ANALYSIS OF KEY CHARACTERISTICS OF RAW MEAT AFFECTING THE PROPERTIES OF COOKED MEAT EMULSION BY PARTIAL LEAST SQUARE (PLS) REGRESSION

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Abstract – The key characteristics of raw meat from different pig breeds including Duroc (D), Large White (LW), Landrace (LR), Two-way cross (LR×LW) and Three-way cross (D×[LR×LW]) affecting the stability and textural characteristics of cooked meat emulsions were analyzed by using Partial Least Square (PLS) regression. Cooked meat emulsion from LW exhibited superior properties to other breeds as indicated by lower water and fat released as well as higher chewiness, gumminess, cohesiveness, resilience, springiness and hardness. The univariate analyzes of those selected properties indicated a significant correlation with higher contents of myofibrillar and sarcoplasmic proteins, smaller muscle fiber diameter and lower myofibril fragmentation of LW meat, as compared to other breeds. Therefore, properties of cooked pork emulsion were influenced by composition and structure of meat, which varied according to the pig breeds.

Key Words – Sausage, Meat product, Meat composition

I. INTRODUCTION

Cooked emulsified meat products or sausages are widely consumed around the world. Basically, emulsion-type sausages, e.g. frankfurters, are made from a mixture of finely chopped meat, fatty tissue, water, ice and additives. In general, meat proteins serve as the emulsifying agent in a meat emulsion. To form a stable meat emulsion, these proteins particularly myosin must surround the finely chopped fat particles before cooking, which important for fat emulsification, gelation and water-holding capacity of processed meats. In addition to meat protein, fat is also an essential component of formulated meat products, contributing to tenderness, juiciness and overall palatability [1]. Although pork has been often utilized for sausage production, the information regarding the effects of pig breeds on quality of cooked pork emulsion is scare. Therefore, the objective of this study was to investigate the quality of cooked pork emulsion in terms of emulsion stability and textural characteristics as influenced by the variation of muscle composition and structure among meats derived from different pig breeds using Partial Least Squares (PLS) regression.

II. MATERIALS AND METHODS

Ten (female) pigs from Duroc (D), Landrace (LR), Large White (LW), Two-way cross from LR and LW (LR×LW), and Three-way cross (D×[LR×LW]) with about 97−108 kg live weight were randomly selected from a commercial abattoir, Betagro Safety Meat Packing Co., Ltd. (BSM), Lopburi, Thailand. At 24 h post-mortem, the loin muscles were used to analyze proximate compositions, muscle protein compositions, muscle microstructure, myofibril fragmentation index (MFI) and pH of ground meat as well as quality of pork sausage [2]. For explanation or prediction of the obtained quality of cooked pork emulsion by the muscle composition and structure variables, the PLS regression [3] with PLS2 algorism of the Unscrambler version 9.8 software (Camo, Oslo, Norway) was carried out.

III. RESULTS AND DISCUSSION

Muscle composition, microstructure, pH of pork from different breeds

LW meat showed higher moisture content than D and LR×LW counterparts, whereas LR and D×[LR×LW] had intermediate values (Table 1). sarcoplasmic protein contents ($p<0.05$). LR meat had the highest level of non-protein nitrogen (NPN) constituents ($p<0.05$). A higher content of alkaline-soluble protein was observed in meats from LW, LR and LR×LW, compared with those from D and D×[LR×LW] ($p<0.05$). In contrast, meats from D and D×[LR×LW] contained higher amount of stromal proteins than those from LW, LR and LR×LW ($p<0.05$).

Table 1. Chemical compositions and characteristics of raw meats and pork emulsions among pig breeds

Parameters	D	LW	LR	LR×LW	D×[LR×LW]
Characteristics of raw meats					
Moisture (% wet basis)	$72.30 \pm 0.85^{b,†,‡}$	74.70 ± 0.28^{a}	73.90 ± 0.56^{a}	74.90 ± 0.28^{a}	74.30 ± 0.71^{a}
Protein (% wet basis)	23.90 ± 0.57^{a}	24.20 ± 0.42^{a}	24.00 ± 0.85^{a}	24.15 ± 0.07^{a}	22.95 ± 0.49^{a}
Fat (% wet basis)	3.54 ± 0.18^{a}	0.58 ± 0.00^{c}	0.25 ± 0.11^{d}	0.47 ± 0.04^{cd}	1.30 ± 0.01^{b}
Non-protein nitrogen (mg N/g meat)	2.47 ± 0.21^{d}	3.36 ± 0.20^{b}	4.11 ± 0.13^{a}	3.38 ± 0.12^{b}	2.99 ± 0.14^{c}
Sarcoplasmic protein (mg N/g meat)	13.12 ± 0.33^{b}	14.09 ± 0.12^{a}	13.55 ± 0.48^{ab}	13.69 ± 0.16^{ab}	13.17 ± 0.09^{b}
Myofibrillar protein (mg N/g meat)	16.91 ± 0.30^{b}	18.75 ± 0.08^{a}	16.47 ± 0.33^{b}	16.98 ± 0.45^{b}	17.04 ± 0.14^{b}
Alkaline-soluble protein (mg N/g meat)	0.32 ± 0.00^{c}	0.65 ± 0.04^{ab}	0.56 ± 0.01^{abc}	0.69 ± 0.21^{a}	0.43 ± 0.04^{bc}
Stromal protein (mg N/g meat)	0.62 ± 0.03^{a}	0.39 ± 0.02^{c}	0.40 ± 0.01^{c}	0.40 ± 0.02^{c}	0.47 ± 0.01^{b}
Fiber diameter (μm)	44.92 ± 0.93^{c}	43.05 ± 0.56^{c}	49.42 ± 0.56^{ab}	46.74 ± 0.88^{b}	51.17 ± 1.41^{a}
Sarcomere length (μm)	1.43 ± 0.01^{a}	1.44 ± 0.03^{a}	1.33 ± 0.06^{b}	1.41 ± 0.01^{ab}	1.43 ± 0.01^{a}
MFI	142.15 ± 0.64^{a}	121.24 ± 10.88^{b}	118.70 ± 0.81^{b}	121.70 ± 5.05^{b}	133.79 ± 7.66^{ab}
pH of ground meat	5.79 ± 0.02^{a}	5.64 ± 0.01^{bc}	5.58 ± 0.03^{d}	5.59 ± 0.00^{cd}	5.68 ± 0.03^{b}
Characteristics of meat emulsion					
$pH_{uncooked\ meat\ emulsion}$	6.03 ± 0.01^{a}	5.94 ± 0.02^{b}	5.93 ± 0.03^{b}	5.93 ± 0.01^{b}	5.96 ± 0.02^{b}
$pH_{cooked\ meat\ emulsion}$	6.22 ± 0.02^{a}	6.12 ± 0.02^{b}	6.12 ± 0.03^{b}	6.11 ± 0.01^{b}	6.14 ± 0.01^{b}
Total fluid released (%)	3.39 ± 0.25^{a}	1.63 ± 0.03^{c}	2.71 ± 0.02^{b}	2.40 ± 0.17^{b}	3.23 ± 0.06^{a}
Water released (%)	3.20 ± 0.24^{a}	1.54 ± 0.04^{c}	2.56 ± 0.03^{b}	2.27 ± 0.15^{b}	3.04 ± 0.05^{a}
Fat released (%)	0.19 ± 0.02^{a}	0.09 ± 0.00^{c}	0.15 ± 0.00^{b}	0.13 ± 0.02^{b}	0.18 ± 0.01^{a}
Hardness (N)	10.91 ± 1.16^{d}	19.75 ± 1.80^{a}	16.63 ± 2.06^{ab}	15.39 ± 0.32^{bc}	13.06 ± 0.04^{cd}
Fracturability (N)	0.19 ± 0.00^{a}	0.19 ± 0.00^{a}	0.19 ± 0.01^{a}	0.19 ± 0.00^{a}	0.19 ± 0.01^{a}
Adhesiveness (N.mm)	-0.41 ± 0.04^{a}	-0.37 ± 0.06^{a}	-0.34 ± 0.06^{a}	-0.53 ± 0.20^{a}	-0.49 ± 0.03^{a}
Springiness (ratio)	0.84 ± 0.01^{c}	0.90 ± 0.00^{a}	0.86 ± 0.00^{bc}	0.87 ± 0.01^{b}	0.85 ± 0.01^{bc}
Cohesiveness (ratio)	0.38 ± 0.02^{b}	0.49 ± 0.00^{a}	0.42 ± 0.02^{b}	0.42 ± 0.01^{b}	0.40 ± 0.01^{b}
Gumminess (N)	4.19 ± 0.73^{c}	9.77 ± 0.99^{a}	7.00 ± 1.18^{b}	6.46 ± 0.74^{b}	5.20 ± 0.15^{bc}
Chewiness (N)	3.53 ± 0.68^{c}	8.81 ± 0.93^{a}	6.05 ± 1.01^{b}	5.66 ± 0.12^{b}	4.45 ± 0.19^{bc}
Resilience (ratio)	0.21 ± 0.03^{b}	0.32 ± 0.01^{a}	0.25 ± 0.02^{b}	0.24 ± 0.01^{b}	0.22 ± 0.01^{b}

D: Duroc; LW: Large White; LR: Landrace; LR×LW: Two-way cross; D×[LR×LW]: Three-way cross.
† Values are given as means ± SD of each animal.
‡ Different superscripts in the same row indicate significant differences ($p<0.05$).

Meat from D had the highest IMF content ($p<0.05$), followed by those from D×[LR×LW], LW, LR×LW and LR, respectively. Although, there were no differences in protein content among meats, the variation in meat protein composition was observed (Table 1). Meat from LW had the highest myofibrillar and sarcoplasmic protein contents ($p<0.05$).

Regarding muscle structure, the fiber diameters of LR and D×[LR×LW] muscles were largest, followed by those of LR×LW muscles, whereas the smallest diameter of fiber was observed in D and LW muscles ($p<0.05$). The mean sarcomere lengths of LR muscle were slightly shorter ($p<0.05$). Additionally, the result of MFI or the index of extent of proteolysis indicated that meat from D had the highest MFI, whereas meats from LR and LR×LW showed the lowest MFI ($p<0.05$) (Table 1). This might be caused by the different proteolytic activity in different breeds. Finally, ground meat from D exhibited the highest pH, followed by those from D×[LR×LW], LW, LR×LW and LR, respectively ($p<0.05$) (Table 1).

Effect of pig breed on properties of pork emulsions

Uncooked and cooked pork emulsions made from D showed higher pH, compared to those from other porks ($p<0.05$) (Table 1). The highest emulsion stability, defined as the lowest percentage of total fluid released (TFR), water released (WR), and fat released (FR) after heat treatment, was found in meat emulsion made from LW, followed by LR or LR×LW. Emulsions made rom D and D×[LR×LW] exhibited the lowest emulsion stability ($p<0.05$) (Table 1). For textural characteristics, cooked pork emulsion made from LW showed the highest hardness, springiness, cohesiveness, gumminess, chewiness and resilience, followed by those made from LR, LR×LW, D×[LR×LW] and D, respectively ($p<0.05$) (Table 1). In contrast, fracturability and adhesiveness of cooked pork emulsion were not influenced by breeds ($p>0.05$).

Univariate analysis of stability and texture of cooked pork emulsion by PLS regression

To performing PLS regression, the qualities of cooked meat emulsion sausage in terms of emulsion stability (TFR, WR and FR) and selected textural characteristics including hardness, springiness, cohesiveness, gumminess, chewiness and resilience, based on their significant correlation with *X*-variables (data not shown), were set as dependent variables (*Y*-variables). Five categorical variables of breeds (D, LW, LR, LR×LW and D×[LR×LW] and 12 variables of raw meat pH, meat composition (moisture, protein and fat), protein composition (non-protein nitrogen, sarcoplasmic protein, myofibrillar protein, alkaline-soluble protein and stromal protein contents) and muscle structure (fiber diameter, sarcomere length and MFI) were set as explanatory variables (*X*-variables).

Based on univariate of emulsion stability, the estimated regression coefficients of explanatory variables for predicting WR, TFR and FR exhibited a similar pattern (Fig. 1a–1c). The main result showed that WR, TFR and FR of cooked meat emulsion made from LW were significantly positively related with the higher contents of myofibrillar protein, sarcoplasmic protein and alkaline-soluble protein and were significantly negatively related with fibre diameter, stromal protein content, MFI value and fat content.

Selected textural parameters of cooked pork emulsion are illustrated in Fig. 2a–2f. It was observed that these regression models tended to be similar and closely interrelated with those of emulsifying properties as previously discussed. In common, all textural attributes of cooked meat emulsion were related positively with the categorical variable of LW, the contents of myofibrillar and sarcoplasmic proteins were related negatively with MFI value.

For the overall summary, the superior in emulsifying and textural properties of cooked pork emulsion made from LW meat could be

(a)
(b)
(c)

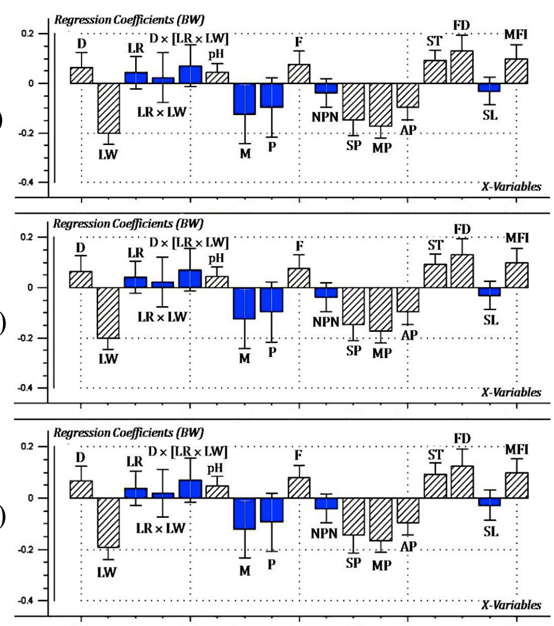

Figure 1. Regression coefficients of explanatory (X) variables for predicting variation in WR (a) and TFR (b) and FR (c). Significant explanatory (X) variables after applying Marten's uncertainty test were shown as striped columns.

Categorical variables were pig breeds. Explanatory (*X*) variables were pH of ground pork (pH). moisture (M), protein (P), fat (F), non-protein nitrogen (NPN), sarcoplasmic protein (SP), myofibrillar protein (MP), alkali-soluble protein (AP), stromal protein (ST), fibre diameter (FD), sarcomere length (SL) and

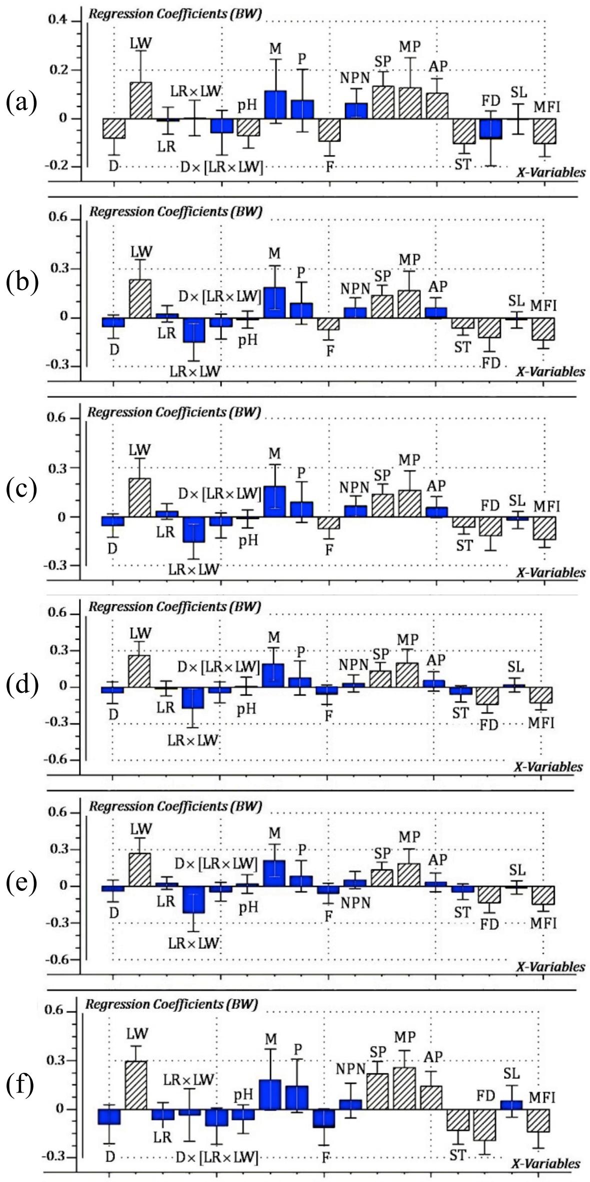

Figure 2. Regression coefficients of explanatory (*X*) variables for predicting variation in chewiness (a), gumminess (b), cohesiveness (c), resilience (d), springiness (e) and hardness (f). Significant explanatory (*X*) variables after applying Marten's uncertainty test are shown as striped column. The details of categorical and explanatory variables as same as defined in Fig. 1

attributed to 1) higher amounts of emulsifyling and gelling components, such as myofibrillar, sarcoplasmic, alkali-soluble proteins [4], 2) lower amounts of insoluble components, such as stromal protein and intramuscular fat, which might interfere or dilute the ability of the myofibrillar proteins to form a strong gel [4] , 3) smaller muscle fiber diameter supported the occurring of strong gel network [5] and 4) lower degradation of myofibril-associated proteins represented as the intact molecules for promoting protein functionality [6].

IV. CONCLUSION

The variation in stability and textural properties of cooked pork emulsion prepared from meats from various pig breeds could be explained by the differences in muscle composition and structure. Based on the univariate analysis, higher emulsion stability and textural properties of LW were influenced by higher amounts of myofibrillar and sarcoplasmic proteins, smaller fiber diameter and lower myofibril fragmentation at the time of use.

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