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Substitution of Phosphate with Liquid Smoke as a Binder on the Quality of Chicken Nugget

E. Abustam, M. Yusuf, M. I. Said

***Abstract*—** One of functional properties of the meat is decrease of water holding capacity (WHC) during rigor mortis. At the time of pre-rigor, WHC is higher than post-rigor. The decline of WHC has implication to the other functional properties such as decreased cooking lost and yields resulting in lower elasticity and compactness of processed meat product. In many cases, the addition of phosphate in the meat will increase the functional properties of the meat such as WHC. Furthermore, liquid smoke has also been known in increasing the WHC of fresh meat. For food safety reasons, liquid smoke in the present study was used as a substitute to phosphate in production of chicken nuggets. This study aimed to know the effect of substitution of phosphate with liquid smoke on the quality of nuggets made from post-rigor chicken thigh and breast. The study was arranged using completely randomized design of factorial pattern 2x3 with three replications. Factor 1 was thigh and breast parts of the chicken, and factor 2 was different levels of liquid smoke in substitution to phosphate (0%, 50%, and 100%). The thigh and breast post-rigor broiler aged 40 days were used as the main raw materials in making nuggets. Auxiliary materials instead of meat were phosphate, liquid smoke at concentration of 10%, tapioca flour, salt, eggs and ice. Variables measured were flexibility, shear force value, cooking loss, elasticity level, and preferences. The results of this study showed that the substitution of phosphate with 100% liquid smoke resulting high quality nuggets. Likewise, the breast part of the meat showed higher quality nuggets than thigh part. This is indicated by high elasticity, low shear force value, low cooking loss, and a high level of preference of the nuggets. It can be concluded that liquid smoke can be used as a binder in making nuggets of chicken post-rigor.

***Keywords*—** Liquid smoke, nugget quality, phosphate, post-rigor.

I. Introduction

PHENOMENON of decreasing functional properties of the meat especially its WHC along with-post rigor time requires an addition of binder in processing the meat to be a pasta product like nugget. The addition of binder in processing meat to produce nugget is intended to have better qualities that being compact, solid and chewy. The most frequently used binder in processing meat products is phosphate in the form of sodium tri poly phosphates (STPP), borax or formalin. Borax and formalin are chemicals hazardous for consumer health, while STTP, although not hazardous, its safety as non-meat ingredient is still questioned by common people.

Improvement of functional properties of meat products in particular water holding capacity is done through the addition of non-meat ingredients, such as the addition of sodium tripolyphospates [1], [2], sodium diphosphate [3], [4], or by using pre-rigor meat with high water binding capacity [5].

E. Abustam, M. Yusuf, and M.I. Said are with the Hasanuddin University, Makassar, Indonesia (phone: 08124207086; e-mail: effendiabu@hotmail.com).

Recently, several studies were conducted to know tmoke as a binder on meat product. In making the beef meatballs, addition of liquid smoke up to t up to t up to t up to t up to the level of 1% of meat weight (w/w) produces meatballs with high quality and quantity of yield [6]-[8]. Other studies conducted by [7]-[9] showed that the quality of meatballs made from *Longissimus dorsi* muscle was shown much better than that made from *Semitendinosus* muscle and *Pectoralis profundus* muscle. The higher level of addition of liquid smoke in making meatballs results in higher quality of meatballs. At the level of 0.75%, tenderness increased by 22.47%, cooking loss decreased by 33.89%, flexibility increased by 22.68%, sensory chewiness increased by 25%, and panelist's level of acceptability increased by 14.06%. Application of liquid smoke on fresh meat has also been shown by [10]-[12].

Liquid smoke is the result of condensation of wood or coconut shell pyrolysis after heating at the temperature of 400-600 °C in a tube or drum. This liquid smoke contains more than 400 chemical compounds such as phenol (4.13%), carbonyl (11.3%) and acid (10.2%) [13], [14]. The chemical compounds in liquid smoke can function as preservatives and emulsifiers [15]. Furthermore, in liquid smoke, some types of acid have also been found to function as gums, i.e. materials of thickeners, emulsion stabilizers and gel formers that are dissolved in water [15]. Utilization of liquid smoke as antioxidant also affects the increase of broiler meat tenderness [16].

In this research, the addition of STTP 0.3% of broiler nugget dough was substituted by the addition of liquid smoke up to 100% (without STTP) [1]. The main materials used were broiler meat from post-rigor thigh and breast.

This research aimed to find out the quality and quantity of broiler nugget yield after the substitution of STTP by liquid smoke.

II. Materials and Method

A. Materials

The materials used were broiler meat from post-rigor thigh and breast of 6 chickens aged 40 days, liquid smoke, ice, tapioca flour, STPP, salt, spices, breadcrumbs, eggs, distilled water, and frying oil.

B. Methods

The study was conducted by using completely randomized design of factorial pattern 2 x 3 where factor 1 was different part of broiler meat (thigh and breast) and factor 2 was the level of substitution of phosphate with liquid smoke 10%

(phosphate 0.3 % + liquid smoke 0%, phosphate 0.15% + liquid smoke 0.15%, and phosphate 0% + liquid smoke 0.3% of meat weight) with 3 replications.

Parameters observed were nugget flexibility, nugget shear force (NSF), cooking loss, nugget elasticity, and acceptability/hedonic test.

C. Preparing Nugget

Process of grinding broiler meat from post-rigor thigh and breast was done separately by using food processor. In order to get a lot of extraction of myosin protein, broiler meat, salt, and some ice are ground first. Phosphate and liquid smoke of formulated weight based on different treatment were added into each dough that was made in the first grinding together with tapioca flour, spices and remaining ice, and it was then grounded until the dough became really homogenous. After the dough was homogenous, it was then weighed to find out the initial weight of each dough (dough of thigh and dough of breast). Dough was moved from food processor to a tray previously coated with plastic to prevent the dough from sticking and it was then cast into a round shape similar to meatball round shape, and was then cooked at temperature 80 ^{o}C for 20 minutes. Round shape was intended to enable nugget flexibility to be measured as an indicator of nugget elasticity level. After cooking, the nugget was re-weighed to find out cooking loss. Materials used for preparing nuggets are shown in Table I.

TABLE I
MATERIALS FOR PREPARING NUGGETS

No.	Type of Materials	Total (%)
1.	Broiler meat	60
2.	Ice	14
3.	Tapioca flour	13
4.	Phosphate and Liquid Smoke*	0.3
5.	Salt*	1.5
6.	Spices**	1.2
7.	Breadcrumbs**	10

*) Based on meat weight
**) Based on dough weight

D. Measurement of Nugget Flexibility

Flexibility is one of the techniques to know the bouncing force of nugget when dropped on a flat surface from a certain height. The higher the bouncing force, the better the nugget quality (chewiness). Measurement of nugget flexibility was done by dropping five different nuggets from the height of 45 cm in glass beaker. Determination of flexibility score was done by dividing the difference between the highest flexibility and the lowest flexibility by four to get an interval between scores. Score 1 indicated poor flexibility and score 4 indicated the best flexibility [6].

E. Measurement of NSF

To find out nugget tenderness, a measurement was done by using Creuzot Dumont (CD) shear force. Nugget sample was made cylinder with a length of 1 cm and a diameter of 0.5 inch, placed in the hole of CD shear force to shear the sample by using a blade with a thickness of 1 mm. The larger the load to shear a nugget sample the tougher the nugget. Shear force value of nugget was stated in kg/cm^2 [6], [17].

F. Measurement of Cooking Loss (CL)

CL is weight loss or sample weight loss during the cooking. CL is determined with [18].

$$CL = \{(DWBC - WAC) / (WBC)\} \times 100\% \quad (1)$$

where, DWBC = Dough weight before cooking; WAC = Weight after cooking.

G. Organoleptic Test (Elasticity Score)

Judgment on organoleptic/chewiness of nugget was done by 10 panelists having been accustomed to doing the organoleptic test. The range of judgment scores of chewiness was 1-6, where: 1 (Really not chewy), 2 (Not chewy), 3 (Rather not chewy), 4 (Fairly chewy), 5 (Chewy), and 6 (Really chewy) [6].

H. Hedonic Test

Panelist's acceptability or hedonic level in nugget organoleptic judgment is one of the tests considered in determining the quality of nugget. This test is also called hedonic test. The range of scores used was 1-7, i.e.: 1). Really unacceptable; 2). Unacceptable; 3). Rather unacceptable; 4). Neutral; 5). Fairly acceptable; 6). Acceptable; 7). Really acceptable [6].

I. Data Analysis

Data were calculated using analysis of variance of factorial pattern to find out the effects of treatment to both factors on nugget flexibility, NSF, CL, chewiness, and acceptability (hedonic) level with the help of SPSS program (SPSS 16, SPSS Ltd., West Street Woking, Surrey, UK). If significant effect was found, then it was continued with the least significant difference test [19].

III. Results and Discussion

A. Nugget Flexibility

1) Effects of Meat Part on the Score of Nugget Flexibility in Post Rigor Condition

Table II shows the average scores of nugget flexibility ranging between 2.10 and 2.67 (average) at different levels of substitution of phosphate with liquid smoke and 2.13-2.44 (average) on different parts of meat (Table III).

Analysis of variance showed that meat part had significant ($P<0.01$) effect on the score of nugget flexibility in post rigor condition where the score of breast part was 13.42% higher than that of thigh part. The higher score of nugget flexibility in post rigor breast part explained that liquid smoke had a very good ability to increase nugget flexibility in breast part as the result of increased functional properties of nugget related to the texture which was compact, solid and chewy. Breast meat part is the part having slower post rigor time (slower glicolitic activity) compared to thigh meat part and also its fat content is

lower than thigh meat part [20] which can explain why nugget flexibility of breast meat part is better in post-rigor condition.

TABLE II
NUGGET QUALITY BASED ON LEVEL OF ADDITION LIQUID SMOKE AND PHOSPHATE

Parameter	Level of Phosphate and Liquid Smoke Addition								
	0.30% + 0%			0.15% + 0.15%			0% + 0.30%		
	T	B	Mean	T	B	Mean	T	B	Mean
Flexibility*	**1.93**	**2.07**	**2.00^{a}**	**2.07**	**2.33**	**2.20^{ab}**	**2.40**	**2.93**	**2.67^{c}**
NSF (kg/cm^2)	**7.08**	**6.95**	**7.02^{a}**	**6.95**	**6.69**	**6.82^{b}**	**6.82**	**6.29**	**6.56^{c}**
CL (%)	**5.07**	**1.71**	**3.39^{a}**	**2.69**	**1.37**	**2.03^{b}**	**0.68**	**0.56**	**0.62^{c}**
Elasticity**	**3.93**	**3.93**	**3.93^{a}**	**4.20**	**4.20**	**4.20^{ab}**	**4.67**	**4.87**	**4.77^{c}**
Acceptability***	**3.93**	**3.83**	**3.88^{a}**	**4.47**	**4.07**	**4.27^{ab}**	**4.83**	**4.40**	**4.62^{b}**

Numbers with different superscript at the same row differ significantly (P<0.05 and P<0.01; T= Thigh, B= Breast. * Scores 1= poor, 2= average, 3= fair, 4= good; ** Scores 1 – 6: 1. Really not chewy, 4. Fairly chewy, 6. Really chewy; *** Scores 1 – 7: 1. Really not acceptable, 4. Neutral, 5. Fairly acceptable, 7. Really acceptable.

2) Effects of Level of Substitution of Phosphate with Liquid Smoke on the Score of Nugget Flexibility in Post-Rigor Condition

Analysis of variance showed that the level of substitution of phosphate with liquid smoke affected the score of broiler nugget flexibility significantly (P<0.01). The higher the level the addition of liquid smoke, the higher score of broiler nugget flexibility. Scores of nugget flexibility increased by 10% and 33.50% respectively at the levels of liquid smoke additions of 50% and 100%. This showed that in post rigor condition, level of addition of only liquid smoke (without phosphate) could play a significant role in increasing the functional properties of nugget product, especially nugget flexibility. The high water binding capacity of pre-rigor breast and thigh can be maintained and even improved on the final product after the addition of liquid smoke.

B. NSF

1) Effects of Meat Part on NSF in Post-Rigor Condition

Analysis of variance showed that meat part had significant (P<0.01) effect on NSF at post-rigor phase, where breast meat part was significantly more tender by 4.46% than thigh meat part. Higher collagen component in thigh muscle to support as the active muscle to support broiler body could explain why thigh muscle was tougher than breast meat. This supported the statement of [21] that thigh muscle contains more collagen than breast muscle. The diameter of the small collagen fibers in the thigh causes the amount of collagen to increase. In addition, red muscle fibers (thigh) are needed to support of standing and walking compared to white muscle fibers (breast) and therefore it has more collagen.

2) Effects of Different Levels of Substitution of Phosphate with Liquid Smoke on NSF in Post-Rigor Condition

Levels of substitution of phosphate with liquid smoke had significant (P<0.01) effect on NSF at post-rigor phase. The higher level of addition of liquid smoke resulted in the lower NSF. In the present study, different levels of substitution of phosphate with liquid smoke differed significantly (P<0.01) among treatments. This explained that the higher the level of addition of liquid smoke the lower the NSF and the nuggets became tender. The addition of liquid smoke at a level of 100% produces a nugget of 6.55% more tender than without the addition of liquid smoke. The ability of liquid smoke to increase water binding capacity at pre-rigor phase and post-rigor phase caused the increase of the tenderness of fresh meat products and processed meat such as nugget and meatball products. This is in line with the results of previous studies on meatball products [6], [7] and on fresh meat [10]-[12].

TABLE III
NUGGET QUALITY BASED ON BROILER MEAT PART AND LEVEL OF ADDITION LIQUID SMOKE

Parameter	Level of Liquid Smoke Addition (%)							
	Thigh				Breast			
	0	0.15	0.30	Mean	0	0.15	0.30	Mean
Flexibility*	1.93	2.07	2.40	2.13^{a}	2.07	2.33	2.93	2.44^{b}
NSF (kg/cm^2)	7.08	6.95	6.82	6.95^{a}	6.95	6.69	6.29	6.64^{b}
CL (%)	5.07	2.69	0.68	2.81^{a}	1.71	1.37	0.56	1.21^{b}
Elasticity**	3.93	4.20	4.67	4.27	3.93	4.20	4.87	4.33
Acceptability ***	3.93	4.47	4.83	4.41	3.83	4.07	4.40	4.10

Numbers with different superscript at the same row differed significantly (P<0.05 and P<0.01; * Scores 1= poor, 2= average, 3= fair, 4= good; ** Scores 1 – 6: 1. Really not chewy, 4. Fairly chewy, 6. Really chewy; *** Scores 1 – 7: 1. Really not acceptable, 4. Neutral, 5. Fairly acceptable, 7. Really acceptable.

C. CL of Nugget

CL is one of the parameters of the quantity and quality of the meat. Meat with high CL indicates that the meat is less capable of maintaining its water binding capacity during the processing period, and as a result the yield becomes low. In processing meat, it is expected that the yield is high or CL is low. Similarly, on nugget, it is expected that the meat used in formulation will produce high yield post processing. Low CL (high yield) is closely related to nugget quality. The higher the CL was, possibly the lower the nugget nutrition quality.

1) Effects of Meat Part on Nugget CL at Post-Rigor Phase

Table III shows CL (%) of broiler nugget based on meat part and different levels of substitution of phosphate with liquid smoke at post-rigor phase.

Analysis of variance showed that CL of nugget at post-rigor phase was affected significantly (P<0.01) by the meat part, where CL on breast muscle was significantly (P<0.01) lower 56.94% than CL on thigh muscle at post-rigor phase. The high

nugget CL on thigh muscle could be explained by low water binding capacity on this muscle as the muscle tended to be tougher due to higher content of collagen; furthermore, thigh muscle also contains higher content of fat [21]; therefore, at the time of post-processing, the nugget suffered from higher CL.

2) Effects of Different Levels of Substitution of Phosphate with Liquid Smoke on Nugget CL at Post-Rigor Phase

Analysis of variance showed that level of substitution of phosphate with liquid smoke had significant ($P<0.01$) effect on nugget CL at post-rigor phase. The higher addition of liquid smoke resulted in lower the CL, where there was a significant ($P<0.01$) difference among treatments. At the level of addition of 100% liquid smoke (without phosphate), the nugget CL was significantly ($P<0.01$) lower 81.71% than the CL at the level of addition of 100% phosphate (without liquid smoke) at post-rigor phase. This showed the ability of liquid smoke to maintain and increase water binding capacity at post-rigor phase, consequently, CL decreased after processing. Previous studies showed CL decreased as level of liquid smoke increased in making meatballs [6], [9], [10] and the increase of water binding capacity with the increased level of liquid smoke on fresh meat [11], [22].

3) Interaction between Level of Substitution of Phosphate with Liquid Smoke and Meat Part on Nugget CL at Post-Rigor Phase

Analysis of variance showed that there was a significant ($P<0.01$) interaction between level of substitution of phosphate with liquid smoke and meat part on nugget CL at post-rigor phase. This means that decreased CL at significant ($P<0.01$) level, and the increase of level of liquid smoke did not in line with the decrease of nugget CL among the meat parts. At the level of addition of phosphate and liquid smoke (0% + 0.30%) the decrease of CL was very low on thigh muscle in comparison to those two other treatments at different levels of addition of phosphate and liquid smoke.

D.Organoleptic Test: Nugget Elasticity

1) Effects of Meat Part on Nugget Elasticity at Post-Rigor Phase

Table III shows score of nugget chewiness based on level of substitution of phosphate with liquid smoke on meat part at post-rigor phase. Analysis of variance showed that meat part did not significantly affect the score of nugget chewiness. This indicated that by ignoring the level of addition of phosphate and liquid smoke, the scores of nugget elasticity among thigh meat part and breast meat part were approximately similar.

2) Effects of Different Levels of Substitution of Phosphate with Liquid Smoke on the Score of Nugget Elasticity at Post-Rigor Phase

Analysis of variance showed that level of substitution of phosphate and liquid smoke had significant ($P<0.01$) effect on the score of nugget chewiness at post-rigor phase. There were significant ($P<0.01$) differences between treatment 1 and treatment 3 as well as between treatments 2 and 3. However, there was no significant difference between treatments 1 and 2. The higher level of substitution of phosphate with liquid smoke resulted higher the score of nugget chewiness. At the level of addition of liquid smoke only (combination of phosphate 0% and liquid smoke 0.30%) score of nugget elasticity was significantly ($P<0.01$) higher 21.37% than the score when there was no addition of liquid smoke (combination of phosphate 0.30% and liquid smoke 0%). This indicated that the addition of liquid smoke on post-rigor meat increased water binding capacity of meat implicating on increased score of nugget elasticity. Previous studies showed increased score of meatball chewiness along with the increased the level of liquid smoke [6], [9].

E. Hedonic Test of Nugget

1) Effects of Meat Part on the Level of Acceptability of Post-Rigor Nugget

Table II shows the score of nugget acceptability based on the level of substitution of phosphate with liquid smoke on meat part at post-rigor phase.

Analysis of variance showed that meat part did not affect the level of nugget acceptability although thigh part had a little higher score of acceptability than did breast part. The more intensive fattening on thigh makes the thigh meat juicier and give more delicious flavor could explain this result. As [21] stated, that thigh meat contained more fat than did breast, although this difference was quite small (< 3%). This slightly higher fat content could improve the perception of juiciness.

2) Effects of Substitution of Phosphate with Liquid Smoke on the Score of Nugget Acceptability at Post-Rigor Phase

Analysis of variance showed that the level of substitution of phosphate with liquid smoke had significant ($P<0.01$) effect on the score of nugget acceptability at post-rigor phase. There was a significant ($P<0.01$) difference between treatments 1 and 3. The higher level of addition of liquid smoke resulted higher score of nugget acceptability. At the level of addition of liquid smoke only (combination of phosphate 0% + liquid smoke 0.30%) score of nugget acceptability was 19.07% and significantly ($P<0.01$) higher than the score when there was no addition of liquid smoke (combination of phosphate 0.30% + liquid smoke 0%) at post-rigor phase. The ability of liquid smoke to increase nugget flexibility and tenderness and to decrease nugget CL caused the score of acceptability increased at post-rigor phase.

IV. Conclusions

1. Substitution of phosphate with liquid smoke up to 0.30% (without phosphate) on post-rigor broiler meat in making broiler nugget produced high flexibility, low NSF, low CL, high nugget elasticity and level of acceptability.
2. Post-rigor breast meat produced the best quality of nugget indicated by high flexibility, low NSF, and low CL.
3. Liquid smoke could be utilized as a binder to increase the functional properties of protein especially water binding capacity of post rigor meat in making nugget.

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Effendi Abustam did his PhD in Food Science from the University of Blaise Pascal Clermont Ferrand France in 1987, MSc in Food Science from the University of Blaise Pascal Clermont Ferrand in 1984 and M.Sc in Animal Production from Institute National Agronomy Paris – Grignon France in 1982 and Engineer of Animal Husbandry from Hasanuddin University, Makassar Indonesia in 1977. Professor in Technology of Animal Products from Hasanuddin University, Makassar Indonesia in 1997. He is currently serving in the Department of Technology of Animal Products, Faculty of Animal Sciences Hasanuddin University Makassar. He was the PI of National Strategic Research Program funded project by DIT. LITABMAS DIKTI in 2012 and 2013 entitled Increased Durability and Quality of Meat and Meat Products Processed through the Addition of Liquid Smoke as The Natural Environmentally Friendly Preservatives.

Muhammad Yusuf did his PhD in Animal Reproduction from Yamaguchi University, United Graduate School of Veterinary Science Yamaguchi Japan in 2010, Sarjana Peternakan (S1) from Faculty of Animal Sciences Hasanuddin University, Makassar Indonesia in 1994. He is currently serving in Department of Animal Production Faculty of Animal Sciences Hasanuddin University Makassar. He was CO-I of National Strategic Research Program funded project by DIT. LITABMAS DIKTI in 2012 and 2013 entitled Increased Durability and Quality of Meat and Meat Products Processed through the Addition of Liquid Smoke as The Natural Environmentally Friendly Preservatives.

Muhammad Irfan Said did his PhD Technology of Animal Products from Faculty of Animal Sciences Gajah Mada University, Yogyakarta Indonesia in 2011, M.Sc in Technology of Animal Products from Faculty of Animal Sciences Gajah Mada University, Yogyakarta Indonesia in 2000, Sarjana Peternakan (S1) in Animal Feed and Nutrition from Faculty of Animal Sciences Hasanuddin University, Makassar Indonesia in 1997. He is currently serving in Department of Technology of Animal Products. Faculty of Animal Sciences Hasanuddin University Makassar. He was CO-I of National Strategic Research Program funded project by DIT. LITABMAS DIKTI in 2012 and 2013 entitled Increased Durability and Quality of Meat and Meat Products Processed through the Addition of Liquid Smoke as The Natural Environmentally Friendly Preservatives.