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Research Article

Influence of degree of doneness on the sensory, physiochemical, nutritional, and microbial properties of beef

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Abstract

This study investigated the impact of six different doneness temperatures (rare, medium-rare, medium, medium-well, well-done, and very well-done) on the sensory qualities, physicochemical properties, and microbiological characteristics of indigenous beef from Bangladesh. The beef was cooked at the following temperatures: Rare: 52 °C, Medium-rare: 57 °C, Medium: 65 °C, Medium-well: 66 °C, Well-done: 71 °C, Very Well-done: 80 °C. The results demonstrated that the sensory qualities of the meat varied dramatically with cooking temperature. Rare meat had the most soft and juicy texture, whereas, extremely well-done beef had the most stiff and dry feel. The physicochemical parameters of the beef, such as moisture content, protein content, and fat content, also varied dramatically with cooking temperature. Rare meat had the highest moisture content and lowest fat level, while extremely well-done beef had the lowest moisture content and highest fat content. The microbiological properties of the beef also changed dramatically with cooking temperature. Rare beef had the highest microbial burden, while extremely well-done beef had the lowest microbial load. This is because cooking at higher temperatures kills more bacteria. Previous Research has explored the effects of varying doneness temperatures on the sensory, physicochemical, and microbiological aspects of beef. However, these investigations have been conducted on beef from different nations and have employed different cooking methods. Therefore, there is a research void on the impacts of doneness temperature on the sensory, physicochemical, and microbiological features of indigenous beef of Bangladesh. The outcomes of this study have significance for optimizing cooking procedures to increase the sensory appeal and ensure the microbiological safety of indigenous beef. The data also imply that well-done meat may be a healthier alternative than medium-rare or medium steak, as it has a reduced microbial load. However, it is crucial to remember that Very Well-done beef should be avoided, as it has a dry and harsh texture. The outcomes of this study revealed that the doneness temperature of well-done, which is 71℃, fits and satisfies the consumers' unique preferences and health concerns.

Introduction

The estimated number of cattle in Bangladesh is 24.85 million heads (DLS, 2023). The native cattle of Bangladesh are known by their regional names which are mainly divided into five types: Red Chittagong (RCC), Pabna (PC), Munshiganj (MC), North Bengal Grey (NBG), and Nondescript Deshi (DES), The Sahiwal (SL) breed, which was introduced to Bangladesh as enhanced zebu dairy cattle six decades ago, is now sparsely dispersed throughout the nation (Bhuiyan et al., 2021). From Hamid et al. (2017), some locations in 1936 began using Bos indicus bulls for mating, which produced better cattle in the chosen regions of the nation. A significant number of crossbred cattle have already been added to the herd of various areas of the country as a result of the government's extensive artificial insemination program, which was established in 1958 (Kamal et al., 2019). Therefore, the country's genetic resources for cattle include indigenous cattle, Red Chittagong cattle, Pabna cattle, North Bengal Grey cattle, Munshiganj cattle, crossbred cattle, and exotic breeds (Holstein and Friesian, Sahiwal, Sindhi and Jersey). Indigenous beef plays a key significance in the cuisine and culture of Bangladesh and is a staple dish for many people there (Ahmed et al., 2010). Around the world, each person consumes 42.1 kg of meat annually. Developed and poor nations consume 82.9 and 31.1 kg annually (FAO, 2009). Bangladesh produces 0.687 million metric tons of meat annually, with beef accounting for 0.191 million metric tons of the total (FAO, 2019). A number total of 8.71 million metric tons of meat are produced, and 7.6 million metric tons are consumed in Bangladesh each year (DLS, 2023). For many people in Bangladesh, beef is a key source of protein and sustenance (Islam et al., 2012 and 2022). As a result, there is a significant need for knowledge about the factors that impact the safety and quality of beef. The degree of doneness, which refers to the degree of cooking and the internal temperature of the beef, is one such variable. The texture, flavor, nutritional content, and safety of the beef may all be altered by its degree of doneness. This study aims to determine the impact of temperature on the quality of indigenous beef. The degree of doneness temperature, or the internal temperature at which the beef is cooked, is manipulated to see how it affects the meat's taste, texture, and overall quality. The results of the study can provide valuable insights into the optimal cooking temperature for indigenous beef to achieve maximum quality and enjoyment. However, there is no information on how temperature and degree of doneness affect the quality of Bangladeshi native beef. By investigating the effects of various cooking temperatures on the flavor, texture, and general quality of indigenous beef, this study seeks to close this gap. The results of this study will be useful information for Bangladeshi cooks, chefs, and meat processors, enabling them to produce high-quality native beef that satisfies consumer expectations and preferences. The research will also aid in our knowledge of the intricate relationships that exist between cooking temperature, meat quality, and customer happiness (Akhter et al., 2022; Ali et al., 2022; Hossain et al., 2021; Rahman et al., 2023; Saba et al., 2018; Siddiqua et al., 2018). May be there is a gap in the research on the effect of doneness temperature on the quality attributes of beef, including tenderness, flavor, color, and juiciness. While there has been a significant amount of research on the effects of temperature on the overall quality and safety of beef, there may be a lack of studies specifically focused on the relationship between doneness temperature and beef quality attributes. To completely comprehend the relationship between doneness temperature and the qualities of beef, additional research is required. This research will also help identify the ideal temperature at which to cook beef in order to obtain the necessary quality and safety results. This will necessitate well-planned research that uses standardized techniques to gauge the qualities of beef while taking into consideration regional variations and cultural preferences.

Materials and methods

Raw materials

A portion of boneless beef from a recently slaughtered bull was obtained from the Local market, Bangladesh Agricultural University, at 8 a.m. The meat sample was immediately transferred to the "Meat Science Laboratory". Other ingredients were collected from the laboratory.

Sample preparation

Fresh beef was taken for the preparation of the sample. First, the beef was properly cleaned with fresh water, and the fat was trimmed with a sharp knife. Then, a portion about 1 inch thick of the beef was taken for each sample. A number of 5 samples in each treatment were prepared to go. Then, the beef was cooked to the desired temperature using a cooking method that allows precise temperature control, such as asous vide or a water bath. The preparation of multiple beef samples at different temperatures was done to study the effect of doneness temperature. After cooking, the beef was removed from the heat source and allowed to cool to room temperature. The beef was cut into uniform slices or cubes for analysis. Different properties such as tenderness, juiciness, flavor, and color using techniques such as sensory evaluation, texture analysis, and chemical analysis were conducted, and the measurement was recorded.

Sensory Evaluation

Sensory evaluation of cooked beef involves assessing various aspects of the meat's appearance, aroma, flavor, texture, and overall acceptability. This assessment, which can be carried out by consumers or trained panelists, offers details on the cooked beef's quality and consumer appeal (Aaslyng, 2022). A panel of evaluators rated the appearance, aroma, flavor, texture, and overall acceptability of samples of beef cooked to different levels of doneness. The results suggest that the highest overall acceptability score was for beef cooked to medium rare doneness, which had the highest scores in aroma and flavor. Beef cooked well done had the lowest overall acceptability score, with lower scores in appearance, aroma, and flavor. The meat samples were provided to them in Petri dishes.

Temperature of the cooked beef

To measure the doneness of cooked beef, a small piece, about 1/2 inch to 1 inch thick, was taken from the center of the meat to ensure an accurate reading. This small piece represented the doneness of the entire piece of meat, as different parts of the meat were cooked at different rates. It's also important to ensure that the temperature is taken in the thickest part of the meat, as this will take the longest to cook to the desired temperature. Using a food thermometer is the most accurate way to measure the internal temperature of cooked beef. The thermometer was inserted into the center of the small piece, avoiding any bones or fat, and kept for a few seconds for the temperature to be stabilized. The USDA recommended that the internal temperature of fully cooked beef should reach 145°F (63°C) for at least 3 minutes to ensure it is safe to eat.

Physicochemical properties measurements

Cooked pH measurement

The pH value in meat was determined by making direct contact between the sensitive diaphragm of an electrode and the meat tissue. Variations in electrical load between the meat and an electrolyte solution (typically Potassium chloride) within the glass electrode are continuously monitored and displayed as the pH reading. Additionally, the pH meter was calibrated and adjusted to match the temperature of the meat being tested.

The samples were cooked to six different internal temperatures. Then, the muscle samples were taken out and cooled at room temperature. After cooling, the sample's pH was measured in the same way as the ultimate pH system. The pH was measured by a pH meter (Hanna HI 99163).

Cooking loss (CL) measurement

To measure cook loss in cooked beef, a kitchen scale was initially used to weigh the raw beef before cooking. After cooking at a certain temperature, the beef was allowed to cool briefly and reweighed using the same kitchen scale. Cook loss was calculated using the provided formula, which involved subtracting the weight of the cooked beef from that of the raw beef and dividing the result by the weight of the raw beef.

$$\text{CL (\%)} = \frac{(\text{Weight before cooking of sample} - \text{weight after cooking})}{\text{Weight before cooking of sample}} \times 100$$

Water holding capacity (WHC)

The WHC was measured according to the methodology of Choi et al. (2018). Thawed samples (one g each) were wrapped in absorbent cotton and placed in a 1.5 ml centrifuge tube. The tubes with samples were centrifuged in a centrifuge separator (H1650-W Tabletop high-speed microcentrifuge) at 10,000 rpm for 10 minutes at 4º C, following which the samples were weighed. The WHC % of the sample is expressed as the following formula:

$$\text{WHC (\%)} = \frac{(\text{Weight of sample after centrifugation})}{(\text{Weight of sample before centrifugation})} \times 100$$

Color value measurement

Color properties such as brightness (CIE L*), redness (CIE a*), and yellowness (CIE b*) were examined for multiple patties samples using a color measurement system (Konica Minolta CR-400, Tokyo, Japan). To calibrate the colorimeter, a standard white plate with particular color coordinates (Y = 81.2; x = 0.3191; y = 0.3263) was utilized, and each sample completed three different tests. The computation of chroma (C*) value and hue angle (h°) value was conducted using two formulas: {(a* + b*)1/2} for chroma and {tan−1(b*/a*)} for hue angle.

In the meat industry, Chroma measurement can be used to assess the color quality of meat. Meat color is an important quality parameter that influences consumer acceptance, as well as safety and shelf-life. The color of meat is affected by various factors, such as animal age, diet, processing conditions, and storage conditions. To measure Chroma in meat, a spectrophotometer is commonly used. A spectrophotometer can measure the reflectance of light from the surface of the meat at different wavelengths, allowing for the calculation of various color parameters, such as Chroma.

Proximate Components

Dry matter

Moisture content was determined by placing an accurately weighed known amount sample(5g) in a pre-weighed porcelain crucible in an electric oven at 1050C for about 24 hours until constant weight was obtained. The loss of moisture was calculated as percent moisture.

$$\text{Moisture content (\%)} = \frac{(Y-Z)}{Y} \times 100$$

Here, S = Sample weight (g), Y = Crucible+ Sample weight (g), Z = Crucible + Dry Sample weight (g), Dry Matter = 100 - % Moisture

Crude protein

The micro-Kjeldahl method was used to calculate crude protein. Using the Kjeldahl equipment, the total nitrogen content of each sample was calculated in triplicate. The samples were digested with 20 ml of concentrated sulfuric acid (H_2SO_4) in the presence of K_2SO_4, $CuSO_4$, and selenium powder to estimate the total nitrogen in this example. Ammonia released by the alkali (NaOH) was then distilled into boric acid and titrated with standard HCl. The nitrogen values thus obtained were converted to total crude protein by multiplying with a factor of 6.25.

A sample of 5g with a 1 g mixture (100 g K_2SO_4 + 10 g $CuSO_4$ + 1 g selenium powder) was taken in a Kjeldahl flask. Added 20 ml concentrated H2SO4 and heated in a digestion unit at 420°C for 45 minutes (extend if not green). After cooling for 30 minutes, introduced 75 ml distilled water and 70 ml NaOH Solution. After five minutes, it was collected with 20 ml boric acid and then titrated with 0.1N HCl until a pink color appeared. The formula:

$$\frac{\text{Titrate required (ml)} \times .014 \text{ (milliequivalent of N2)} \times \text{Strength of HCl}}{\text{weight of the sample}} \times 100$$

% of CP = % of nitrogen × conversion factor (6.25)

Ether extract

Ether extract content was determined by Soxhlet apparatus using diethyl ether. At first, the flask weight was taken. Then, a 5gm sample was taken in a thimble and added 200 ml acetone in a Soxhlet. Extraction was done at 40-45°C, which took about 7-8 hours. After extraction, the flask was taken out and dried in an oven for 30 minutes at 100°C. The flask containing ether extract was cooled in a desiccator and weighed. The calculated value for ether extract content was obtained as a percent of the sample. The formula:

$$\text{\% of ether extract} = \frac{\text{Weight of the ether extract}}{\text{Weight of the sample}} \times 100$$

Ash

Weighed samples were taken in porcelain crucibles and heated at 100°C in an electric oven. The crucibles were then placed in a muffle furnace and heated at 550°C for 6 hours. The crucibles were then cooled in desiccators. The average weight in the percentage of each sample of the remaining material was taken as ash. The formula**:**

$\text{\% of ash content} = \frac{E}{C} \times 100$ Where, E = Weight of ash, C = Weight of sample

Microbial Assessment

Total viable count

TVC, or Total Viable Count, is a method used to assess the live microorganisms in a food sample, such as cooked meat, which is crucial for gauging food quality and safety. The TVC procedure for cooked meat involved the following steps: First, a 10 g sample of the meat was collected and blended in a sterile diluent. Serial dilutions were prepared from 10^-2 to 10^-6. Then, solid media such as plate count agar (PCA), MacConkey agar (MA), and potato dextrose agar (PDA) were used for analysis. The media were sterilized, poured into Petri dishes, and inoculated with diluted samples. After incubation at 35°C for 24-48 hours, colonies were counted, and the TVC was calculated as colony-forming units per gram (CFU/g). This count was crucial for determining food safety and quality, aligning results with regulatory standards.

Various glassware and equipment, including pipettes, a blender, and an incubator, were used throughout the process. The diluted samples were spread on the media, and colonies were counted using ISO recommendations. The results were expressed as Log10 CFU/g, providing a measure of the viable microorganisms in the meat sample.

Statistical model and analysis

Statistical analysis was conducted by SAS (previously "Statistical Analysis System"), which is a statistical software suite developed by SAS Institute for data management, advanced analytics, multivariate analysis, business intelligence, criminal investigation, and predictive analytics. Data were statistically analyzed using SAS Statistical Discovery software, NC,USA. DMRT test was used to determine the significance of differences among treatment means. Duncan's Multiple Range Test (DMRT) was used to determine the significant differences between two treatment means at values $p<0.05$.

Results and Discussion

Sensory Evaluation

The total samples were divided into six treatment groups. These were treated as T_1 (52°C for Rare), T_2 (57°C for Medium Rare), T_3 (65°C for Medium), T_4 (66°C for Medium well), T_5 (71°C for Well done) and T_6 (80°C for Very Well done). The six honorable judges evaluated the sample of each group. For the panel test, panelists were chosen from among a highly skilled staff. Sensory evaluation was carried out in individuals under controlled conditions of light, temperature, and humidity. All panelists took part in orientation sessions before the sample evaluation to become familiar with the scale qualities (acceptable color, tenderness, juiciness, flavor, and overall perception of the beef sample). The AMSA 2016 edition 8- and 9-point scales were used to calculate sensory scores. The samples were placed on plates and then given back for additional chemical analysis. The observations of different treatments are shown in Table 1.

Color

The observation of the color score of different treatments is shown in Table 1. The range of overall observed color scores at different treatments was from 2.1 to 6. Six treatments indicate that there were no significant differences ($p>0.05$). The most preferable color was observed in T_5 among the six treatments, and the less preferable color was observed in T_1. A Similar finding was that the consumers should use a food thermometer to be sure ground beef patties reach 160 °F (USDA-ARS/FSIS, 1998), whereas the treatment T_5 was 71°C (159.8°F). According to Berry et al. (1994), it has been demonstrated that beef patties cooked to 66°C are visually indistinguishable from those cooked to 71°C.

Flavor

The Flavor scores of different treatments are shown in Table 1. The range of flavor scores among the six treatments was from 1.6 to 7.4. All treatments indicated that there were no significant differences ($P>0.05$) in the flavor of all treatments. The most preferable flavor observed was in $T_{5,}$ which were 7.4. It indicates that beef steak has intense flavor intensity according to The AMSA 2016 edition 8- and 9-point scales. It was found in a study for steaks cooked at 71°C and 77°C that flavor preferences were strongly connected with beefy and roasted flavor characteristics (Lorenzen et al., 2005).

Tenderness

The overall observed tenderness scores range at different treatments was 1.6 to 7.8. The same superscript was observed from different treatments, indicating there were no significant differences ($p>0.05$) in tenderness scores. The elements that makeup meat alter as it is heated. The structural changes brought about by such changes modify the meat's texture. Less-temperature-cooked steaks had better scores for tenderness and juiciness, as well as lower Warner-Bratzler shear values, indicating that they are more tender and loved than higher-temperature-cooked steaks (Davuluri et al., 2005)

Juiciness

The juiciness scores of the treatments are shown in Table 1. The overall observed juiciness scores range at different treatments was 1.6 to 4.1. Among these six treatments, the most preferable juiciness was observed in T_4 and T_5. In these treatments, the steak was slightly dry and slightly juicy, which caused customer satisfaction in both ways. The result of this experiment was also related to (Liu et al., 2018) findings. Consumers used juiciness as an indicator of freshness or even eating quality (Akhter et al., 2009, Ali et al., 2022; Hossain et al., 2021). Eyas (2001) indicated that diminution in juiciness occurs because LDPE has a high permeability to moisture.

Overall Acceptability

The range of overall acceptability scores of different treatments was 2.52 to 8.64. There were no significant differences ($p>0.05$) in overall acceptability. Among these six treatments, the most preferable were T_4 and $T_{5.}$ Both of the treatment shows a result of 8 on the scale of 9 for better acceptability. The least preferable treatment was T_1 and $T_{2,}$ which maintained the cooking temperature of beef at 52°C and 80°C, respectively. Depending on how well the meat is, its physicochemical properties can alter, impacting its flavor. However, there is still much to learn about the specific changes that occur when the internal temperature of the meat increases, and research has not yet used standardized cooking methods or conditions Schwartz et al. (2022).

Table 1. Effect of Degree of Doneness on Sensory parameters in cooked beef

Variables	T_1 (Mean± SEM)	T_2 (Mean± SEM)	T_3 (Mean± SEM)	T_4 (Mean± SEM)	T_5 (Mean± SEM)	T_6 (Mean± SEM)	Level of Significance
Color	$2.1±0^{d}$	$3.2±0.37^{c}$	$5±0.32^{ba}$	$6±0.32^{a}$	$4.8±0.37^{b}$	$2.8±0.58^{cd}$	<0.0001
Flavor	$1.6±0.24^{e}$	$3.4±0.24^{d}$	$4.8±0.2^{c}$	$5.8±0.37^{b}$	$7.4±0.24^{a}$	$6±.32^{b}$	<0.0001
Juiciness	$8.0±0^{a}$	$7.4±0.24^{ba}$	$6.6±0.51^{b}$	$5.4±0.51^{c}$	$4.1±0.32^{d}$	$1.6±0.4^{e}$	<0.0001
Tenderness	$7.8±0.2^{a}$	$6.6±0.24^{b}$	$4.6±0.24^{c}$	$4.8±0.2^{c}$	$4.4±0.4^{c}$	$1.6±0.24^{d}$	<0.0001
Overall acceptability	$2.52±0.24^{d}$	$6.48±0.24^{c}$	$6.84±0.37^{bc}$	$8.64±0.2^{a}$	$8.28±0.24^{ba}$	$3.96±0.37^{d}$	<0.0001

Mean in each row havingdifferent superscript varies significantly at values $p < 0.05$. T_1 = 52° C, T_2 = 57°C, T_3 = 65°C, T_4 = 66°C, T_5 = 71°C, T_6 = 80°C.

Physiochemical Quality

Cooked pH

The Cooked pH of different treatments is shown in Table 2. The range of overall observed cooked pH at different treatments was 6.84 to 6.51. The same superscript was observed, indicating that there were significant differences (p<0.05) in cooked pH among these treatments. The pH of meat can undergo variations throughout the cooking process owing to many processes, including the breakdown of proteins and the release of acids. The normal pH of beef normally fluctuates between 5.5 and 6.2. This pH range is mildly acidic, which is characteristic of many meat items. Among these six treatments, the most preferable cooked pH was observed from T_5 and T_6. The highest amount of cooked pH indicates this product is preferable for consumers' health than other treatment groups.

A study by Li et al. (2017) found that the rise in pH for cooked meat is attributed to the reduction of free acidic groups as the flesh temperature increases during cooking. However, no significant variations in the pH of cooked samples were identified when beef or veal patties were cooked to varied internal target temperatures (55°C to 76°C). Only a modest pH Increase from 5.98 to 6.09 was recorded in beef samples after cooking from 55 °C to 76 °C. As meat cooks, its natural fluids are released. These fluids might contain acids that were present in the meat. The Rate of pH drop is a strong predictor of the color and drip loss of meat (Aberle et al., 2001). Higher ultimate pH (pHu) in animals can be related to poor glycogen reserve due to insufficient feeding (Mushi et al., 2009).

Cooking Loss

The cooking loss of several procedures is illustrated in Table 2. The overall observed cooking loss range for different treatments was 66.03 to 22.19%. The fully varied superscript shows there were major differences (p<0.05) in cooking loss. The cooking loss of meat during heat treatment is caused by the contraction of muscle fibers and intramuscular connective tissue, the intensity of which also depends on the temperature and device used. The Observed results from the six treatments indicated the highest cooking loss in the T_5 and T_6.

Overall, the T_5 was the best for the consumers' health. Cooking beef is the most efficient way to remove bacteria-causing food-borne illnesses. The suggested combination of temperature and duration of 70 °C for 2 min lowers the Listeria monocytogenes bacteria by more than 6 log (Jezek et al., 2019). The mentioned study demonstrated that attention must be paid to the cooking of meat from the standpoint of food safety and that the achievement of a temperature of 70 °C in the center of the product is not always a matter of course during cooking by consumers.

The impact of cooking procedure on protein oxidation might be linked to the following aspects: cooking procedure results in the loss of antioxidant substances, such as antioxidant enzymes; cooking process can also lead to the denaturation of myoglobin and the release of iron, which further enhances the formation of free radicals implicated in lipid and protein oxidation (Traore et al., 2012). The meat also tended to shrink during the cooking process due to the denaturation of meat protein; the loss of water and fat also contributed to the shrinking process Serdaroglu et al., (2006).

Water Holding Capacity (WHC)

The subjective evaluation of the water Holding Capacity score of six treatments is provided in Table 2. The range of mean value of the overall observed WHC score was 96.00 to 24.7. The most preferred WHC was detected in beef (p< 0.05). The most favorable WHC was discovered in fresh condition. The findings revealed that the drip loss was degraded considerably (p< 0.05) with the increased storage duration for both treatments. In the first treatment, the sample was cooked in 52°C, where the sample was 96.2, which was higher than other treatments. In Table 2, the T_5 with the desired pH level has the most consumer acceptability. It was shown in Gault, (2003) that increased WHC, as evaluated by swelling ratio in both raw and cooked meat, greatly impacted cooked meat softness, irrespective of the connective tissue composition of the muscles. The results matched a set of exponential decay equations connecting swelling ratio to cooked meat toughness. Genya (2017) stated that the water-holding capacity (WHC) is the ability of meat to hold all or part of its water, and one of the most essential features of meat quality. Weight loss due to purge or drip loss ranges from 2% to 10% when beef is chopped into chops. These losses impose an economic burden to meat processors and merchants. In addition, drip loss is a significant visual indication to judge meat quality (Modoak et al., 2009). Some studies have revealed that consumers in most nations detest drip loss in meat.

Table 2. Effect of Degree of Doneness on physiochemical attributes of cooked beef

Variables	T_1 (Mean± SEM)	T_2 (Mean± SEM)	T_3 (Mean± SEM)	T_4 (Mean± SEM)	T_5 (Mean± SEM)	T_6 (Mean± SEM)	Level of Significance
WHC (%)	96.2 ± 1.28^{a}	92.6 ± 0.29^{a}	64.4 ± 0.52^{b}	66.4 ± 0.35^{b}	36.7 ± 0.33^{c}	24.7 ± 0.36^{c}	<0.0001
pH	6.60 ± 0.04^{ba}	6.48 ± 0.05^{c}	6.51 ± 0.02^{c}	6.59 ± 0.04^{b}	6.67 ± 0.04^{a}	6.65 ± 0.04^{ba}	<0.0001
Cooking loss (%)	22.19 ± 0.64^{e}	28.48 ± 0.64^{d}	45.40 ± 0.78^{c}	47.96 ± 1.15^{c}	53.47 ± 1.77^{b}	66.03 ± 2.37^{a}	<0.0001

Mean in each row havingdifferent superscript varies significantly at values $p < 0.05$. T_1 = 52° C, T_2 = 57°C, T_3 = 65°C, T_4 = 66°C, T_5 = 71°C, T_6 = 80°C.

Instrumental color measurement

L*

The findings of the color analysis (CIE L*) indicated substantial changes across the six treatment groups (T_1-T_6). The L* value of beef similarly dropped as the cooking temperature increased. This was because the heat caused the fat in the meat to melt and escape. This lack of fat made the meat look lighter.

The observed changes in CIE L* values in Table 3 showed that the treatments had a considerable influence on the lightness of the samples. Specifically, T_2 demonstrated the greatest mean lightness value (58.39), showing that this treatment resulted in a much lighter look of the samples. On the other hand, T_6 displayed the lowest mean brightness value (45.74), suggesting a darker look compared to the other treatments. The results were significantly different ($p<0.05$).

In a study, Moya et al. (2021) cooked beef steaks at different temperatures and measured the L* value of the meat at different time intervals. They found that the L* value of the meat increased with cooking time at all temperatures. However, the rate of increase was faster at higher cooking temperatures. The researchers also found that the L* value of the meat reached a plateau at a certain cooking time, which depended on the cooking temperature. The results of this study suggest that cooking temperature can have a significant impact on the lightness of beef. At lower cooking temperatures, the L* value of the meat increases slowly, but at higher cooking temperatures, the L* value of the meat increases more rapidly. This was because the denaturing and break-down of myoglobin occurs more rapidly at higher cooking temperatures.

a*

The investigation of the color parameter CIE a* produced noteworthy changes among the four treatment groups (T_1-T_6), with statistically significant variance detected ($p < 0.05$). The mean values for each treatment group range from 17.22 to 10.43. From examining the specific treatment groups, T_1 displayed the greatest mean redness value (17.22), while T_3 had the lowest mean redness value (7.65). This means that T_1 resulted in samples with a considerably redder appearance, whereas T_3 generated samples with a less strong red color.

When beef is cooked, the myoglobin protein in the flesh combines with oxygen to generate metmyoglobin, which has a brown hue. This causes the a* value of the meat to decline. The degree of change in the a* value of beef depends on the cooking temperature. In a study published in the Journal of Food Science, researchers discovered that the a* value of beef reduced by an average of 10 units when the meat was cooked from 50 to 70 degrees Celsius (122 to 158 degrees Fahrenheit). The drop in a* value was more apparent at higher cooking temperatures. The study also demonstrated that the a* value of beef was changed by the cooking process. The a* value declined more when the beef was cooked in a pan than when it was prepared in an oven. This is because the pan cooking method provides greater cooking temperatures.

b*

The color analysis in Table 3 based on the CIE b* parameter developed significant effects across the various treatment groups (T1-T6). The means and standard errors of the means for each treatment were as follows: T_1 (12.62±0.77), T_2 (14.46±0.60), T_3 (14.13±0.80), T_4 (15.39±1.56), T_5 (15.28±1.01), and T_6 (15.72±0.41). This great statistical significance ($p<0.05$) demonstrates the significant influence of the treatments on the observed color variance, especially in terms of yellowness.

Table 3. Effect of Degree of Doneness on Instrumental Color of cooked beef

Variables	**T_1 (Mean± SEM)**	**T_2 (Mean± SEM)**	**T_3 (Mean± SEM)**	**T_4 (Mean± SEM)**	**T_5 (Mean± SEM)**	**T_6 (Mean± SEM)**	**Level of Significance**
CIE L*	58.39 ± 2.88^{a}	52.76 ± 2.98^{ab}	52.64 ± 4.74^{ab}	49.31 ± 2.63^{ab}	49.54 ± 1.71^{ab}	45.74 ± 2.17^{b}	<0.0001
CIE a*	17.22 ± 1.2^{a}	12.43 ± 1.52^{b}	7.65 ± 0.70^{c}	8.05 ± 0.97^{c}	9.28 ± 0.41^{c}	10.43 ± 0.71^{bc}	<0.0001
CIE b*	12.62 ± 0.77^{b}	14.46 ± 0.60^{ba}	14.13 ± 0.80^{ba}	15.39 ± 1.56^{ba}	15.28 ± 1.01^{ba}	15.72 ± 0.41^{a}	<0.0001
SI/Chroma value	21.89 ± 1.3^{a}	19.18 ± 1.3^{ba}	16.08 ± 0.92^{b}	17.38 ± 1.8^{b}	17.92 ± 0.99^{ba}	18.92 ± 0.42^{ba}	<0.0001
Hue Angle	36.71 ± 1.7^{c}	49.94 ± 3.1^{b}	61.59 ± 1.8^{a}	62.58 ± 1.1^{a}	58.45 ± 2.0^{a}	56.49 ± 2.1^{a}	<0.0001

Mean in each row having different superscript varies significantly at values $p< 0.05$. Again, mean values having the same superscript in each row did not differ significantly at $p> 0.05$. T_1= 52° C, T_2= 57°C, T_3= 65°C, T_4 = 66°C, T_5 = 71°C, T_6 = 80°C. SI = Saturation Index, CIE = Commission Internationale de l´Eclairage

The measured values of CIE b* hint at considerable changes in the yellowness of the samples treated to different treatments. Notably, T_6 had the highest mean CIE b* value (15.72), suggesting a greater prevalence of yellow compared to the other treatments. Conversely, T_1 displayed the lowest mean CIE b* value (12.62), implying a comparably lower amount of yellowness. Increased cooking temperature may impact the b* value of beef. The b* value is a measure of yellowness, and it is one of the three values used in the CIE Lab* color space. When beef is cooked, the myoglobin protein in the flesh combines with oxygen to generate metmyoglobin, which has a brown hue. This causes the b* value of the meat to drop.

A study published in the journal Food Chemistry evaluated the influence of cooking temperature on the b* value of beef. The study indicated that the b* value of beef was reduced by an average of 5 units when the meat was cooked from 50 to 70 degrees Celsius (122 to 158 degrees Fahrenheit). The drop in b* value was more pronounced at higher cooking temperatures. The study by Bae et al. (2018) found similar results in terms of NaCl-treated chicken meat.

SI/Chroma Value

The data analysis concerning SI/Chroma value yielded exciting findings, with statistically significant variance observed among the various treatment groups (T_1-T_6), which is shown in Table 3. These data clearly demonstrate that the applied treatments had a considerable influence on the SI/Chroma value of the samples. The SI/Chroma values give insights into the saturation or intensity of color, and the differences detected imply modifications in the vividness of color among the different treatments. The Range was observed between 16.08 to 21.89. The cooking temperature has a substantial influence on both the SI index and the chroma value of beef. Increasing the cooking temperature increases the SI index and reduces the chroma value. This is because increasing the cooking temperature denatures the proteins in beef, making them harder and less red. In the treatments, T_4 started to show a pale red with no pinkish color. The T_5 had the greyish color, which was more palatable and a consumer preference.

An article by Zhang et al. (2009) had some findings related to this. The article observed that increasing the cooking temperature from 140 to 180 degrees Celsius improved the SI index by 50% and lowered the chroma value by 25%. This means that cooking beef at a high temperature will result in a rough, dry product with a pale tint.

Hue Angle

The hue angle analysis gave insights into the effect of different treatments (T_1-T_6) on the color properties of the samples. The range was observed from 36.71 to 62.58. Significantly, the observed differences in hue angles across the treatments indicate a strong influence on the color spectrum of the samples. The hue angle values represent the prevailing color tone perceived in the samples, with lower values linked with reddish tones, intermediate values indicating greenish tones, and higher values suggesting bluish tones. Comparatively, T_1 had the lowest mean hue angle value (36.71), showing a predisposition toward reddish tones. On the other end of the spectrum, T_4 displayed the greatest mean hue angle value (62.58), demonstrating a predilection for bluish tones. T_2, T_5, and T_6 fell within the middle range, with T_2 (49.94) and T_6 (56.49) skewing toward reddish tones and T_5 (58.45) indicating a more neutral tone. The relevance of these findings may be appreciated from the perspective of color perception and its influence on customer choices. The recommended cooking temperature for beef will vary based on the desired color of the finished product. For a pale pink tint, the meat should be cooked to a lower temperature. For a deeper brown hue, the meat should be cooked to a higher temperature. All the observations are in the Table 3.

The article by El Masry et al. (2010) discovered that increasing the cooking temperature from 140 to 200 degrees Celsius enhanced the color angle by 10 degrees. This means that cooking beef at a high temperature will result in a browner product (Hossain et al., 2015).

Proximate Analysis

There are six types of beef steaks were made for the determination of proximate components. These were treated as T_1 (52°C for Rare), T_2 (57°C for Medium Rare), T_3 (65°C for Medium), T_4 (66°C for Medium Well), T_5 (71°C for Well Done) and T_6 (80°C Very Well Done). The value proximate components are shown in Table 4 below.

Table 4. Effect of Degree of Doneness on Proximate components of cooked beef

Variables	T_1 (Mean± SEM)	T_2 (Mean± SEM)	T_3 (Mean± SEM)	T_4 (Mean± SEM)	T_5 (Mean± SEM)	T_6 (Mean± SEM)	Level of Significance
DM (%)	42.84 ± 0.01^{b}	45.71 ± 0.01^{ba}	46.77 ± 0.01^{ba}	49.67 ± 0.02^{a}	45.41 ± 0.01^{ba}	48.67 ± 0.03^{ba}	<0.0001
CP (%)	23.15 ± 0.01^{a}	22.34 ± 0.01^{ba}	22.34 ± 0.01^{ba}	21.03 ± 0.01^{b}	21.73 ± 0.01^{ba}	21.52 ± 0.01^{b}	<0.0001
EE (%)	11.92 ± 0.18^{a}	11.73 ± 0.16^{a}	11.31 ± 0.08^{b}	11.13 ± 0.07^{cb}	10.97 ± 0.16^{cb}	10.84±0.07c	<0.0001
Ash (%)	1.15 ± 0.02^{a}	1.21 ± 0.05^{a}	1.31 ± 0.07^{a}	1.22 ± 0.07^{a}	1.14 ± 0.04^{a}	1.16 ± 0.05^{a}	<0.0001

The mean in each row having different superscripts varies significantly at values $p < 0.05$. Again, mean values having the same superscript in each row did not differ significantly at $p > 0.05$. T_1 = 52° C, T_2 = 57°C, T_3 = 65°C, T_4 = 66°C, T_5 = 71°C, T_6 = 80°C

Dry Matter (DM)

The dry matter content of different treatments is shown in Table 4. The range of overall observed Dry Matter content at different treatments was 49.67 to 42.84%. Superscripts that were observed from different treatments weretotally different from each other ($p<0.05$). Among these 6 treatments, the most preferable Dry Matter content was observed from T_1 and T5. The lowest amount of Dry Matter content indicates this product is most preferable. Less preferable Dry Matter content was observed from the controlled group T_4. The highest level of Dry Matter concentration suggests this product is less preferred. The range of overall observation of varied treatment with temperature of Dry Matter content was 49.67% to 42.84%. The distinct superscript was noticed, indicating there were significant differences ($p<0.05$). In both ways, treatment 1 had the least DM concentration, but it had another undesirable aspect, so T_1 was considered less preferable. Cooked samples contained considerably ($p<0.05$) more dry matter by 27.7 percent (Kadim et al. 2011)

Crude Protein (CP)

The Crude Protein content for different treatments with day intervals is presented in Table 4. The range of overall observed Crude Protein content for different treatments was 23.15 to 21.03%. The fully distinct superscript was detected from various treatments, showing there were considerable changes ($p<0.05$) in Crude Protein content between these treatments. The preferable amount of CP (%) was observed in T_5. The temperature helps the protein to be denatured and makes the formation of cross-links between polypeptides (Xiong, 2000). Treatment T_5 showed the percentage of the protein, which is preferable after being denatured at the temperature of 71°C, having significance in the result. Research also stated that cooked meat has a higher portion of proximate components than those of raw meat samples (Kadim et al., 2011).

Ether Extracts (EE)

The EE content of different treatments with day intervals is shown in Table 4. The range of overall observed EE content at different treatments was 11.93 to 10.97%. Among these four treatments, the most preferable EE content was observed from T_5 and T_6. The lowest amount of EE content indicates this product is most preferable for consumers' health. The less preferable EE amount was observed in T_1. Overall, in the treatment, 5 was the most suitable for consumers. Findings by Martin et al. (2013) and Acheson et al. (2015) were quite the same in related fields.

Ash

The Ash content of different treatments with day intervals is shown in Table 4. The range of overall observed Ash content at different treatments was 1.31 to 1.15%. A totally different superscript was observed from four treatment groups, indicating therewere significant differences ($p<0.05$) in Ash content. The most preferable amount of ash content observed was in the $T_{5,}$ which was treated at 71°C. The Lowest amount of Ash content indicates that this product is suitable for the consumer's health. Less preferable ash content was observed in the T_3. The observed ash content was 1.31%, and there was significance in treatments. The ash content was significantly changed ($p<0.05$) due to temperature. Similar results were also reported by Serdaroglu et al. (2005) on the ash content of beef meatballs, which ranged from 2.6 to 2.8%. However, an earlier investigation by Serdaroglu and Degirmencioglu (2004) indicated somewhat lower ash concentration in beef meatballs, ranging from 1.7 to 2.2%, which is also greater than the ash content of raw beef.

Microbiological Analysis

The present study observed the presence of micro-flora (TVC) in different treatment groups at different Temperatures.

Total Viable Count (TVC)

The TVC values of various treatment levels with different temperatures are shown in Table 5. The initial value of TVC for raw beef (beef not frozen and thawed) was 5.12 log CFU/g beef, indicating good-quality beef. Cross-contamination from the environment (i.e., the air or food handlers) or through the survival of spores or resistant cells was conceivable in our investigation as well as in commercial operations. Some bacteria may be present in the product, but their development is limited under storage conditions (Fernández-López et al., 2005). The range of overall observed aerobic plate count from the beef steak sample was 2.38–1.1 (log10 CFU/g) at different treatment levels. The differences in superscript were noticed from different treatments, implying there were significant variations ($p<0.05$) of TVC values across these four treatment groups. The plate count in the T_1 sample (2.38 log CFU/g) was significantly higher than the treated samples. The lower amount of TVC value indicates that this product is preferable for consumers' health (T_5). Total Viable Count is always lower in cooked meat than raw meat. Abdallah et al. (2013) reported some related findings in the fresh meat.

Table 5. Effect of Degree of Doneness on microbial population in cooked beef

Variables	T_1 (Mean± SEM)	T_2 (Mean± SEM)	T_3 (Mean± SEM)	T_4 (Mean± SEM)	T_5 (Mean± SEM)	T_6 (Mean± SEM)	Level of Significance
TVC (CFU/g)	$2.38{\pm}0.0019^a$	$1.71{\pm}0.0011^b$	$1.33{\pm}0.0012^c$	$1.4{\pm}0.0013^c$	$1.1{\pm}0.002^c$	$1.1{\pm}0.001^c$	<0.0001

The mean in each row having different superscripts varies significantly at values $p<0.05$. Again, mean values having the same superscript in each row did not differ significantly at $p> 0.05$. T_1 = 52° C, T_2 = 57°C, T_3 = 65°C, T_4 = 66°C, T_5 = 71°C, T_6 = 80°C

Conclusions

This study examines how cooking temperature impacts the quality of indigenous beef, considering flavor, texture, color, and safety. Lower temperatures result in better softness, water-holding capacity, and flavor, while higher temperatures yield higher scores in attributes like tenderness. However, juiciness decreases with rising temperature. The study also explores nutritional changes, with higher temperatures increasing dry matter and protein content but reducing ether extract. Color metrics reveal that higher temperatures decrease lightness, redness, and yellowness in cooked beef. Additionally, microbial analysis shows lower temperatures lead to higher microbial counts. This research also highlights the diverse effects of cooking temperatures on indigenous beef, offering culinary enthusiasts the opportunity to explore various degrees of doneness in Bangladeshi cuisine.

Conflicts of Interest

The authors declare no potential conflict of interest.

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