory properties compared to 0.2% papain. This study recommends using *S. commune* w.e. up to a concentration of 2.5% as a meat tenderizer. Further research is needed to determine the effect of *S. commune* extract on connective tissue, sarcomere length, and myofibrillar proteins of meat from various meat-producing livestock species, as well as to determine the appropriate method of applying *S. commune* extract to tenderize meat.

Authors' contribution

Tatang Sopandi; conceptual framework, research design, data collection, preparation of article publication, Yola A Astuti; data collection, Abelya P Herdina; data collection, Wardah; data collection and analysis, preparation of article publication.

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