EFFECT OF PHOSPHATE REPLACER ON PHYSICOCHEMICAL PROPERTIES OF BEEF

Ari Wibowo[1], Panumas Somjid[1], Worawan Panpipat[1], Siriporn Riebroy[2] and Manat Chaijan[1,*]
[1]Department of Agro-Industry, School of Agricultural Technology, Walailak University, Nakhon Si Thammarat, 80160, Thailand
[2]Food and Nutrition Program, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand
*Corresponding author email: cmanat@wu.ac.th

Abstract – The effect of phosphate replacer (3% MSG + 0.75% NaOH + 2.5% NaCl) on physicochemical properties of tumbled beef meat was evaluated in comparison with 3% mixed phosphate or control (without tumbling). The results showed that the pH increased with the decrease in hardness after tumbling with both phosphate and phosphate replacer ($p<0.05$). For the cooked meat, phosphate and phosphate replacer showed significantly lower expressible drip, suggesting the higher water retention of meat treated with those solutions compared to control Although control showed the highest surface redness index ($p<0.05$) but, for the relative metmyoglobin content of exudates from raw meats, phosphate replacer treated sample showed the lowest content ($p<0.05$). The results suggested that phosphate replacer may prevent the oxidation of interior myoglobin but not for the surface one. Therefore, 3% MSG + 0.75% NaOH + 2.5% NaCl can be applied as a novel phosphate replacer in raw and cooked meats due to its ability to improve water holding capacity, tenderness and oxidative stability of interior myoglobin.

Key Words – phosphate replacer, water holding capacity, color, beef

I. INTRODUCTION

Eating habit has changed in decades, which is, the consumers more concerned to consume healthy meat and meat products to enhance the quality of life and longevity. Due to the consumer demands on healthy foods and increasing global competition, the meat product manufacturing sector attempts to embrace new processing technologies and new ingredient systems [1]. Thus, development of phosphate replacer becomes important in meat processing industry.

Phosphates have been used widely by meat processing industry due to their ability to retain water, decrease the shrinkage of myofibrils and hence reduce the degree of purge in processed meats [2]. Phosphates impart a number of functional properties in meat products. For instance, phosphates can activate proteins to increase hydration and water-binding capacity and can increase the binding properties of proteins to improve texture [2, 3]. Additionally, phosphates may function synergistically with other ingredients to prevent meat discoloration and rancidity through chelating of heavy-metal ions [4]. Thus, phosphates have a great role for the desired textural properties and partly affect the color and flavor of processed meats.

It has been reported that 3% MSG containing 0.75% NaOH and 2.5% NaCl (pH 11.5) can be used as an alternative phosphate replacer in seafood [5]. However, this novel phosphate replacer has not been applied in meat and its effect on physicochemical properties, especially water holding capacity and color, of meat has not been reported. Therefore, this study aimed to evaluate the effect of such phosphate replacer on physicochemical properties of beef meat subjected to tumbling and cooking.

II. MATERIALS AND METHODS

Collection and preparation of beef meat

Primary knuckles beef meat (6 kg) were purchased from local market in Thasala, Nakhon Si Thammarat, Thailand. The samples were transported in the insulated box containing ice using a ratio of meat and ice of 1:1 (w/w) to the Department of Agro-Industry, Walailak University within 30 minutes. Upon arrival, meat samples were diced (~3x3x3 cm^3) and randomly divided into three groups (2 kg each). The first group was designed as control (without tumbling) and the other two groups were tumbled with 250 ml of 3% blended phosphate (sodium tripolyphosphate + sodium pyrophosphate; 1:2 w/w) (pH 9.2)) and with 250 ml of phosphate replacer (3% MSG + 0.75% NaOH + 2.5% NaCl (pH 11.5)) for 30 min (10 min tumbling took after by 10 min rest and 10 min tumbling) utilizing a vacuum tumbler. Afterwards, all raw samples were stored in a chiller (5°C) for 2 h prior to analyses for pH, expressible moisture, hardness, color and metmyoglobin content. The color of raw meat was also determined after 24 h chilled storage in order to monitor the storage effect on color retention. For cooking procedure, samples were steamed until the core temperature reached 85°C. After cooling down, the cooked meat samples were subjected to analyses for pH, expressible moisture, hardness and color following the methods as described below.

Measurement of pH

The pH was determined using a slurry method in which 5 g of the meat sample was homogenized in 20 ml of deionzed water using a homogenizer at 13,600 rpm for 30 sec and the pH of homogenate was measured using a pH meter calibrated at pH 4.0 and 7.0 equipped with a pH electrode [6].

Expressible drip

Expressible drip was measured according to the method of Ng [7]. A sample with a thickness of 0.5 cm was weighed and placed between two pieces of Whatman filter paper No. 1 at the top and three pieces of the same type of filter paper at the bottom. The standard weight (5 kg) was placed on the top of the sample and maintained for 2 min. The sample was then removed and weighed again. Expressible drip was calculated and expressed as percentage of sample weight.

Hardness measurement

Hardness of meat samples were measured using the texture analyzer equipped with a spherical plunger (diameter 5 mm; depression speed 60 $mm.min^{-1}$) as described by Chaijan *et al*. [6].

Color measurement

Surface color analysis was performed by using a portable Hunterlab Miniscan/EX instrument (10° standard observers, illuminant D65, Hunter Assoc. Laboratory; VA, USA). The instrument was calibrated to a standard white tile and a black glass. The tristimulus *L** (lightness), *a** (redness/greenness), and *b** (yellowness/blueness) measurement mode was used as it relates to the human eye response to color. The redness index (a*/b*) of sample was calculated as described by Chen *et al*. [8]

Measurement of metmyoglobin content

The analysis of metmyoglobin content of exudates from raw samples was performed as described by Chaijan *et al.* [6]. The exudates were subjected to absorbance measurement at 630 and 525 nm using a distilled water as blank. A high A_{630}/A_{525} ratio indicates a high relative proportion of metmyoglobin.

Statistical analysis

A completely randomized design (n = 3) was used in this study. All parameters studied were determined in triplicate. Data were subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan's multiple-range test. Statistical analysis was performed using the Statistical Package for Social Science (SPSS 8.0 for windows, SPSS Inc., Chicago, IL).

III. RESULTS AND DISCUSSION

pH, expressible drip and hardness

The pH of raw meat without tumbling was 5.57 and the pH increased significantly after tumbling with both phosphate and phosphate replacer ($p<0.05$; Table 1). The increase in pH of tumbled meats was due to the adsorption of phosphate and phosphate replacer, in which, both additives had an alkalinity characteristic, and can increase the pH value of meat. It has been reported that alkaline phosphates may leads to rise in pH inside the meat, whether in raw or cooked meat product [4]. Moreover, different individual phosphates show significantly different pH values [4]. For the phosphate replacer, the alkalinity was due to the present of MSG and NaOH. After cooking, the pH of all samples tended to increase. This was probably due to the formation of volatile base substance upon steaming which may responsible for the cooked meat or meaty flavor. Moreover, the pH of treatments with phosphate and phosphate replacer were still higher than control ($p<0.05$) (Table 1).

Table 1. pH, expressible drip and hardness of raw and cooked beef meat without and with tumbling with phosphate and phosphate replacer

Parameters	Control	Phosphate	Phosphate replacer
pH			
Raw meat	5.57±0.08a*	5.76±0.07b	5.80±0.03b
Cooked meat	5.72±007a	5.95±0.03b	5.82±0.03b
Expressible drip (%)			
Raw meat	12.80±4.39a	18.25±3.52a	18.87±0.71a
Cooked meat	24.15±5.58b	6.62±1.04a	5.48±1.40a
Hardness (N)			
Raw meat	31.03±1.24b	23.51±3.42a	25.43±3.69a
Cooked meat	18.04±5.75a	11.63±2.17a	19.13±5.07a

Values are given means±SD from triplicate determinations.
*Different letters in the same row indicate significant differences ($p<0.05$).

The water holding capacity (WHC) in meat has an important role whether in raw meat and cooked meat as meat products. It can affect the performance of the meat before cooking and juiciness on mastication [9]. Expressible drip can be used to determine the water holding capacity of meat and meat products [7]. The lower the expressible drip the higher the water holding capacity [7]. Lawrie *et al.* [9] pointed out that decrease of the *in vivo* water-holding capacity is manifested by exudation of fluid known as drip. From the results, no significantly differences between raw tumbled and non-tumbled meats ($p>0.05$) (Table. 1). After tumbling for 30 min and chilling for 2 h, the phosphate and phosphate solutions may not yet completely occupy in meat or the solutions did not working properly at the beginning, even the meat was tumbled by vacuum tumbler. For the cooked meat, phosphate and phosphate replacer showed significantly lower expressible drip, suggesting the higher water retention of meat treated with those solutions compared to control ($p<0.05$). Increasing of WHC in both cooked meat samples was probably due to the ability of solutions to enhance of ionic strength of meat, especially after thermal treatment. As stated by Fallis [11], salt or solution containing salt can improve the WHC of meat. Furthermore, the essential function of salt added in meat is to solubilize the functional myofibrillar proteins which mainly participate in water binding of meat [10].

For the hardness test (Table 1), it was noted that phosphate and phosphate replacer had an important role in tenderness of raw meat. Adding of phosphate or phosphate replacer can neutralize the cross-linkage between actin and myosin, formed during rigor mortis, and support dissociation of actomyosin complex into separate fibers again [4]. Moreover, those substances can increase the solubility of muscle proteins [4]. Such changes would decrease the hardness of meat definitely ($p<0.05$). When meat underwent cooking, the hardness of all samples decreased and the values were comparable among samples ($p>0.05$).

Surface redness index and metmyoglobin content

The surface redness index of raw and cooked beef meat without and with tumbling with phosphate and phosphate replacer is shown in Table 2. For the raw meat, control showed the highest redness index ($p<0.05$) and no difference in redness index between samples treated with phosphate and phosphate replacer was observed during 2 h chilled storage ($p>0.05$). The same trend was also found after storage for 24 h but the redness index decreased to some extent. After cooking, the redness index of all samples obviously decreased and finally reached the same content ($p>0.05$). The results suggested that both phosphate/phosphate replacer, tumbling process and thermal treatment can induce the oxidation of myoglobin, particularly at the surface of meat. Myoglobin plays the largest role in determining beef color in the raw and cooked state [2]. The process of cooking denatures myoglobin, which is responsible for the characteristic dull brown color of cooked meat products [2].

For the relative metmyoglobin content of exudates from raw meats with and without tumbling previously chilled for 2 h, it was noted that phosphate replacer treated sample showed the lowest metmyoglobin content, followed by phosphate treated sample and control, respectively ($p<0.05$) (Table. 2). The results suggested that phosphate replacer may prevent the oxidation of interior myoglobin but not for the surface one. The exposure of oxygen and light at the surface in the presence of phosphate and salt may facilitate the oxidation of myoglobin and hence discoloration of meat occurred. This result was in accordance with the redness index (Table 1) in which the control showed the highest value.

Table 2. Surface redness index of raw and cooked beef meat and metmyoglobin content of raw beef meat without and with tumbling with phosphate and phosphate replacer

Parameters	Control	Phosphate	Phosphates replacer
Redness index (a*/b*)			
Raw meat (2 h)	1.41±0.12b*	1.09±0.10a	1.15±0.08a
Raw meat (24 h)	1.24±0.06b	0.96±0.05a	1.07±0.11a
Cooked meat	0.35±0.07a	0.33±0.03a	0.35±0.06a
Relative metmyoglobin (A_{630}/A_{525})	0.48±0.01c	0.25±0.05b	0.12±0.02a

Value are given means±SD from triplicate determinations.
*Different Letters in the same row indicate significant differences ($p<0.05$).

IV. CONCLUSION

Phosphate replacer (3% MSG + 0.75% NaOH + 2.5% NaCl) can be utilized rather than typical blended phosphate in raw and cooked meat due to its ability to retain water holding capacity, enhance delicacy of meat and may prevent the oxidation of myoglobin.

ACKNOWLEDGEMENTS

This work was supported by Walailak University.

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