Nutritional value and color of se’i processed from cull cow meat from different body condition score and smoked at different smoke method

G E M Malelak*, I Benu, A E Manu and I G N Jelantik
Faculty of Animal Science, The University of Nusa Cendana
Jln. Adisucipto, Penfui, Kupang, Nusa Tenggara Timur, Indonesia

Corresponding author: geminimalelak@staf.undana.ac.id

Abstract. Se’i (smoked meat) quality influenced by fresh meat quality and smoking method. Meat from cull cow at different body condition scores (BCS) and which are smoked using different method produce different quality of se’i. This research was aimed to study the effect of different smoking methods on nutritional value and color of se’i made from meat of Bali cattle cows with different BCS. The experimental design used was completely randomized design $3 \times 4$ with factorial patterns. The first factor was smoking method namely open, close and liquid smoke method. The second factor was BCS namely BCS 2, BCS 3 and BCS 4. The parameters measured were se’i nutritional value (water, protein and fat content) and color ($L$ (lightness), $a$ (redness) and $b$ (yellowness)). Data were analysed using ANOVA, followed by Least square means (LSM). Results showed that water and protein content was depend on BCS, as BCS increased, water content decreased and protein content increased ($p<0.01$). Se’i color also depend on BCS, as BCS increase, the value of $a$ and $b$ decrease while the $L$ increases. In conclusion, BCS factor was influencing se’i quality rather than smoking method.

1. Introduction
Se’i is a traditional smoked meat product, made from beef or pork, sliced into rope-shape, spiced with salt and saltpeter, cured and then smoked. As traditional products, there are not standardized control during processing thus the quality of se’i produced was different among the producers. Factors influencing se’i are quality of raw material (fresh meat) and smoking method. Factor that affect on fresh meat quality is body condition scores (BCS). Fresh meat coming from cow with different body condition score have a different water, protein, fat and mineral composition [1,2], thus it could affect the quality of fresh meat and further quality of se’i.

Different smoking methods such as opened smoking (conventional method), which is commonly used by people since ancient times to cook se’i, causes a lot of smoke and heat to spread. It can affect the amount of smoke and heat reaches to the meat surface during smoking process. Other smoking method is closed smoking. In this system, smoke and heat could reach maximally to the meat surface during smoking.

In the process of smoking meat using gas smoke, all smoke components will stick directly to the meat surface, causing the smoked meat to have distinctive flavor and color. However, some of components in smoke are harmful to health such as polycyclic aromatic hydrocarbons (PAHs) and tar. PAH is a pollutant component that is carcinogenic, mutagenic and cytogenic [3]. To reduce this risk,
liquid smoke can be used instead of gas smoke. The use of liquid smoke has been reported previously [4] and the level of benzo (a) pirene (BaP) in smoked se’i using liquid smoke was lower than close method [5].

In Timor, commonly, se’i processed from Bali cattle meat, either from young or old, male or female, productive or culling cattle, with various of body condition score (BCS). Thus se’i produced is not standardized in its characteristics or quality. Aim of this study was to know the effect of different method of smoked (openly, closely and using liquid smoke) and different BCS (mirroring meat quality) on the nutritional composition (moisture, protein, total fat) and the colour (lightness (L), redness (a) and b(yellowness) of produced se’i.

2. Materials and methods

2.1. Meat and experimental design

The experimental design in this study was Completely Randomized Design (CRD) using 2 factors. The first factor was the smoked method which consists of P0= open smoking / control; P1 = smoking in a closed way / using a drum; P2 = liquid smoke (oven smoking). The second factor was BCS namely S1 = BCS 2; S2 = BCS 3; S3 = BCS 4. In total, 12 kg of Bali cattle meat, taken from bicep femoris (BF) muscle of culled Bali cows with different body condition score (BCS), 4 kg per BCS category. The meat was purchased from the Oeba slaughterhouse in Kupang.

2.2. Se’i processing

The meat was separated from excess subcutaneous fat then cut into flat shape with 3 mm in thickness. The meat was weighed to determine the amount of salt and saltpeter needed. As amount of 2% salt and 300 mg of saltpeter were added to every kg of meat.

Saltpeter was mashed then dissolved using water (±2 mL) then mixed with the meat and added salt, mixed well then marinated for ± 12 hours. Before marinating, the meat from each BCS divided into 3 parts for smoked method treatment (P1 to P3). In P3, meat was injected using 1% (v/w) of liquid smoke at several point of the meat.

After marinated, the meat was place on the frame then different smoked method was applied. All the meat surface covered with kusambi (Schleicheria oleosa) leaf while smoking. The source of heat was kusambi(Schleicheria oleosa) wood, except the oven.

Smoking process was done separately for each BCS group. It took 45–60 minutes until well-done. Then the meat was cooled and cut into pieces ±5 cm as sample from each BCS and each smoking methods combination to be analysed according to the specified parameters measured.

2.3. Measured variables and measurement method

2.3.1. Nutritional value. Water, protein, and total fat content were analyzed according to AOAC methods [6].

2.3.2. Color determination. The L (lightness, black-white) (darkness-lightness), a (redness/greeness) and b (yellowness/blueness) values were measured on se’i surface by use a Minolta colorimetry (Minolta Chromameter Reflectance II CR-200/08).

2.4. Data analysis

All data were analyzed by using ANOVA, followed by Least square means (LSM) to test the difference between treatments. The data analysis were done with the help of SAS 9.1.3 portable.
3. Results and discussion

3.1. Nutritional content of fresh meat.

The average percentage of water, protein and fat of fresh meat took from cull Bali cow with different body condition score were presented in Table 1. It shows that water and fat content increased from BCS 2 to BCS 4, while the protein content decreased (P<0.05).

Table 1. Percentage of water, protein and fat (%) of fresh meat took from cull Bali cow with different body condition score

| Body Condition Score (BCS) | Water (%)  | Protein (%)  | Fat (%)   |
|----------------------------|------------|--------------|-----------|
| 2                          | 62.25±0.03a | 28.62±0.74c  | 6.42±0.17a |
| 3                          | 65.36±0.09b | 25.59±0.08b  | 7.05±0.03b |
| 4                          | 67.12±0.12c | 21.03±0.007a | 8.96±0.02c |

Means in the same variable with different superscripts differ significantly (P<0.05).

Previous study Schnell et al [7] reporting an increase of one scale of BCS led to a 12.65% increased in fat and a 12.2% decreased in protein in Brahman-cross, Holstein, Brown Swiss and British cattle. The increasing in fat content in cull Bali cow in this study was 0.63% from BCS 2 to BCS 3, and 2.64% from BCS 3 to BCS 4, while the decrease in protein from BCS 2 to BCS 3 was 3.03%, and 4.56% from BCS 3 to BCS 4. The difference in this experiment was due to the different breeds used. Breed is one of the important factors affecting the distribution of fat tissue and also the protein content in meat [8].

3.2. Nutritional value of se’i

The average percentage of water, protein and fat content of se’i are shown in Table 2. It can be seen that water content of se’i from BCS 2, 3 and 4 in open smoked system is higher than in closed smoked system and also given liquid smoke. However, in BCS 3 and 4 those that were given liquid smoke had lowest water content namely; 59.52% and 59.66% respectively, has the highest protein content 36.17% and 36.14% respectively. This because at the time of giving liquid smoke, the liquid smoke had filled the meat cell causing loosening of the meat fibers, thus during smoking, hot temperature cause a lot of water lost, as the result the non-water component content in se’i is increases. Moreover, it also can be explained due to during heating processes, proteins are denaturated and it cause 20–40% lost of water and fat [9]. It stated previously Braeckman and Palka [9,10] that at internal temperature of 50–60°C and 60–70°C it causes shrinkage of myofibril proteins and collagen.

Table 2. Average of water, protein and fat (%) content of se’i processed from different body condition score and smoked methods

| Body Condition Score | Smoked methods | Water (%)  | Protein (%)  | Fat (%)  |
|----------------------|----------------|------------|--------------|----------|
| 2                    | Open           | 63.07b     | 32.27ab      | 4.81     |
|                      | Close          | 62.10b     | 33.01ab      | 4.72     |
|                      | Liquid smoke   | 62.25b     | 32.40b       | 5.46     |
| 3                    | Open           | 62.71bc    | 33.39b       | 4.97     |
|                      | Close          | 61.38b     | 33.11ab      | 5.01     |
|                      | Liquid smoke   | 59.52a     | 36.17b       | 5.57     |
| 4                    | Open           | 63.86c     | 32.05a       | 4.81     |
|                      | Close          | 62.32bc    | 32.10ab      | 4.72     |
|                      | Liquid smoke   | 59.66a     | 36.14b       | 5.46     |
| SEM                  | 0.0270         | 0.0395     | 0.19         |
| P                    | <0.0001        | 0.0001     | 0.993        |

Note: SEM= standard error means; Means in the same variable with different superscripts differ significantly (P<0.05).
In can be seen in Table 1 that the protein content in BCS 3 and 4 are lower than in BCS 2, so that in BCS 3 and 4, the protein denatured faster during heating which causes more water lost. On the other hand, the highest water content was in se’i processed from BCS 2 and BCS 4 which were smoked openly, namely 63.07% and 63.86% respectively. This is because during open smoking, heat spreads everywhere, so the heat reached the meat surface is lower than closed smoking or liquid smoke application. This causes the evaporation process to run slowly which causes more water left in se’i than closed smoking or given liquid smoke.

Figure 1. The relationship of BSC and smoking methods on water content os se’i

Figure 2. The relationship of BSC and smoking methods on protein content os se’i

The relationship of BCS and smoking methods on water content and protein content of se’i were shown in Figure 1 and Figure 2. It can be seen that the changing in water and protein content of se’i which is smoked in different ways depends on BCS, as BCS increase, the water content tend to decrease whereas protein content tend to increase.

Se’i fat content in this study was ranged from 4.72–5.69% (Table 2). The nutritional content of processed meat is determined by the composition of fresh meat and mainly depends on the ratio between protein, fat and water [11]. In this study, the nutritional content of fresh meat varied between BCS (Table 2), however, the fat content after smoking was the same.

3.3. Color of se’i

3.3.1. Lightness value. The average color of se’i can be seen in Table 3. The lowest Lightness value is in se’i from BSC 3 which is given liquid smoke. The decrease in L value indicates a darker meat color due to the browning reaction [12]. In the Maillard reaction, that carbonyl group from reducing sugar (aldose) reacts with the primary amine group from food to produce N-glycosamine and water (Schiff’s base). The glucosamine group changes to ketosaminbe (amino ketose). The result of the amadori reaction is dehydration form fulfuraldehide derivatives (from pentose) or fulfural metal hydroxyl (from hexose). The dehydration process then produces an intermediate product in the form of methyl-dicarbonyl which is followed by decomposition to produce reducing agents and dicarboxylys such as’ methyglyoxak, acetote and diacetyl. The active aldehydes of the products of 3rd and 4th stages are polymerized without including an amino group (called an aldol condensation) or with amino group to form a brown compound called melanoidin (brown pigment).

The increase in Lightness value is due to the meat losing its red color, and the L value will increase when the temperature increases from 65–71°C. When the temperature increases the denaturation of protein increases and the soluble myoglobin content decreases [13]. Denaturation of protein during heating causes a loss of 20–40°C water and fat, while at a temperature of 75°C it loses more than 30% water and more than 40% fat. Water lost is due to evaporation from the meat surface, while fat lost as drip [14].

The increase in L value in BCS 4 can be attributed to the lower protein content of fresh meat of BCS 4 compared to in BCS2 and BCS 3. Therefore, when heating the protein denatured rapidly which causes se’i to lose soluble myoglobin content, so that more bright. The results of previous study Moon S S et al [15] reported that the L value of beef steak is influenced by the level of fat or marbling, the higher the marbling content in meat the higher the L value. In this study, all meat has no marbling.
only subcutaneous fat and intermuscular fat. The thickest subcutaneous is (± 6.5 cm) in BCS 4 and in BCS 3 is 3 cm while BCS 2 had no fat. The total fat content in fresh meat of BCS 4 was the highest (8.96%) compared to BCS 3 (7.05%) and the lowest was in BCS 2 (6.42%). Thus the highest fat content in BCS 4 can explain the highest value of \( L \) in se’i. In Figure 3 it was seen that the changes in the Lightness value of se’i depending on BCS, as BCS increase, the Lightness value also increase.

Table 3. Average of Lightness (\( L \)), redness (\( a \)) and yellowness (\( b \)) value of se’i processed from different body condition score and smoked methods

| Body Condition Score | Smoked methods | Lightness (\( L \)) | Redness (\( a \)) | Yellowness (\( b \)) |
|----------------------|----------------|--------------------|------------------|--------------------|
| 2                    | Open           | 32.94\(^b\)        | 19.99\(^f\)      | 11.32\(^\#\)       |
|                      | Close          | 35.86\(^c\)        | 17.12\(^c\)      | 16.11\(^i\)        |
|                      | Liquid smoke   | 30.78\(^b\)        | 20.97\(^g\)      | 8.25\(^b\)         |
| 3                    | Open           | 36.32\(^c\)        | 19.96\(^f\)      | 11.23\(^l\)        |
|                      | Close          | 37.31\(^c\)        | 19.60\(^c\)      | 10.81\(^c\)        |
|                      | Liquid smoke   | 27.74\(^a\)        | 20.94\(^c\)      | 11.64\(^k\)        |
| 4                    | Open           | 40.07\(^d\)        | 16.71\(^b\)      | 10.36\(^d\)        |
|                      | Close          | 36.09\(^d\)        | 17.54\(^d\)      | 8.01\(^a\)         |
|                      | Liquid smoke   | 35.77\(^c\)        | 16.24\(^a\)      | 10.02\(^c\)        |
| SEM                  | 0.0905         | 0.017              | 0.012            |
| P                    | 0.0003         | <0.0001            | <0.0001          |

Note: SEM = standard error means; Means in the same variable with different superscripts differ significantly (\( P<0.05 \)).

Figure 3. The relationship of BCS and smoking methods on Lightness (\( L \)) value of se’i

3.3.2. Redness value. The average redness (\( a \)) value can be seen in Table 3. The lowest redness (\( a \)) value is in se’i processes from BCS 4 and given liquid smoke, and the highest is in se’i processes from BCS 2 and 3. The increase of redness value especially caused by a change from bright red oxymyoglobin (OMb) or light brown metmyoglobin (MMb) to purplish-red myoglobin (DMb), so that the color is redder [16]. Data from Hunt et al [17] is same as that reported by Machlik S M [18] that MMb (brown) and OMb (bright red) denatured at temperature that lower than DMb (purple-red). As previously explained, the internal temperature of the meat ranges from 70–75°C. Earlier study Yancey et al [19] reported that an internal temperature 65.5°C beef steak are red and cook at 76.7°C the redness value reduced.

The high redness value in BCS 2 or BCS 3 which were given liquid smoke was due to the fact that the amount of heat reaches the meat surface was more evenly distributed so that the change of protein denaturation from MMb (brown) and OMb (bright red) to DMb (purple–red) running smoothly. Se’i produced from BCS 4 which given liquid smoke, even though the internal temperature of sample was same during smoking, the water content of raw neat was higher than BCS 2 and 3 (Table 1) the sample took a longer time to cook thus, the redness (\( a \)) value is low. The averages time needed for semi to well-done in BCS 2 and BCS 3 which were given liquid smoke was 45–60 minutes while those that smoked in oven (giving liquid smoke) took 60–90 minutes. Study reported Özcan A U and Bozkurt H [20] that the longer smoking time causes the value redness (\( a \)) decrease. The change in the value of redness is related to the degradation of myoglobin. Protein denaturation will form deoxymyoglobin (DMb), oxymyoglobin (OMb) then metmyoglobin / brownish-red (MMb). The value of deoxymyoglobin (DMb), oxymyoglobin (OMb) is higher than metmyoglobin / brownish-red (MMb).
This is a concern in the se'i smoking process, so that the smoking temperature is controlled. Moreover, the time needed for the meat to reach uniform maturity and it does not take too long, then the distinctive color of se'i can be achieved. In Figure 4 showed that the changes in the Redness value of se'i depending on BCS, as BCS increase, the Redness value tended to decrease.

3.3.3. Brightness (b) value. The average brightness (b) value can be seen in Table 3. It can be seen that the lowest brightness (b) value is in se'i processed from BCS 4 and smoked closed, namely 8.01; while the highest brightness (b) value is in se'i which is processed from BCS 2 and smoked closed, namely 16.11. A high b value in the treatment combination indicates that se'i tends to be yellow compared to blue, and if the b value is low it indicates that se'i tends to be blue rather than yellow. A decrease in the value of b indicates a browning reaction [12].

The value of b is influenced by temperature and duration of cooking. According to Sen [13] the value of b will increase when the temperature increases from 65–71°C. According to Hunt et al [17] and Machlik [18] that color change is influenced by temperature, where MMb (brown/brown) and OMb (bright red) denatured at a lower temperature than DMb (purple-red/dark red). In this study, the internal temperature of se'i during heating ranged from 70–75°C for all BCS and all curing methods. The value of b is influenced by temperature and duration of cooking. According to Sen [13] the value of b will increase when the temperature increases from 65–71°C.

According to Hunt and Machlik [17,18] that color changes are influenced by temperature, where MMb (brown/brown) and OMb (bright red / bright red) are denatured at temperatures lower than DMb (purple-red / dark red). In this study, the internal temperature of se'i during heating ranged from 70–75°C for all BCS and all smoking methods.

Besides temperature, the b (yellow-blue) value of processed meat is influenced by the cooking time. In sucuk processing, the b (yellow-blue) value increases at the first 30 minutes of cooking, but at the end of cooking (50 minutes) the b value decreases [21]. The low b value in BCS 4 which was smoked closed was due to the fact that fat and water content in the BCS 4 meat was higher than other BCS so that it required a longer cooking time. The cooking time is longer; causing the b value to decrease and the se'i is browner.

The high value of b (yellow-blue) in BCS 2 which is smoked closed can be caused by the low content of water and fat, so se'i cooks quickly. In closed smoking, the heat concentration is concentrated on the surface of the meat, so the meat cooks quickly. Although there is a change in color as per this research, what is visible to the naked eye is still in the typical se'i color range. The results of test on consumer acceptance the color of se'i meat show that 61.6% of the panellists agree that the color se'i this research is the typical color of se'i. In Figure 5 showed that the changes in the Brightness value of se'i depending on BCS. As BCS increase, the Brightness value decrease.

4. Conclusions
The fat content was the same for all treatments. Se'i processed from BCS 2 and 3 which were given liquid smoke had the highest redness (a). The changing of water and protein content also color (L, a and b) value of se'i depending on Body Condition Score.
Acknowledgment
The authors particularly wish to thank to the financial support of Directorate for Higher Education, the Ministry of Technology Research and Higher Education for the research grant.

References
[1] Otto K L, Ferguson J D, Fox D G and Sniffen C J 1991 J. Dairy Sci. 74 852–9
[2] Whittier J C, Steevens B and Weaver D 1993 Body Condition Scoring of Beef and Dairy Animals (University of Missouri Extention)
[3] Darmadji E P 2009 Teknologi Asap Cair dan Aplikasinya Pada Pangan dan Hasil Pertanian Inaugural Speech of Professor, Faculty of Agricultural Technology (Indonesia: Universitas Gadjah Mada)
[4] Malelak G E M, Sipahelut G M, Jelantik I G N, Denoratu M R and Lalal H J D 2015 Med. Pet. 38 89–94
[5] Malelak G E M, Deno R M R, Lestari G A Y, Benu I and Jelantik I G N 2020 Jurnal Ilmu dan Teknologi Hasil Ternak 15 78–85
[6] (AOAC) Association of Official Analytical Chemists 1995 Official Methods of Analysis 16th ed. Association of Official Analytical Chemists (Virginia, USA)
[7] Schnell T D, Belk K E, Tatum J D, Miller R K and Smith G C 1997 J. Anim. Sci. 75 1195–202
[8] Golze M, Strehle S, SchröderCh and Klos K 2009 Schlacltkörperwert und Fleisehqualität von Altbulen (German: Fleisehrinder) pp 24–8
[9] Braeckman, Ronsse F, Cueva H P and Pieters J 2009 J. food eng. 93 437–43
[10] Palka K and Daun H 1999 Meat Sci. 51 237–43
[11] Gaitán J J A, Somovilla V O, España E F, Pérez A J and De Pedro S E J 2008 Meat Science 78 391–9
[12] Bozkurt H 2006 Meat Sci. 73 442–50
[13] Sen A R, Naveena B M, Muthukumar M and Vaithiyanathan S 2014 J. Food Sci. Technol. 51 970–5
[14] Oroszvari B K, Rocha C S, Sjoholm I and Tornberg E 2006 J. Food Eng. 74 1–12
[15] Moon S S, Yang H S, Park G B and Joo S T 2006 Meat Sci. 74 516–21
[16] Lawrie R A and Ledward D A 2006 Lawrie’s Meat Science 7th ed. (Cambridge, England: Woodhead Publishing)
[17] Hunt M C, Sorheim O and Slinde E 1999 J. Food Sci. 64 847–51
[18] Machlik S M 1965 The Effect of Heat on Bovine Myoglobin Derivative in Model System and in Beef Semitendinosus Muscle PhD. Dissertatiion (Indiana: Purdue University)
[19] Yancey J W S, Wharton M D and Apple J K 2011 Meat Sci. 88 1–7
[20] Özcan A U and Bozkurt H 2015 Int. J. Food Prop. 18 2422–32
[21] Bozkurt H and Belibagli K B 2009 J. Sci. Food Agric. 89 1168–117