*Carcass Fabrication*

**Evaluation of Fabrication Efficiency, Meat Quality, and Microbiological Safety of Beef Steaks Prepared using Dry Blade Cut and Wet Blade Cut Methods**

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**ABSTRACT**

This study investigated the effect of conventional dry blade cut (dry cut) and proprietary wet blade cut (wet cut) on fabrication efficiency, quality, and microbial safety of beef steaks. Six beef ribs were fabricated into steaks using the two cutting methods. Fabrication time was significantly shorter for the wet cut compared to the dry cut due to the absence of bone dust removal (*P* < 0.05). Microscopic imaging demonstrated that wet cut steaks had smoother surfaces than dry cut steaks, with center surfaces being smoother than edge surfaces, regardless of the cutting method. Steak weight decreased gradually during storage, with a significant reduction observed after day 9 (*P* < 0.05), but no difference was found between the two cuts. There were no significant differences in pH and lipid oxidation between the cuts, though the pooled pH value of wet cut tenderloins was higher than that of dry cut tenderloins. The brightness (*L*\*) and redness (*a*\*) values of loin significantly decreased on days 3 and 12, respectively, while these values declined for tenderloin on days 6 and 9. Yellowness (*b*\*) was not changed during storage except days 3 and 6 for tenderloin. Initial microbial populations of mesophilic aerobic bacteria and coliforms increased to 6.3 – 6.39 and 5.2 – 5.9 log CFU/g on day 12, with no significant difference between the two cuts (*P* > 0.05). Overall, the wet cut improves fabrication time and surface smoothness, while muscle quality, oxidation, and microbial populations were comparable to the conventional dry cut.

**Key words**: Steak fabrication, circular blade cut, meat quality, muscle color, microbial population.

**1.** **Introduction**

The purpose of carcass fabrication is to convert whole carcasses into smaller, consumer-preferred meat cuts. This process is essential for meeting the market demands and consumer convenience. Given the variability in the size and muscle composition of animal carcasses, appropriate cutting technologies and fabrication methods are vital for separating meat from bone and tendon, distinguishing thinner cuts from thicker cuts, and isolating tender, high-value meats from tougher, less desirable cuts. Traditionally, circular blade saws are used for primary and intermediate cuts, followed by manual trimming for final cuts. However, conventional blade saws generate meat debris, bone dust or chips, and fat smearing on the meat surface, which negatively impact cutting efficiency, product yield, visual appearance, and overall meat quality. Subsequently, an additional step is required to scrape debris and smeared fat from the meat surface, a labor-intensive, time-consuming, and costly task (McGeough, 2016).

To address these challenges, the meat industry has adopted waterjet cutting (WJC) technology to improve cutting yield, cost-efficiency, and labor effectiveness while minimizing cross-contamination and bacterial transmission with no blade contact (Malone et al., 1994; Alitavoli & McGeough, 1998; Wulfkuehler et al., 2014). This technology, first developed in 1935, has evolved to cut diverse materials, including meat, paper, stainless steel, stone etc. (Fourness et al., 1935; Rice, 1965; Guidorzi, 2022). Wang and Shanmugam (2009) demonstrated the potential of abrasive waterjet cutting (AWJC), using salt as an abrasive, to cut meat with bone. Despite its advantages, AWJC systems involve significantly higher initial installation and maintenance costs compared to traditional blade cutting systems. Additionally, waterjet cutting processes are slower, generate wastewater, and require specialized training for operation (Liu et al., 2022).

Recently, an innovative cutting technology, Kleen KutTM (wet circular blade cut or wet cut), has been developed to enhance fabrication efficiency by simultaneously removing saw residues such as meat debris, bone fragments, blood, etc. by water while cutting (Chaffin and Jones, 2009). This system incorporates dual water nozzle orifices strategically positioned adjacent to the saw blade, delivering water to both sides of the cutting blade. The water acts as a lubricant, effectively removing meat residues and preventing their adherence to meat surfaces during fabrication.

The primary objective of this study was to evaluate the fabrication efficiency, meat quality, bacterial populations, and visual appeal of beef steaks that were prepared using conventional circular bald cut (dry cut) and wet circular blade cut (wet cut).

# **2. Materials and Methods**

# ***2.1. Muscle Selection and Fabrication into Steaks***

Six wholesale beef ribs (2 beef ribs/each of 3 replications) were purchased from a local federally inspected abattoir at 48 h postmortem, using Institutional Meat Purchases Specification (IMPS): Beef Loin, Short Loin, short-cut (IMPS # 174). The loins were vacuum packed, transported in 4 h under ice, and stored at 4 oC in the meat processing center at California Polytechnic State University (Cal Poly, San Luis Obispo, CA). On the following day, the loins were fabricated into 2.54 cm-thick steaks, using both dry cut and wet cut methods in the Cal Poly meat processing center (**Fig. 1**). A total of 72 steaks (12 steaks from each rib) were prepared to evaluate fabrication efficiency immediately after cutting as well as the quality and safety of steaks during display (**Fig. 2**). The first two steaks from the caudal side of the loins were designated for scanning electron microscope imaging, while the remaining steaks, toward the cranial side of the loins, were displayed in a retail case. For case-ready display, the steaks were overwrapped with an oxygen permeable polyvinyl chloride film using a single-roll over wrapper before being placed on polystyrene trays.

***2.2. Fabrication Time***

Fabrication time (sec) was evaluated for the total time required for steak cut and surface scrap.

***2.3 Scanning electron microscope (SEM) image***

After cutting steaks, muscle samples (10 mm x 10 mm) were removed from either the center or edge of the steak and fixed at 4 oC for 12 h in 4% glutaraldehyde buffered at pH 7.4 with 0.1 M sodium phosphate. The samples were then rinsed in the buffer for 4 h, followed by dehydration by exchanging with graded ethanol series (25%, 50%, 75%, 95%) for 2 h at each gradation followed by three 2 h changes in 100% ethanol. The samples were then mounted on aluminum stubs using double-sided carbon conductive tape (Ted Pella, Inc, Redding, CA) and coated with gold for 60 s in a Denton Vacuum Desk IV sputter coater (Denton Vacuum LLC, Moorestown, NJ). Samples were prepared for SEM imaging by mounting on aluminum stubs with double-sided carbon tape (Electron Microscopy Sciences, Hatfield, PA) and were examined at 1,000 x magnification in a Hitachi TM-1000 Tabletop scanning electron microscope (Hitachi, Schaumburg, IL).

# ***2.4. Steak Preparation for Display in Retail Case***

Approximately 12 steaks per wholesale beef rib were cut, and 8 normal steaks were selected. The steaks were placed on retail trays with pads to display on shelves in a coffin-style retail case for 12 days at 4 – 5 oC (Howard-McCray, Model SC-CMS 35-6, HMC Enterprises LLC, Philadelphia, PA) under continuous fluorescent (34 W Warm White light; F40/Spec./RS/EW/Alto, Philips Lighting Company, Somerset, Versailles, KY) (**Fig. 1**). During storage, the steaks were randomly rotated daily, and physicochemical and microbiological changes were evaluated at 0, 3, 6, 9, and 12 days.

***2.4.1 Storage yield (%)***

To evaluate storage yield, each steak sample was individually weighed to record its initial weight before display. The steak weight for each storage day was then determined using the equation: (end-storage weight/initial-storage weight) x 100.

***2.4.2 pH measurement***

To measure pH, duplicate 5g steak samples were homogenized in 50 ml of deionized water using a homogenizer (Brinkmann Homogenizer, Wesbury, NY) to measure pH value, using a pH electrode (Accumet AB 15, Fisher Scientific, Pittsburgh, PA).

***2.4.3 Lipid oxidation (TBARS value)***

Lipid oxidation was assessed using the Thiobarbituric acid reactive substances (TBARS) method described by by Pikul et al. (1989). On each sampling day, duplicate 10-g samples were taken from the surface (2 mm thick), and TBARS values were reported as mg malondialdehyde (MDA) equivalents per kg of steak.

***2.4.4 Color***

Commission Internationale de l’Éclairage (CIE) *L*\*, *a*\*, and *b*\* values were assessed for the steak surface color after 30 min of blooming. *L*\* indicates lightness, *a*\* represents redness, and *b*\* denotes yellowness. Measurements were taken using a chromameter (8-mm aperture, illuminant C; 10◦ observer angle, CR-400, Konika Minolta Sensing Inc., Osaka, Japan) calibrated with a white plate (*L*\*, 97.28; *a*\*, −0.23; *b*\*, 2.43). Three readings per steak were obtained for each of the CIE values. Measurements were taken on major loin muscle (Longissimus thoracis et lumborum) and the tenderloin muscle (Psoas major) in the areas free from obvious blood-related defects such as bruises, hemorrhages, or full blood vessels (Fletcher et al., 2000).

***2.4.5 Microbiological analysis***

On each sampling day, each stake was randomly taken and aseptically opened after wiping the package surface with 70% (vol/vol) ethanol. Using a sterile scalpel, a 25 g meat sample was taken, diluted 1:10 (wt/vol) in phosphate-buffered saline (PBS), and homogenized for 1 min in a Stomacher 4000 (Seward, Norfolk, England). For bacterial enumeration, serial 10-fold dilutions of stomached samples were prepared, and 0.1 ml of each dilution was plated in duplication on standard method agar (Acumedia, Lansing, MI) for mesophilic aerobic bacteria (MAB) and on 3M petrifilms (3M Microbiology Products, St. Paul, MN) for coliform detection. Coliforms were identified as red and blue colonies with associated gas bubbles.

***2.5. Statistical analysis (need to update)***

Physicochemical and microbial data in three replications were statistically analyzed using one-way analysis of variance (ANOVA) that was performed by Proc MIXED procedure of SAS (SAS Institute, 2022) in a completely randomized design. Having no interaction among the storage days, data were pooled and analyzed for the cutting factor of dry cut versus wet cut. If significance was determined (*P* < 0.05) in the model, dependent variable means (storage day and cutting factor) were separated using the least significant difference procedure of SAS (*P* < 0.05; SAS Institute 2022).

# **3. Results and Discussion**

# ***3.1. Steak appearance and fabrication time: dry cut vs. wet cut***

A conventional band saw is a powerful tool used to fabricate carcasses into wholesale cuts, retail cuts, and individual steaks by cutting through muscle and bones. However, it leaves saw residues, such as protein, fat, blood, and bone fragments, on the steaks. Fig. 2 depicts the following: the dry cut saw (**Fig. 2a**), a steak after dry cut (**Fig. 2b**), the scrapping step to remove saw residues (**Fig. 2c**), the wet cut process (**Fig. 2d**), and a steak after wet cut (**Fig. 2e**). Steaks produced by the dry cut method exhibited saw dust that required manual removal through scrap. In contrast, steaks from the wet cut process appeared cleaner, likely due to the water from nozzle orifices positioned on both sides of the blade. Additionally, the fabrication time of the wet cut was significantly shorter than that for dry cut (*P* < 0.05) (**Fig. 3**).

***3.2. SEM image of beef steaks***

The scanning electron microscope (SEM) images revealed that the edge surfaces of steaks (**Fig. 4a, b**) appear rougher than their center surfaces (**Fig. 4c, d**), regardless of cutting method. This difference may result from increased physical vibrations at the edges during cutting, compared to the center, where gentle pressure is applied between the upper and lower portions of the steak. Steaks processed with the dry cut method (**Fig. 4a, c**) showed rougher surfaces than those from the wet cut method (**Fig. 4b, d**). The wet cut blade, equipped with waterjet nozzles, created a film of water on the blade surface, serving as a lubricant during cutting (Chaffin et al., 2009). This lubrication likely reduced physical friction and minimized muscle scratch caused by bone residues, resulting in smoother steak surfaces.

***3.3. Storage yield during storage***

Throughout storage, steak yield dropped from 100% to 97.2%, with significant reductions observed on day 9 and day 12 (*P* < 0.05) (**Table 1**). This weight loss is attributed to dehydration during storage, driven by the difference in water vapor pressure between the meat surface and the surrounding air (Campanone et al., 2002). Additional factors, such as muscle size (or surface-to-volume ratio), fat thickness, and skin covering also impact steak weight (Bustabad, 1999; Cutting and Malton, 1973). In this study, no significant difference in steak weight was observed between dry cut and wet cut steaks throughout storage.

***3.4. pH during***

The pH of steaks, which ranged from 5.4 to 5.8 at 24 h postmortem, is considered normal. A pH of 6.1 or higher indicates dark, firm, and dry (DFD) meat, while a pH of pH 5.3 or lower suggests pale, soft, and exudative meat (AtlasScientific, 2023; Ijaz et al., 2020; Zhang et al., 2009). At 0-day storage, approximately 72 h postmortem, the pH values of loin and tenderloin were 5.59 and 5.51, respectively. The initial pH of loin (5.59) reduced steadily to 5.45 over 12 days of storage, with significant reductions observed on days 9 and 12 (*P* < 0.05). A similar trend was seen for tenderloin, with pH values remaining within the normal pH range (5.51 – 5.41). When comparing cutting methods, the dry cut tenderloin showed a higher pH (5.52) than the wet cut tenderloin (5.42), whereas no differences were observed for loin (**Table 1**).

***3.5. TBARS during storage***

Throughout the storage period, TBARS scores of loin and tenderloin continuously increased. Significant increases were observed on day 6 and day 9 for the loin, and on days 6, 9, and 12 for the tenderloin, compared to the previous storage days (P < 0.05) (**Table 1**). The initial TBARS values of loin (0.19) and tenderloin (0.27) rose to 1.02 and 1.18, respectively, by the end of the storage period.

Preventing lipid oxidation in muscle foods is crucial because it affects sensory qualities, influences consumer purchasing decision, and can result in economic losses (Barden and Decker, 2016; Dirinck et al., 1996; Liu et al., 1995). It has been noted that greater oxidation occurs when meat undergoes more physical damage during processing like mincing, tumbling, and emulsion, as opposed to simple chopping or cutting (Shimizu, H. and Iwamoto, S., 2022; Hosseini et al., 2020). However, in our study, no significant differences in TBARS were observed between the dry cut and wet cut methods.

***3.5. Color***

Muscle color and visual appearance are critical factors, as they are often used to assess freshness and make purchasing decisions (Lanari et al. 2002; Northcutt, 1997; Feldhusen et al. 1995). On the surface of fresh meat, the degree of color (brightness *L*\*, redness *a*\*, and yellowness *b*\*) typically increases significantly during the first 5 h postmortem due to oxygen exposure and becomes less intensive after 5 days of storage (Feldhusen et al. 1995). During the 12-day display of loin and tenderloin cuts in a coffin-style retail case at 4 – 5 oC, brightness (*L*\*) values gradually decreased from 55.7 to 51.3 for loin and from 53.4 to 52.2 for tenderloin (**Table 1**). Considering 3 – 4 days postmortem at the time of fabrication and initial display, the color intensity of both muscles was likely at or near its peak during the first day of display. Consequently, the color intensity declined continuously as storage time increased. Comparing cutting methods, the loin from the dry cut method showed higher *L*\* value than those from the wet cut method (P < 0.05%), whereas no significant difference was observed for tenderloin (**Table 1**).

A similar trend of decreasing color intensity was observed for redness (*a*\*) during the display period, although no significant differences were detected between cutting methods for either muscle. These results are aligned with previous studies, which reported a progressive decline in both oxymyoglobin and redness values (CIE *a*\*) with extended storage (Jeremiah and Gibson, 2001a, b). Feldhusen et al. (1995) reported that oxymyoglobin values increased during 1 – 3 days postmortem and decreased after 13 days, accompanied by a rise in metmyoglobin-reducing activity. For yellowness, the color intensity of the loin remained stable throughout the display period, with no significant change. However, an exception was observed for the tenderloin, which exhibited changes on days 3 and 6 (**Table 1**). Similarly, Jeremiah and Gibson (2001a) reported that the yellowness of striploin (*Longissimus lumborum*) was unaffected by display over 30 h, although overall color intensity decreased with prolonged storage up to 24 weeks.

***3.6. Microbiology during storage***

Fresh beef provides an ideal source for bacterial growth due to its abundant nutrients, high water activity, and optimum pH (FAO, 2019; Oliveira et al., 2008). The initial populations of mesophilic aerobic bacteria (MAB) after fabrication ranged from 4.9 to 5.2 log CFU/g. These levels increased to 6.3 – 6.39 log CFU/g after 12-days of display at 4 oC for beef loin, with no significant difference observed between the cutting methods (*P* > 0.05). Bacterial growth showed a significant increase after day 6 and leveled off by day 9 (**Fig. 5**). The initial total coliform counts ranged from 2.5 to 3.5 log CFU/g and significantly increased after day 6, reaching 5.2 – 5.9 log CFU/g by day 12. Similar to MAB, no significant difference was observed between the two cutting methods (P > 0.05) (**Fig. 6**). Stopforth et al. (2006) reported comparable initial contamination levels in fresh beef cuts, with total aerobic plate counts ranging from 4.0 to 6.2 log CFU/g and total coliform counts from 1.1 to 1.8 log CFU/g.

**4. Conclusions**

In the meat industry, the dry cut method (or traditional circular blade cut) has long been a primary tool for breaking down animal carcasses into customer cuts. However, the conventional method requires an additional step to scrape bone dust and fat/protein smears from the meat surface. By contrast, wet cut technology significantly improved fabrication efficiency without affecting muscle quality and microbial populations compared to dry cutting. Further research is required to explore the use of antibacterial solutions during wet cutting to extend the shelf-life and maintain the quality of meat cuts.

**CRediT authorship contribution statement**

**K. B. Chin:** Writing – original draft, data curation, conceptualization, funding acquisition. **D. Ma:** Formal analysis, methodology, data curation, conceptualization. **S. Pokharel:** Writing – Review & edition, data curation. funding acquisition. **L. H. Laiho:** Writing – review & edition, methodology, data curation, visualization **J. Young:** Conceptualization, supervision, methodology, funding acquisition. **I. Kang:** Writing – review & editing, visualization, supervision, methodology, data curation, funding acquisition.

**Declaration of competing interest**

The authors declare no conflicts of interest.

**Data availability**

Data will be made available on request.

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