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Relationship between water-holding capacity and intramuscular fat content in Japanese commercial pork loin

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Objective: The relationship between water-holding capacity (WHC) and intermuscular fat (IMF) was studied in Japanese commercial pork.
Methods: Longissimus muscles of pigs (n = 62), obtained from two meat packing plants, were analyzed for IMF content, moisture content, drip loss, cooking loss, and pH. Pairwise relationships among these traits were determined using correlation analyses.
Results: IMF content was significantly correlated with moisture content (r = –0.88; p<0.01) and pH (r = 0.32; p<0.05), but not with drip loss (r = –0.23; p = 0.07) or cooking loss (r = –0.10; p = 0.42). In contrast, drip loss was significantly (and negatively) correlated with pH (r = –0.57; p<0.01).
Conclusion: IMF content was not significantly correlated with WHC in pork, and so ultimately, we consider pH to be one of the most important factors influencing WHC in pork meat.

Keywords: Meat Quality; Pork; Water-holding Capacity; Drip Loss; Intramuscular Fat; pH

INTRODUCTION

The water-holding capacity (WHC) is the ability of meat to hold all or part of its water, and one of the most important traits of meat quality. Weight loss due to purge or drip loss ranges from 2% to 10% when meat is cut into chops [1]. These losses produce an economic cost to meat processors and retailers. In addition, drip loss is an important visual cue to assess meat quality. Some studies have suggested that consumers in most countries dislike drip loss in meat [2,3].

In addition to WHC, intramuscular fat (IMF) contributes to meat quality. Aaslyng et al [4] suggested that juiciness experienced later in the chewing process was determined by a combination of the water content, IMF content and the saliva production during chewing of the pork. In addition, some studies have indicated a relationship between IMF content and the sensory traits of "juiciness" and "tenderness" in pork [5-8]. Consumer preference tests indicate that pork with an average IMF of 5.78% and 3.78% scores higher (p<0.05) eating acceptability than that with IMF of <2.19% [6]. Given these preferences, genetic markers of meat with high IMF has been studied [9,10]. In addition, feeding approaches designed to increase IMF content have been studied; for example, a reduction in dietary lysine showed a significant increase (in the longissimus dorsi of pigs) in IMF content (6.7%) relative to experimental controls (3.5%) [11].

As described above, both WHC and IMF are important traits affecting the quality of pork, and so relationships between WHC and IMF have been extensively studied. Cannata et al [12] reported that pork loins of hybrid barrows (from Italy), with high visual marbling, scored a significantly lower drip loss than pork with low visual marbling, but there was no difference in cooking loss. In contrast, pork loins of Large White and Landrace pigs (in Poland) with high fat content had higher cooking loss than pork with low fat content, but there was no difference in drip loss [13]. In addition, Huff-Lonergan et al [14] reported a significant positive correlation between lipid content and cooking loss in pork loin of F2 generations of Berkshire and Yorkshire pigs. If there is a relationship between the IMF and WHC, WHC might be improved by IMF content, however results of relationship between the IMF and WHC are not consistent among studies. Here, the IMF content of pork in previous studies mainly ranged between 1% and 4% [12,13]. In Japan, feeding technique of high IMF of pigs were reported [11] and some pig breeds were created which is based on the high IMF content [15]. Thus, there is a high interest in IMF of pork in Japan, and it is expected to investigate the relationship between IMF and WHC in pork with higher IMF content than previous studies. However, there is no information regarding the relationship between IMF content and WHC of pork obtained from three-way cross-bred Landrace×Large White×Duroc (LWD) pigs, which is the traditional, commercially produced breed in Japan. Therefore, in this study, we hypothesized that the relationship between IMF and WHC becomes clearer by analysis of pork produced in Japan (with a variety of IMF contents), and we investigated the IMF content, WHC and relating factors of WHC.

MATERIALS AND METHODS

Samples

Experiments were performed on samples of longissimus muscle obtained from 62 carcasses of finishing pigs slaughtered at the Ibaraki Kyodo meat Co., Ltd. (Tsuchiura, Japan) (n = 32; 18 females, 14 castrated males) and at the Tochigi prefectural animal husbandry Co., Ltd. (Utsunomiya, Japan) (n = 30; 16 females, 14 castrated males). Carcasses weight was 67 to 87 kg, with an average of 75 kg. Loin samples were prepared at each meat plant, then refrigerated and delivered to our institute. All analyses were performed about 72 h after pigs were slaughtered.

Drip loss

Drip loss was determined using the suspension method of Honikel [16]. Longissimus muscle of the 13th to 15th thoracic vertebrae was used to measure drip loss. Each muscle was sliced to 2.0-cm in thickness, and processed into a disk with a diameter of 4 cm. Samples were put into netting and suspended in a plastic bag, ensuring that there was no contact between the sample and the bag. Samples were stored in this manner at 4°C for 24 h. The weight of each slice was recorded before and after being suspended. Drip loss was expressed as a percentage of weight loss after suspension relative to the initial weight of the slice. Drip loss was measured in 3 replicate samples from each carcass, with the average value recorded as the drip loss for each sample.

Cooking loss

To determine cooking loss, longissimus muscle of 1st to 2nd lumbar vertebrae was processed in the same manner used for the drip loss experiment. Muscle disks were put into polyethylene bags and subjected to heat treatment using a water bath set at 95°C for cooking to an endpoint internal temperature of 75°C. The internal temperature of each sample was monitored using a thermo recorder (TR-52S, T and D, Nagano, Japan). Thereafter, samples were chilled in crushed ice and held for 30 min. Weight loss after cooking was calculated and expressed as the percentage of the weight before cooking. Cooking loss was measured using two replicates from each carcass and the average was recorded as the cooking loss for each sample.

pH

Ultimate pH was measured directly on the surface of a cutting plane of the 13th thoracic vertebra at about 72 h after slaughter, using a pH meter (LAQUA D -71, Horiba, Kyoto, Japan) equipped with a flat, ion-sensitive, field-effect transistor electrode (0040-10D, Horiba, Japan). pH was measured in three replicates from each carcass and the average value was recorded as the pH for each sample.

Intermuscular fat and moisture

Samples were prepared from the longissimus muscle of the 11th to 12th thoracic vertebrae (ahead) and the 3rd to 4th lumbar vertebrae (backward). Measurements for IMF were conducted using the Soxhlet method, and moisture was measured using the atmospheric heating drying method. IMF and moisture content were analyzed by the Japan Food Research Laboratories (Tokyo, Japan). IMF and moisture content were recorded as the average of the ahead and backward samples because there was no difference in the IMF and moisture contents between the two samples using Student's t-test (data not shown).

Statistical analysis

Statistical analyses were performed using SAS (ver 9.4) (SAS Institute, Cary, NC, USA). Summary statistics for each trait were calculated using a MEANS procedure and the results of our 62 pork samples were summarized and compared with results from previous work on pork quality. Moreover, relationships between the traits were determined by calculating linear correlation using the CORR procedure.

RESULTS AND DISCUSSION

Summary statistics for each trait are shown in Table 1. In this

Table 1. Summary of pork loin quality traits

Traits	n	Average	Median	SD	Minimum	Maximum
IMF (%)	62	3.59	3.55	1.40	0.80	7.15
Moisture (%)	62	73.80	73.88	1.02	70.60	75.95
pH[1)]	60	5.93	5.93	0.14	5.71	6.29
Drip loss (%)	62	2.89	2.41	1.55	1.00	7.62
Cooking loss (%)	62	23.00	23.48	2.70	16.85	28.90

SD, standard deviation; IMF, intermuscular fat.
[1)] Due to problems with electrode, n = 60.

study, the range in IMF content was 0.80 to 7.15, with an average of 3.59%. Daszkiewicz et al [13] found that IMF was ≤2% for most (83.78%) samples in their study of the relationships between IMF content and meat quality traits of 74 pork loins [13]. Font-i-Furnols et al [7] reported a range in IMF content from 0.53% to 5.98%. Therefore, IMF content revealed in this study was slightly higher and the range was wider than literature in previous studies. Moisture content was 73.80%, which was similar to some studies [8,17,18]. The pH in our study was 5.93, which was higher that the pH range (5.65 to 5.83) in previous studies [8,14,19]. These studies measured an internal pH by glass electrode; however, we measured a surface pH by ion-sensitive field-effect transistor electrode because this electrode could measure pH by without destruction of pork. The type of electrode used in this study is probably responsible for the slight difference in pH data. In addition, Doherty et al [20] demonstrated that surface pH by combination electrode was significantly higher than internal pH on lamb loin by glass electrode. Therefore, the high pH of pork presented in this study might also be due to differences between internal and surface.

Drip loss was 2.89%, which was similar to previous studies using the same suspension method [12,19]. Cooking loss was 23.0%, which was almost the same magnitude of loss as previous studies; however simple comparisons could not be made because the heating treatment procedures differed among studies [8,14,21].

Pearson correlation coefficients are shown in Table 2. IMF content was significantly (and negatively) correlated with moisture content (r = –0.88; p<0.01). It is generally accepted that moisture content of beef correlates negatively with fat content [22,23]. Likewise, moisture is replaced by fat in pork as well.

Table 2. Pearson correlation coefficients between IMF, moisture, pH, drip loss and cooking loss of pork

Item	IMF	Moisture	pH	Drip loss	Cooking loss
IMF	1	−0.88**	0.32*	−0.23	−0.10
Moisture	-	1	−0.13	0.19	0.16
pH	-	-	1	−0.57**	−0.13
Drip loss	-	-	-	1	0.34**
Cooking loss	-	-	-	-	1

IMF, intermuscular fat.
** p<0.01, * p<0.05.

As shown in Table 2, IMF content was not significantly correlated with drip loss (r = –0.23; p = 0.07) or cooking loss (r = –0.10; p = 0.42). Cannata et al [12] reported a significant negative correlation between lipid content of meat and cooking loss. In contrast, Huff-Lonergan et al [14] found a significant positive correlation between total lipid content and cooking loss. Here, in this study, there was no significant correlation between the IMF and the WHC even if the LWD which had a higher IMF than previous studies. Thus, relationship between IMF content and WHC are not consistent among studies, including our own.

On the other hand, the physical factors might be affect to WHC. The majority of moisture in muscle is held within the structure of the muscle and muscle cells [24]. pH fall of post mortem induced myosin denaturation [25,26] and an increase in extracellular spaces [27], both of which increase drip loss. In our study, pH was significantly and negatively correlated with drip loss, a finding similar to the results of previous studies using a wide variety of pig breeds [14,28-30]. Therefore, it has been suggested that the effect of pH on WHC is greater than effect of IMF content on WHC. On the other hand, high post-mortem temperature also induces protein denaturation and increases the amount of extracellular spaces, which then increase drip loss [25,31]. Post-mortem temperatures in meat plants and on delivery trucks were not controlled in this study. Thus, slight differences in post-mortem temperature might have affected the WHC in our study. Moreover, pre-slaughter stress may increase early post-mortem temperatures, cause declines in pH, and increase drip losses of the longissimus dorsi in pigs [32]. Changes in these physical factors contribute to WHC and so may have influenced the relationship between IMF and WHC in our study.

Nutritional factors might also affect IMF and WHC. The IMF content of pork loin is significantly increased by reductions in protein intake [33] or lysine intake [34]; however, WHC did not differ in these studies. In addition, supplementing the diet of pigs with vitamin E decreases drip loss in pork [35]. As described above, both IMF and WHC are affected by nutritional effects. However, the nutritional content of feed consumed by pigs in our study is not known. Therefore, differences in nutritional factors could have influenced the relationship between IMF and drip loss in our study.

In conclusion, IMF was not significantly correlated with WHC, and the correlation between pH and WHC was higher than the correlation between IMF and WHC in LWD breeds, which is the most common breed produced in Japan. Therefore, it was suggested that it is difficult to improve WHC by only increasing of IMF content, and pH control is more important for improving WHC than IMF content. Because both IMF and WHC are important characteristics for meat quality, it is necessary to improve them respectively by management of such as a slaughter stress, post-mortem temperatures, and nutritional factors.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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