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Characterization of Nutritional Value for Twenty-one Pork Muscles

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ABSTRACT : A study was conducted to evaluate nutritional value for twenty-one pork muscles. Ten market-weight crossbred pigs (five gilts and five barrows) were used for evaluating proximate chemical composition, cholesterol, total iron, calorie and fatty acid contents. As preliminary analysis revealed no noticeable sex effect, pooled data from both sexes were used for the final analysis. *M. rectus femoris* had the highest moisture content, while *m. latissimus dorsi* was lowest in moisture content ($p<0.05$). Protein content was highest for *m. longissimus dorsi* and lowest for *m. supraspinatus* ($p<0.05$). The *tensor fasciae* and *latissimus dorsi* muscles contained the highest intramuscular fat ($p<0.05$), while *rectus femoris, adductor* and *vastus lateralis* were lowest in intramuscular fat content. When simple correlations between chemical values were computed for the pooled dataset from all muscles, intramuscular fat had significant ($p<0.05$) negative linear relationships with moisture ($r = -0.85$) and protein ($r = -0.51$) contents. Calorie levels were not significantly affected by fat content, while *rectus femoris* and *latissimus dorsi* muscles showed lowest and highest calorie contents, respectively ($p<0.05$). Polyunsaturated fatty acid content was highest ($p<0.05$) for both *m. adductor* and *m. rectus femoris*, while it was lowest for *m. longissimus dorsi*. Collectively, the current study identified a large amount of variation in nutritional characteristics between pork muscles, and the data can be used for the development of muscle-specific strategies to improve eating quality of meats and meat products. (**Key Words** : Pork, Muscles, Nutritional Characteristics)

INTRODUCTION

Pork belly and boston butt are the most demanding and popular cuts in Korean markets and consequently their retail prices are much higher than other cuts (KMTA, 2007). On the other hand, pork picnic shoulder and ham are often regarded as a lower value cuts and utilized for processed meat products. Most previous studies compared physical, chemical and textural characteristics between three to eight pork muscles (Briskey et al., 1960; Topel et al., 1966; Lin et al., 1985), while a limited number of studies reported the nutritional characteristics of pork cuts (Moss et al., 1983; Dorado et al., 1999). The previous studies focused on differences in pH, moisture content, fat content, myoglobin content and shear force, remaining nutritional values for individually specific pork muscles which are significant information for cut- and muscle-based sale and/or for the best use of individual muscle in processed products.

Recently, pork industry in Korea has made various efforts to identify the potential value of the prime cuts, especially the shoulder and ham that are well-suited for processed products in new product development. However, the general characteristics of industrial primal cuts are confounded by various individual muscles, and little information is known on the value of individual muscles. Therefore, there are great needs for determining quality and nutritional characteristics of individual muscles for the best use of individual muscles as meat and processed products. Given that current study was conducted to identify the proximate chemical composition, cholesterol content, total iron content, calorie content, and fatty acid composition for twenty-one pork muscles.

MATERIALS AND METHODS

Animal and sampling

A total of ten crossbred (five gilts and five barrows) were sampled from a market-weighted industrial population (carcass weight: 86.00±5.68 kg), and slaughtered at a commercial abattoir. Pigs were fed at a commercial diet

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Table 1. The average cold carcass weight, backfat thickness and retail lean meat from different pigs with their sex and number (Mean±standard deviation)

Sex	Number	Carcass weight (kg)	Backfat thickness (mm)	Retail lean meat (kg)
Barrow	5	88.20±5.63	24.80±2.39	56.24±2.62
Gilt	5	83.80±5.36	21.40±4.45	54.41±2.90
Total	10	86.00±5.68	23.10±3.81	55.32±2.78

under an industrial environment, and transported approximately 2 h from farm to the slaughter house before being slaughtered after approximately a 4-h resting with free access to water. Carcasses were chilled at 0°C for 24 h and were transported to the National Livestock Research Institute (NLRI) and kept at 2°C for further 3 days. Carcass characteristics are tabulated in Table 1. At 4 days postmortem, twenty one muscles were dissected from right hand side shoulder (*m. infraspinatus* (379.00±50.76 g), *pectoralis profundi* (tube) (293.30±32.46 g), *pectoralis profundi* (Fan) (504.30±140.12 g), *brachiocephalicus* (191.80±32.11 g), *latissimus dorsi* (234.00±88.39 g), *subscapularis* (144.90±26.20 g), *supraspinatus* (420.50± 28.31 g), *triceps brachii* (794.40±54.32 g)), ham (*m. adductor* (344.60±35.45 g), *biceps femoris* (1,449.40±178.83 g), *gastrocneminus* (903.10±173.36 g), *gluteus medius* (894.30±136.16 g), *gluteus superrificialis* (245.60±66.98 g), *gracilis* (287.50±20.59 g), *rectus femoris* (456.20±76.72 g), *semimembranosus* (1,154.30±138.71 g), *semitendinosus* (493.00±34.38 g), *vastus intermedius* (302.30±29.70 g), *tensor fasciae latae* (213.20±29.72 g), *vastus lateralis* (369.30±40.48 g)) and loin (*m. longissimus dorsi*). Knife removable subcutaneous fat was trimmed off, and homogenized by using a grinder (MN-22S, Hankook Fujee Industries Co. Korea). The ground pork was portioned for objective measurements, vacuum packaged in barrier bags (polyethylene+nylon, 20×29 cm), and stored at -40°C until analysis.

Determination of nutritional value

Moisture, protein, fat and ash contents were measured in accordance with the methods reported by AOAC (1990). Cholesterol content was determined using a previous method (Naeemi et al., 1995) with a minor modification. Briefly, one gram (±0.01 g) of the frozen was spiked with 0.5 ml (5α-cholestane stock solution, 1 mg/0.5 ml) internal standard, and added to 5 ml saturated methanolic KOH in a 35 ml screw-capped vial. The vial was capped and then heated for 30 min at 80°C. After cooling at room temperature, 5 ml cyclohexane was added to and then shaken for 1 min. An aliquot (1 μl) of the cyclohexane layer was injected into the Gas Chromatography (Agilent Model 6390, USA). The operating conditions of Gas Chromatography: column, fused silica capillary column (30×0.32 mm id) coated with SE-30 with film thickness of 0.25 (HP-5); carrier gas, nitrogen; oven temperature, 180 to 280°C, 20°C/min, hold at 280°C for 10 min; injector, splitter, 20 ml/min; temperature, 290°C; detector, flame ioniztion detector at 300°C. Cholesterol concentrations were determined by means of the internal standard and calibration curve.

Total iron content was determined by Matilainen and Tummavuori (1996). Briefly, 20 g of frozen sample was weighed into a ceramic crucible, and laid in ashes in a muffle furnace (Kukje trading corp., Korea) at 600°C for 4 days. After cooling at room temperature, samples were further digested with 50% HCl overnight. Digested samples were diluted with distilled-deionized water up to 100 ml. Total iron content was detected by an inductively coupled Plasma Atomic Emission Spectroscopy (SpectroFlame, Spectro analytical Instruments, Germany) at 259.94 nm, and quantified with a standard curve using 0.5, 1, 2, 4, and 8 ppmn of iron.

Calorie contents were analyzed using Calorie meter (1261, Parr instrument, USA) and expressed as cal/g sample (AOAC, 1995). Total lipids were extracted using chloroform-methanol (2:1, v/v) according to the procedure of Folch et al. (1957). An aliquot of total lipid extract was methylated as described by Morrison and Smith (1964). Fatty acid methyl esters were analyzed by a gas chomatograph (Varian 3,600) fitted with a fused silica capillary column, omegawax 205 (30 m×0.32 mm ID, 0.25 μm film thickness). The injection port was at 250°C and the detector was maintained at 300°C. Results were expressed as percentages of the total fatty acid (saturated, unsaturated, mono-unsaturated, and poly-unsaturated fatty acid contents) detected based on the total peak area (Cho et al., 2005). For all objective measurements above an average of triplicates were used for each sample.

Statistical analysis

As there was no sex effect, pooled data were analyzed using the General Linear Models (GLM) of the Statistical Analysis System (SAS, 1998). Significant differences among muscles were analyzed by Duncan's Multiple Range test at $p<0.05$.

RESULTS AND DISCUSSION

At the wake of growing concerns on health problems related to meats and meat products, identification of nutritional values for individual pork cuts become a

Table 2. Percentage of moisture, protein, fat and ash contents for twenty-one pork muscles

Muscles	Moisture	Protein	Fat	Ash
Infraspanatus	74.82^{cdef}	18.78^{jkl}	4.97^{bcd}	0.94^{bcdef}
Pectoralis profundi (tube)	73.89^{fgh}	19.80^{fghi}	5.07^{bcd}	0.96^{bcdef}
Pectoralis profundi (fan)	74.24^{efg}	20.11^{defgh}	4.40^{cdef}	0.97^{bcdef}
Brachiocephalicus	73.48^{gh}	19.34^{ijk}	6.05^{ab}	0.92^{cdef}
Latissimus dorsi	72.2^{il}	19.63^{ghi}	6.92^{a}	0.94^{bcdef}
Subscapularis	75.02^{cdef}	20.28^{cdefg}	3.37^{efg}	0.96^{bcdef}
Supraspinatus	74.76^{def}	18.51^{l}	5.35^{bc}	0.93^{bcdef}
Triceps brachii	75.34^{bcde}	19.98^{efghi}	3.44^{efg}	1.00^{abcd}
Adductor	76.11^{abc}	21.25^{ab}	1.67^{i}	1.05^{a}
Biceps femoris	74.90^{cdef}	19.81^{fghi}	4.43^{cdef}	0.96^{bcdef}
Gastrocneminus	74.80^{cdef}	19.58^{ghi}	4.82^{cd}	0.90^{ef}
Gluteus medius	75.31^{cde}	20.76^{bcd}	3.22^{fg}	1.01^{ab}
Gluteus superrificialis	73.95^{fgh}	20.47^{cdef}	4.58^{cde}	1.00^{abc}
Gracilis	75.88^{abcd}	19.61^{ghi}	3.79^{defg}	0.91^{def}
Rectus femoris	76.82^{a}	20.56^{bcde}	1.54^{i}	1.01^{ab}
Semimembranosus	75.48^{bcde}	20.89^{bc}	3.07^{gh}	0.98^{abcde}
Semitendinosus	74.31^{efg}	18.80^{jkl}	6.12^{ab}	0.88^{f}
Vastus intermedius	75.72^{abcd}	18.66^{kl}	4.40^{cdef}	0.94^{bcdef}
Tensor fasciae latae	72.80^{hi}	19.48^{hij}	7.03^{a}	0.93^{bcdef}
Vastus lateralis	76.62^{ab}	20.53^{cdef}	1.73^{i}	0.98^{abcde}
Longissimus dorsi	75.51^{bcde}	21.79^{a}	2.02^{hi}	0.99^{abcde}

$^{a-l}$ Means in the same column with different letters are significantly different ($p<0.05$).

significant issue, but very limited information (if any) is accessible. Here we reports, for the first time, chemical and meat quality traits of twenty-one pork muscle. Table 2 presents twenty-one pork muscles were ranked in moisture, protein, fat, and ash contents. As a preliminary analysis revealed no significant sex effect, pooled data from both sex were used for final analysis. Results showed that *rectus femoris* muscle had the highest moisture content (76.82%), followed by *m. vastus lateralis* (76.62%), while *m. latissimus dorsi* showed the lowest moisture content with 72.20%. According to the result of Nold et al. (1999), the percent of moisture reported for muscles was 75.6% (*rectus femoris*) to 69.1% (*gluteus medius*). In this study, moisture content of ham most muscles was greater than that of shoulder muscles. The low fat content reported for *rectus femorsis* (1.54%) is in agreement with Briskey et al. (1960), Topel et al. (1966) and Nold et al. (1999), who reported that *rectus femorsis* had the lower fat content than the other muscles. Nold et al. (1999) reported *semimembranosus*, *biceps femoris*, and *gluteus medius* had 2.15%, 2.12%, and 1.75% fat, respectively. In the case of protein, *longissimus dorsi* muscle showed the highest values with 21.79% while *supraspinatus* muscle was lowest with 18.51%.

Intramuscular fat has a significant effects for determining eating quality through its effect on prevention of over-cooking for the grilling cooking method, stimulation of salivary and reduction of biting pressure at consumption (Thompson, 2002). Although there are limited reports on intramuscular fat content for individual pork cut, the current data revealed that *tensor fasciae latae* and *latissimus dorsi* muscles contained the highest chemical intramuscular fat (7.03% and 6.92%, respectively), while *vastus lateralis*, *adductor* and *rectus femoris* muscles had the lowest (1.73%, 1.67%, and 1.54% respectively). Overall, fat content of shoulder muscles was higher than that of ham muscles, but *semitendinosus* muscle was higher than the other ham muscles and more similar to *brachiocephalicus* among shoulder muscles. A previous study reported that, for the same breed with a similar backfat thickness, intramuscular fat for *triceps brachii*, *longissimus dorsi*, *gluteus medius*, *semimembranosus*, *biceps femoris*, *semitendinosus* muscles were 4.4%, 4.1%, 3.4%, 3.9%, 4.1%, and 7.8%, respectively (Prusa et al., 1988). Similarly, our previous study (Hwang et al., 2005) showed intramuscular chemical fat content of approximately 2-3% in longissimus muscle of commercial pork breed, but the current population showed relatively a higher fat content for the given muscle. When simple correlations between chemical values for pooled dataset from all muscles intramuscular fat had significant ($p<0.05$) linear relationships with moisture ($r = -0.85$), and protein ($r = -0.51$) contents. It could be expected from the nature of muscle composition, but again support that intramuscular fat content is a significant determinant for eating quality.

The cholesterol content of twenty-one pork muscles did not differ significantly due likely to a large variation between animals, while *m. Infraspnatus* had the highest content (91.60 mg/100 g) and *m. longissimus dorsi* had the lowest (63.63 mg/100 g) (Table 3). Cholesterol content in meat cuts and its relationship to fat content have been received significant attention from scientific and

Table 3. Cholesterol, total iron, and calorie contents for twenty-one pork muscles

Muscles	Cholesterol (mg/100 g)	Total iron (ppm)	Calorie (cal/g)
Infraspanatus	91.60	11.70[a]	1,739.70[cde]
Pectoralis profundi (tube)	80.24	8.78[bcd]	1,856.30[abc]
Pectoralis profundi (fan)	74.80	6.93[ef]	1,755.20[cde]
Brachiocephalicus	75.59	9.75[b]	1,866.10[abc]
Latissimus dorsi	68.26	7.17[def]	1,935.50[a]
Subscapularis	86.73	9.67[bc]	1,628.80[efgh]
Supraspinatus	80.86	9.29[bc]	1,765.50[bcde]
Triceps brachii	70.79	7.52[def]	1,667.10[defg]
Adductor	77.96	7.45[def]	1,519.30[hi]
Biceps femoris	73.54	6.38[f]	1,732.40[cde]
Gastrocneminus	75.39	8.15[cde]	1,773.40[bcde]
Gluteus medius	78.33	6.95[ef]	1,689.30[def]
Gluteus superrificialis	77.40	6.57[ef]	1,752.30[cde]
Gracilis	66.59	7.45[def]	1,583.00[fgh]
Rectus femoris	74.44	7.08[ef]	1,423.40[i]
Semimembranosus	72.99	6.44[ef]	1,583.10[fgh]
Semitendinosus	67.46	7.02[ef]	1,799.60[abcd]
Vastus intermedius	72.45	11.88[a]	1,672.90[defg]
Tensor fasciae latae	63.82	6.42[f]	1,899.50[ab]
Vastus lateralis	76.43	6.67[ef]	1,518.10[hi]
Longissimus dorsi	63.63	4.48[g]	1,545.30[ghi]

[a-i] Means in the same column with different letters are significantly different ($p<0.05$).

consumer's point of view, but data from various experiments has varied. A number of previous studies reported lower levels of cholesterol in *longissimus* muscle with 57 mg/100 g (Dorada et al., 1999) and 59 mg/100 g (Moss et al., 1983). Similarly Bohac and Rhee (1988) reported cholesterol content of 55.9 mg/100 g, 53.1 mg/100 g, and 59.7 mg/100 g for *longissimus dorsi*, *semimembranosus*, and *semitendinosus muscles*, respectively. These figures are considerably lower than our current result. On the other hand, Tu et al. (1967) reported that the cholesterol contents were 62 and 65 mg/100 g for pork *longissimus dorsi* and *semitendinosus*, respectively, and the values are very close with our current data. A previous study (Dorado et al., 1999) identified a significantly high linear relationship between intramuscular fat content and cholesterol levels ($r = 0.88$, $p<0.05$), but our results could not find any meaningful correlations between these factors. However, given the factors affecting the relationships such as breed, age of animal, feeding and rearing environment (Tu et al., 1967), the result was not surprising. Similarly, Rhee et al. (1993) failed to find any relationship between fat content and cholesterol levels in pork muscles. The study showed that pork with 9 g/100 g, 14 g/100 g, and 18 g/100 g fat content had 62 mg/100 g, 64 mg/100 g, and 62 mg/100 g of cholesterol contents, respectively.

A wide range of total iron content was observed among twenty-one pork muscles (Table 3). Overall, total iron content of the foreleg muscles had higher than that of the hind leg muscles, and the highest iron contents were observed in *m. vastus intermedius* and *infraspanatus* (11.88 ppm and 11.70 ppm, respectively), while *m. longissimus dorsi* (4.48 ppm) had the lowest ($p<0.05$). The results were very close with an reported data for pork (9.2 ppm for overall pork cuts, Moss et al., 1983), but approximately a half of beef muscles (22.8 and 21.4 ppm for *infraspinatus* and *gluteus medius*, respectively, Yancey et al., 2006).

Calorie content was lowest ($p<0.05$) for *m. rectus femoris*, and was highest for *m. latissimus dorsi* (Table 3) and that was due to the higher fat content in internal muscle. The rationale was evidenced by a strong positive correlation for pooled data from all muscles between calorie content and fat content in the current study ($r = 0.81$; $p<0.0001$).

Fatty acid compositions in meat have received an increased interest considering these implications for human health and product quality (Wood et al., 2003). The ratios of polyunsaturated fatty acids to saturated fatty acids are widely used to evaluate the nutritional value of fat. In the current study, total contents of polyunsaturated fatty acid were the highest ($p<0.05$) for *adductor* and *rectus femoris*, while the lowest for *longissimus dorsi* (Table 4). The monounsaturated fatty acid composition of the *biceps femoris* and *longissimus dorsi* had higher than that of others, while *rectus femoris* and *subscpularis* had lower than others ($p<0.05$). The saturated fatty acid composition of the *latissimus dorsi* had higher than that of others ($p<0.05$). Previous study found that fatty acid composition of triglycerides from *longissimus dorsi* of pork was 42.5% of saturated, 50.3% of monounsaturated, and 7.2% of polyunsaturated and *biceps femoris* of pork was 36.2% of saturated, 49.0% of monounsaturated, and 14.9% of polyunsaturated (Leseigneur-Meynier and Gandemer, 1991).

Table 4. Percentage of fatty acid for twenty-one pork muscles

Muscles	Saturated	Unsaturated	Mono-unsaturated	Poly-unsaturated
Infraspanatus	37.05^{abcd}	62.95^{abcd}	49.86^{abc}	13.09^{bcde}
Pectoralis profundi (tube)	37.69^{abcd}	62.32^{abcd}	49.49^{abc}	12.82^{bcde}
Pectoralis profund I (fan)	37.90^{ab}	62.10^{cd}	49.92^{abc}	12.18^{cde}
Brachiocephalicus	38.04^{ab}	61.96^{cd}	50.21^{abc}	11.75^{def}
Latissinus dorsi	38.31^{a}	61.69^{d}	49.56^{abc}	12.13^{cde}
Subscapularis	37.71^{abc}	62.29^{bcd}	47.82^{c}	14.47^{ab}
Supraspinatus	37.19^{abcd}	62.81^{abcd}	50.01^{abc}	12.80^{bcde}
Triceps brachii	35.73^{d}	64.27^{a}	51.34^{ab}	12.94^{bcde}
Adductor	36.09^{bcd}	63.91^{abc}	48.74^{bc}	15.17^{a}
Biceps femoris	36.34^{abcd}	63.66^{abcd}	51.64^{a}	12.03^{cde}
Gastrocneminus	35.84^{cd}	64.16^{ab}	50.65^{ab}	13.51^{abcd}
Gluteus medius	37.64^{abcd}	62.37^{abcd}	48.65^{bc}	13.72^{abc}
Gluteus superrificialis	37.90^{ab}	62.10^{cd}	49.93^{abc}	12.17^{cde}
Gracilis	37.30^{abcd}	62.70^{abcd}	50.99^{ab}	11.71^{def}
Rectus femoris	36.93^{abcd}	63.07^{abcd}	47.93^{c}	15.14^{a}
Semimembranosus	36.90^{abcd}	63.11^{abcd}	51.04^{ab}	12.06^{cde}
Semitendinosus	37.91^{ab}	62.09^{cd}	50.60^{ab}	11.49^{ef}
Vastus intermedius	36.75^{abcd}	63.25^{abcd}	50.01^{abc}	13.24^{bcde}
Tensor fasciae latae	37.47^{abcd}	62.53^{abcd}	50.35^{abc}	12.18^{cde}
Vastus lateralis	36.69^{abcd}	63.31^{abcd}	49.93^{abc}	13.38^{bcd}
Longissimus dorsi	38.09^{ab}	61.91^{cd}	51.59^{a}	10.32^{f}

$^{a-f}$ Means in the same column with different letters are significantly different ($p<0.05$).

The current results are overall in agreement of the previous studies.

IMPLICATIONS

There was a large amount of variation in nutritional properties among many specific pork muscles. Our results provided a basis for the development of muscle-specific strategies to improve the quality and value of muscles from pork. This information will facilitate the development of new products using pork picnic shoulders and hams, which considered to be lower value than other cuts such as the pork belly in Korean pork industry. Furthermore, the current dataset may help to identify new marketing strategies for pork cuts such as picnic shoulders and hams in Korea.

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