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Quality of Bali Beef and Broiler after Immersion in Liquid Smoke on Different Concentrations and Storage Times

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***Abstract*—**The aim of this study was to improve the durability and quality of Bali beef (M. *Longissimus dorsi*) and broiler carcass through the addition of liquid smoke as a natural preservative. This study was using *Longissimus dorsi* muscle from male Bali beef aged 3 years, broiler breast and thigh aged 40 days. Three types of meat were marinated in liquid smoke with concentrations of 0, 5, and 10% for 30 minutes at the level of 20% of the sample weight (w/w). The samples were storage at 2-5°C for 1 month. This study designed as a factorial experiment 3 x 3 x 4 based on a completely randomized design with 5 replications; the first factor was meat type (beef, chicken breast and chicken thigh); the 2nd factor was liquid smoke concentrations (0, 5, and 10%), and the 3rd factor was storage duration (1, 2, 3, and 4 weeks). Parameters measured were TBA value, total bacterial colonies, water holding capacity (WHC), shear force value both before and after cooking (80°C – 15min.), and cooking loss. The results showed that the type of meat produced WHC, shear force value, cooking loss and TBA differed between the three types of meat. Higher concentration of liquid smoke, the WHC, shear force value, TBA, and total bacterial colonies were decreased; at a concentration of 10% of liquid smoke, the total bacterial colonies decreased by 57.3% from untreated with liquid smoke. Longer storage, the total bacterial colonies and WHC were increased, while the shear force value and cooking loss were decreased. It can be concluded that a 10% concentration of liquid smoke was able to maintain fat oxidation and bacterial growth in Bali beef and chicken breast and thigh.

***Keywords*—**Bali beef, chicken meat, liquid smoke, meat quality

I. Introduction

THE quality changes of fresh meat due to biochemical and microbiological processes which occur during storage include fat oxidation and development of bacterial colonies which should be suppressed through preservation. Preservation is generally carried out by reducing the temperature between 2^0 and 5^0C, adding preservatives and or combining cooling and preservative addition that intended to extend the durability of meat and its processed products.

Due to the consumers' health grounds, liquid smoke, a safe, natural, and environmentally friendly preservative has been developed. Liquid smoke is the result of condensation of wood or coconut shell pyrolysis after being heated at a temperature of 400-600°C in a tube or drum and purified from carcinogenic compounds.

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This liquid smoke contains more than 400 chemical compounds such as phenol (4.13%), carbonyl (11.3%) and acid (10.2%) [1], [2]. The compounds contained in the liquid smoke can serve as a preservative and emulsifier [3]. Furthermore, within the liquid smoke, some types of acids serving as a gum, which functions as materials thickeners, emulsion stabilizers and water-soluble gel shaper, were also found [3].

Efforts to improve the decreasing functional properties of meat during storage and processed meat products have been carried out by adding additional non-meat ingredients in order to enhance the ability of the meat in binding water (water holding capacity), for instance, by adding sodium tri-polyphosphate [4]-[7], sodium di-phosphate [8], [9], or by using meat with higher water holding capacity on pre-rigor condition [10], [11].

Liquid smoke as a binder in beef meatballs production has been shown in the previous studies, in which the meatballs added by liquid smoke at a level of 0.5% increased their elasticity in the sensory test. Similarly, the resilience increased as the levels of liquid smoke increased [12], [13]. Meanwhile, the addition of 1% liquid smoke is capable to maintain the quality of meatballs for 2 week period of storage [14]. The use of liquid smoke as an antioxidant also causes an increase in the tenderness of broiler meat [15]. Moreover, liquid smoke can be used as antioxidants on oxidative stability of jumbo catfish sausage during storage [16].

The objective of study was to examine the effects of different liquid smoke concentrations and storage times at refrigerator temperature (2-5^0C) on the quality of Bali beef, and chicken broiler breast and thigh.

II. Materials and Methods

This study was using fresh meat of the 3-year-old male Bali cattle especially in the muscle part of *Longissimus dorsi*, and carcass of broilers aged 40 days, especially breast and thigh parts. Bali beef (*Longissimus dorsi*), chicken breast and thigh were marinated in liquid smoke in the concentrations of 0, 5, and 10% at 20% level of the sample weight (w/w) for 30 minutes. Then, the storage was carried out at the temperature of 2-5^0C for 1 month.

The study was arranged using a Completely Randomized Design of factorial pattern 3 x 3 x 4, in which the first factor was the types of meat (beef, chicken breast and thigh), the second factor was the concentration of liquid smoke (0, 5 and

10%), and the third factor was storage time duration (1, 2, 3, and 4 weeks) repeated for 5 times.

All parameters were measured weekly, including the rate of fat oxidation (TBA test), total bacterial colonies (TPC test), and water holding capacity, shear force of raw and cooked meat (80^0C - 15 minutes), and cooking loss.

TBA test was performed to measure the level of rancidity caused by fat oxidation during storage [17]. Total Plate Count Test (TPC) was conducted to examine the development of bacteria during storage by counting the number of bacterial colonies per gram sample [18]. Measurements on the water holding capacity of raw meat was carried out by using *Filter - Paper Press Method* as proposed by Hamm, 1986 [19]. Shear force of meat (kg/cm^2) serves as an assessment indicator of beef and chicken tenderness using CD Shear Force [19]. Cooking loss (%) was calculated based on the ratio between the weight loss during heating and the weight before heating [20].

The data were calculated using analysis of variance, followed by LSD test when a significant difference was encountered [21]. All calculations were performed with the help of SPSS program (SPSS 16.0, SPSS Ltd. West Street Working Surrey, UK).

III. Results and Discussion

A. Fat Oxidation Level (TBA value)

TABLE I
TBA Value, TPC, and WHC and Significance Level

Treatments	TBA (mg MDA/kg)	TPC (cfu/g)	WHC (%)
Meat Types:	Sig: 0.01	Sig: NS	Sig: 0.01
- Beef	0.055	7.62x10^7	30.85^a
- Chicken Breast	0.071	8.51x10^7	34.80^b
- Chicken Thigh	0.038	5.25x10^7	33.28^b
Concentrations:	Sig: 0.01	Sig: 0.08	Sig: 0.01
- 0%	0.072^x	1.10x10^{8x}	35.35^x
- 5%	0.049^y	5.80x10^{7xy}	32.42^y
- 10%	0.042^{yz}	4.70x10^{7y}	31.16^y
Storage time	Sig: NS	Sig: 0.01	Sig: 0.01
- 1 weeks	0.052	9.78x10^{6a}	31.00^a
- 2 weeks	0.046	6.59x10^{5a}	33.62^b
- 3 weeks	0.060	4.33x10^{7a}	33.31^b
- 4 weeks	0.061	2.31x10^{8b}	33.98^b

Description: Numbers with different superscripts in a column differ significantly (P <0.01). TBA=thiobarbituric acid, MDA=malonaldehyde, TPC=total plate count, WHC=water holding capacity

Analysis of variance showed that the types of meat and liquid smoke concentration had significant (P <0.01) effect on TBA, but the storage time did not differ (Table I).

TBA value (fat oxidation) between beef and chicken breast and chicken thigh differed at the levels of 0.07 and 0.06, respectively.

This implies that the level of significance between 0.06 and 0.07 (error rates of 6% and 7%) in TBA value of chicken thigh meat was 30.91%, lower than the TBA value of Bali beef. Contrary the TBA value of chicken breast meat was 22.54%; higher than TBA value of Bali beef, while the TBA value of chicken thigh meat was 46.48%; lower than that the chicken breast meat. The low TBA value of chicken thigh meat indicated that the rate of fat oxidation during in the cold storage temperature (2-5^{0}C) of this meat did not as an intensive as it did both chicken breast meat and beef.

Although the number of fat in chicken thigh had higher than that in chicken breast, the higher proportion of unsaturated fatty acids in chicken breast meat could explain the high levels of fat oxidation in line with the high TBA value at chicken breast meat. TBA value of Bali beef was lower than that of chicken breast meat due to the fat oxidation which occurred more intensively in unsaturated fatty acids (chicken breast) than in saturated fatty acids (beef), resulting higher TBA value in chicken breast meat.

Higher concentration of liquid smoke, TBA value declined reaching up to 31.94% and 41.67% at 5% and 10% concentrations, respectively in comparison without liquid smoke (concentration of 0%); however, there was no significant difference between 5% and 10% concentrations. This indicated that liquid smoke could inhibit the fat oxidation during storage.

Storage time duration did not significantly affect the TBA value of Bali beef and chicken meat (breast and thigh) treated by liquid smoke. Although there was a tendency that the TBA value increased during storage, this study confirmed that the liquid smoke as an antioxidant was able to maintain the oxidation level during storage duration.

B. Bacteria Development (TPC)

The analysis of variance showed no significant effect of meat type on TPC, but the concentration of liquid smoke was affected (P =0.08). Furthermore, storage time was also affected (P =0.01) the total number of bacterial colonies (Table I).

Although the type of meat did not significantly affect the total number of bacterial colonies, there was a tendency that the lowest total bacterial colonies was found in chicken thigh meat (5.25x10^7), followed by Bali beef (7.62x10^7) and reached highest in the chicken breast meat (8.51x10^7). These three types of meat have resulted in total bacterial colonies that exceed the standard of IEC/SNI of 1x10^6 cfu/g. This indicates that the total bacterial contamination of Bali beef in slaughter house was considerably high and the possibility of bacterial contamination addition occurring during the sample preparation prior to and during the liquid smoke immersion. Similar condition occurred in the chicken breast meat which showed the highest total bacterial colonies.

The concentration of liquid smoke affected (P <0.08) the TPC values. There was a significant different between the concentration of 0% and 10%, but the concentration between 0% and 5% and between 5% and 10% did not differed. At a concentration of 10%, the total bacterial colonies decreased by 57.3% from untreated with liquid smoke (concentration of 0%) in which this explained that the liquid smoke at a concentration of 10% had sufficient potential to reduce the total number of colonies of bacteria on meat.

The duration of storage also had significant effect on the total number of bacterial colonies. However, storage periods of week 1 and week 2 and week 3 and between week 2 and week 3 did not differed. This indicated that the development of bacteria was intensified during storage at week 4 where the total bacterial colonies increased by 95.8% at week 1, 99.7% at week 2, and 81.3% at week 3, respectively. Regardless of the types of meat and level of liquid smoke concentration, liquid smoke immersion in fresh meat performed for 30 minutes at the level of 20% of the meat weight (w/w) during storage resulted in increased total bacterial colonies which were still high in weeks of storage ranging from 81.3% to 99.7%. An increased duration in liquid smoke immersion for above 30 minutes up to several hours allowed the liquid smoke to be dispersed and absorbed well in the meat; as a result, the growth of bacteria could be inhibited.

C. Water Holding Capacity Value of Meat (WHC)

Analysis of variance showed that the effects of the types of meat, concentration of liquid smoke, and storage time on WHC values were significant (P <0.01) (Table I). The WHC value of beef was markedly lower (11.35%) than that of the chicken breast meat, and then that of chicken thigh meat (7.30%). Meanwhile, the WHC value of chicken breast meat was not significantly different from that of chicken thigh meat. The lower WHC value of beef compared to chicken meat was probably due to the composition of chicken meat that containing higher proportion of white fiber than that of the beef, thus resulted in a quicker formation of rigor mortis and higher water holding capacity (WHC) as well [19]-[22].

The concentration of liquid smoke had significant (P <0.01) effect on WHC. Higher liquid smoke concentration reduced the WHC. However, there was no significant different between the concentrations of 5% and 10%. Thus, this is not in line with the previous studies in which an addition of liquid smoke concentration of 10% in Bali beef (*Longissimus dorsi*) could increase the WHC as the level of liquid smoke increased. It can be concluded that the use of liquid smoke to increase WHC on *Longissimus dorsi* muscle of Bali cattle ranging from 1.0% to 2.0% of the meat weight (w/w) [23]. This difference might be possibly caused by the level of liquid smoke used in this study which was quite high at 20% of the sample weight (w/w), and it was soaked for 30 minutes before storage. Compared with the previous studies, despite its low liquid smoke level, the liquid was left to be absorbed during storage.

Storage time had significant (P <0.01) effect on WHC of fresh meat, however there was no significant difference between the storage in week 2 and week 3 as well as in week 4 and also between week 3 to 4. The storage resulted in an increase in WHC; in which at week 4, WHC increased up to 9.61% from week 1.

This indicated the ability of the liquid smoke to increase the minimum WHC by 8.45% on week 2 of storage, and this was significantly useful in handling fresh meat as raw materials during the storage period before being processed. In general, WHC may decrease during storage if there is no additional extra material that serves to retain WHC.

The results showed that the addition of liquid smoke regardless of the concentration and type of meat could increase WHC during storage. An increased water holding capacity during meat storage which was added by liquid smoke indicated that liquid smoke had a role in loosening the myofibril fibers bond forming the empty spaces filled with water in semi-free form. Therefore, the water holding capacity of the meat increased [24].

D. Shear Force Value (SFV) of Raw Meat

Analysis of variance showed that the type of meat, concentration of liquid smoke, and storage time had significant (P <0.01) effects on SFV of raw Bali beef (*Longissimus dorsi*) (Table II).

Chicken breast meat had lower shear force values in comparison to the beef (13.24%) and chicken thigh (23.38%), indicated that raw chicken breast meat was tender than those for raw beef and chicken thigh meat. Meanwhile, shear force value of chicken breast meat was 23.38% lower than chicken thigh meat. The characteristics of the muscle structures on the three different types of meat, particularly the collagen content and structure of the connective tissue, cause the differences in tenderness [19].

Chicken thigh muscle contains more connective tissues (collagen) than the chicken breast muscle, thus resulting in less tenderness in the muscles of chicken thigh. Meanwhile, in *Longissimus dorsi* muscle of Bali cattle, although the content of collagen was quite low, most probably that different age between chicken and beef resulted beef had less tender than chicken breast.

The higher the concentration of liquid smoke reduced the SFV; although there was no significant difference between the absence of liquid smoke addition with a concentration of 5% as well as between 5% and 10%. This indicated that the addition of liquid smoke would increase the tenderness of raw meat at the concentration of 10%. The liquid smoke which was previously assumed to loosen the meat myofibrils fibers or cause a positive tissue damage on myofibrils fibers has, in fact, increased meat tenderness (the SFV decreases) [24].

As the meat storage duration became longer, the liquid smoke and shear force values were decreased, although there were no differences between week 2, 3 and 4, as well as between week 3 and 4. Similar to the discussion in the concentration on tenderness, the liquid smoke might increase the tenderness level as the storage time increased by neglecting the concentrations at different storage time.

E. Shear Force Value (SFV) of Cooked Meat

Analysis of variance showed that the types of meat, concentrations, and storage time had significant (P <0.01) effect on shear force values of cooked meat (Table II).

Cooked Bali beef (*Longissimus dorsi*) produced significantly higher SFV by 92% than that of the cooked chicken breast, and higher than cooked chicken thigh by 71.43%. In regards to raw meat, the SFV of beef ranked second after the chicken thigh meat; however, for cooked meat, Bali beef (*Longissimus dorsi*) was on the first place obtaining the highest value of shear force. This indicated that the muscle structure of *Longissimus dorsi,* particularly in Bali cattle, collagen at a temperature of 80^0C for 15 minutes of cooking, was unable to dissolve completely, and the similar situation also occurred in chicken breast and thigh meat.

TABLE II
SHEAR FORCE VALUE OF RAW AND COOKED MEAT, COOKING LOSS AND SIGNIFICANCE LEVEL

Treatments	SFRM (kg/cm²)	SFCM (kg/cm²)	CL (%)
Meat Types:	Sig: 0.01	Sig: 0.01	Sig: 0.01
- Beef	0.68^{a}	0.96^{a}	26.76^{a}
- Chicken Breast	0.59^{b}	0.50^{bc}	17.32^{bc}
- Chicken Thigh	0.77^{c}	0.56^{c}	20.67^{c}
Concentrations:	Sig: 0.01	Sig: 0.01	Sig: 0.01
- 0%	0.73^{x}	0.73^{x}	18.98^{x}
- 5%	0.69^{xy}	0.67^{xy}	21.27^{y}
- 10%	0.63^{y}	0.62^{y}	21.76^{y}
Storage time	Sig: 0.01	Sig: 0.01	Sig: 0.05
- 1 weeks	0.78^{a}	0.76^{a}	21.42^{a}
- 2 weeks	0.71^{ab}	0.72^{a}	20.20^{a}
- 3 weeks	0.63^{b}	0.60^{b}	21.43^{ab}
- 4 weeks	0.62^{b}	0.61^{b}	19.63^{c}

Description: Numbers with different superscripts in a column differ significantly (P <0.01). SFRM=Shear force of raw meat, SFCM=Shear force of cooked meat, CL=Cooking loss

Different range of ages between Bali beef and broilers could be as an explanation to investigate the condition. At the young age, the collagen structure in a state of thermo labile will easily dissolve if compared to Bali beef used in this study which had more thermo stable collagen structure [19].

Higher concentration of liquid smoke added resulted in lower the SFV of the cooked meat although there was no significant difference between those untreated with liquid smoke and those with a concentration of 5%, as well as between 5% and 10%. This is in line with what occurred in shear force of raw meat.

F. Cooking Loss

Analysis of variance showed that cooking loss was affected significantly by types of meat, concentrations of liquid smoke (P <0.01) and storage time (P <0.05) (Table II). The cooking loss of Bali beef was significantly (P <0.01) higher 54.50% than chicken meat and 29.46% than that of chicken thigh meat. While for chicken meat, no significant different was found between breast meat and thigh meat. This is in line with the lower water holding capacity on Bali beef compared with WHC on chicken breast and thigh (Table I). Lower WHC would produce high cooking loss due to inability of the meat to retain water bound in protein during cooking process. The chicken meat had lower cooking loss than that of Bali beef cattle meat as chicken meat contained white fiber proportion higher than that of beef meat, resulting in rigor mortis which was formed more quickly with its higher ability to bind water (WHC) [19]-[22] so that the cooking loss became lower during cooking process.

As the concentration of liquid smoke was increased the cooking loss would also increase if compared between smokeless liquid (concentration 0%) and liquid smoke concentrations of 5% and 10%. Nevertheless, there were no significant differences between the concentrations of liquid smoke at 5% and 10%. This is not in line with the previous studies where the increase of the level of liquid smoke concentration by 10% of Bali beef (*Longissimus dorsi*) caused WHC to increase due to the increasing level of liquid smoke, and the increasing WHC would generate a low cooking loss [23]. This difference might be caused by the high level of liquid smoke used in this study which was at 20% of the weight of the sample (w/w), and it was soaked for merely 30 minutes before storage. Compared with the previous studies, although using lower liquid smoke level, the meat was left to infuse during the storage.

The duration of storage had significant (P <0.05) in affecting the meat cooking loss, yet there were no differences among the storage periods of week 1 to week 2, and 3. Storage resulted in a decrease in cooking loss in which at week 4, cooking loss decreased by 8.36% of cooking loss at week 1.

IV. CONCLUSIONS

1. Types of meat resulted differences of TBA, WHC, SFV, and cooking loss values. The TBA of the chicken thigh meat was lower 30.91% than that of Bali beef, and the TBA chicken breast meat was higher 22.54% than that Bali beef. Meanwhile, the TBA of chicken thigh meat was lower 46.48% than that of chicken breast meat. The total bacterial colonies were likely similar among all three types of meat. WHC of Bali beef was lower (11.35%) than that of chicken breast meat and even lower (7.30%) than chicken thigh meat. The SFV of chicken breast meat was significantly lower 13.24% than that of Bali beef and 23.38% than that of chicken thigh meat, respectively. Meanwhile, the SFV of chicken breast meat was lower 23.38% than that of the chicken thigh meat. The cooking loss of Bali beef was higher 54.50% than that of chicken breast meat, and higher 29.46% than that of the chicken thigh meat.
2. When the concentration of liquid smoke becomes higher, the TBA will directly decline, reaching at 41.67% at a concentration of 10% if compared with smokeless liquid (with concentration of 0%), and the total bacterial colonies decrease 57.3% at a concentration of 10% of smokeless liquid (concentration of 0%); similarly, WHC and SFV also decreased.
3. The longer storage time resulting higher WHC reaching at 9.61% at week 4 from week 1. Moreover, the SFV was decreased; cooking loss was also decreased 8.36% at week 4 from week 1, while the total bacterial colonies increased ranging from 81.3% to 99.7%.
4. Liquid smoke can be used as a natural preservative and considerably environmentally friendly on beef and chicken with a concentration of 10%.

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