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Relationship between the Lactic Acid Content and Sour Taste of Broiler Broth and the Broth of *Choshu-Kurokashiwa*—a Japanese *Jidori* Chicken

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The present study aimed to determine whether lactic acid content is associated with the intensity of the sour taste of *Choshu-Kurokashiwa* broth. Chicken broth was prepared using breast (*pectoralis major*) and leg (thigh + drumstick) meat of male and female *Choshu-Kurokashiwa* and broilers. These broths were assessed by a screened and trained panel and analyzed for sour taste substances (lactic, citric, pyruvic, malic, succinic, acetic, phosphoric, aspartic, and glutamic acids) and pH. The sensory sour taste was significantly higher in the *Choshu-Kurokashiwa* breast broth than in the broiler breast broth ($P<0.001$), and no significant difference was observed in the leg broths among the breeds ($P>0.05$). *Choshu-Kurokashiwa* breast broth had a significantly higher lactic acid content than broiler breast broth ($P<0.001$). The leg meat broth of male *Choshu-Kurokashiwa* had a significantly lower lactic acid content than that of female *Choshu-Kurokashiwa* and broiler leg meat ($P<0.01$). The sensory sour taste score was significantly and positively correlated with lactic acid content in the breast broth ($P<0.001$), but not in the leg broth ($P>0.1$). No other organic acids were detected. Phosphoric acid and glutamic acid contents were higher in broiler broth than in *Choshu-Kurokashiwa* broth for both breast and leg meat ($P<0.001$). In the breast broth, the aspartic acid content was not significantly different ($P>0.1$), and in the leg broth, it was higher in broiler and female *Choshu-Kurokashiwa* broth than in male *Choshu-Kurokashiwa* broth ($P<0.001$). The present study suggests that high lactic acid content contributes to the sour taste of the *Choshu-Kurokashiwa* breast broth and demonstrated that the lactic acid content is an essential indicator for determining the sour taste of *Choshu-Kurokashiwa* breast meat.

Key words: broiler, *Choshu-Kurokashiwa*, indigenous chicken, lactic acid, sensory, sourness

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Introduction

Consumers have diverse preferences for chicken meat. In Japan, broilers account for 90% of the chicken meat market (Ministry of Agriculture, Forestry, and Fisheries, 2021). However, some consumers are willing to purchase high-quality Japanese chicken meat, known as "*jidori*" meat. Even though the price of *jidori* meat is two to five times that of broiler meat, consumers buy *jidori* meat because of its unique texture, odor, and taste (Koizumi *et al*., 1991; Hikichi *et al*., 2020).

Jidori breeders face the challenge of improving the growth performance of *jidori* while maintaining its sensory characteristics. The production of *jidori* is more costly than that of broilers because of the lower stocking densities, longer fattening period, and the cost associated with open non-cage floor rearing systems based on rulings of the Japanese Agricultural Standard (Ministry of Agriculture, Forestry and Fisheries of Japan, 1999). Therefore, it is necessary to improve profitability through weight gain of chicken. However, breeding without considering sensory factors may lead to a loss of palatability.

Some studies (Fujimura *et al*., 1996; Matsuishi *et al*., 2005) have focused on the umami taste of *jidori* meat and reported that the palatability of *jidori* meat was not based on the strength of the umami taste. Horinouchi *et al*. (2016) prepared *jidori* and broiler breast broth and asked the panel to choose one of the five basic tastes to describe the characteristics of the broth. They found that 38% of the panel chose umami taste, and 57% chose sour taste as the characteristic taste of *jidori* broth, whereas 75% of the panel chose umami taste and only 10% chose sour taste as the characteristic taste of broiler broth. Thus, although tastes other than umami, especially sourness, likely characterize the taste of *jidori* breast meat, only a few studies have focused on the components that

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contribute to the sour taste.

Organic acids are responsible for the sour taste of foods (Neta *et al*., 2007). In particular, lactic acid, which is contained in approximately 0.5 g of 100 g chicken meat (Zhang *et al*., 2012), intensifies the sour taste. In chicken meat, lactic acid accumulates during glycolysis after slaughter (Pösö and Puolanne, 2004). The final lactic acid content of chicken meat is negatively correlated with the chicken growth rate (Berri *et al*., 2001; Le Bihan-Duval *et al*., 2008). Given that *jidori* grows more slowly than broilers because of their genetic characteristics (Rikimaru and Takahashi, 2010; Oosaka *et al*., 2017), more lactic acid is assumed to accumulate in *jidori* meat. Therefore, the sour taste of *jidori* is thought to be caused by the high accumulation of lactic acid. However, the relationship between lactic acid content and sour taste intensity in *jidori* meat has not been thoroughly studied.

In the present study, I aimed to determine whether lactic acid content is associated with the intensity of the sour taste of *jidori* meat. Therefore, I prepared chicken broth of *Choshu-Kurokashiwa*, a *jidori* breed, and a broiler, and sensory evaluation of both broths was done by a screened and trained panel. The substances responsible for the sour taste were also analyzed.

Materials and Methods

Samples

All chicken breast and leg meat used in this study were purchased directly from the Fukawa Poultry Cooperative commercial farm (Nagato-shi, Yamaguchi, Japan). Both *Choshu-Kurokashiwa* and broilers were fed at the farm. Because the rearing period of *Choshu-Kurokashiwa* was divided into sex, both sexes were purchased. The sex of broilers was unknown. *Choshu-Kurokashiwa* (male and female) and broilers were slaughtered at 84–86, 98–100, and 46–49 days of age, respectively, according to the normal selling age. Eleven males and females each of *Choshu-Kurokashiwa* and 11 broilers were used for chicken broth preparation. At the farm, right after the slaughter, the left breast (*pectoralis major*) and right leg meat (thigh + drumstick) were removed from each carcass, and the leg meat was deboned. The meat was then transported to the authors' laboratory and stored at 4℃ for 24 h to complete post-mortem glycolysis. On the day following slaughter, the meat samples were weighed, and the skin and visible fats were trimmed off. The samples were then cut into 2.5×2.5×2.5-cm pieces and minced through a 5-mm plate using an electric mincer (MG-116J, Yasukichi, Gifu, Japan). Finally, 66 minced chicken meat samples (two muscle parts × three chicken groups × eleven individuals) were prepared.

Chicken Broth Preparation

Chicken broth was prepared according to the National Livestock Breeding Center (2005), with some modifications. The minced chicken meat (100 g) and purified water (200 mL) were added to a 500-mL beaker (HARIO SCIENCE, Tokyo, Japan). The beakers were then covered with aluminum foil and placed in a pot of boiling water. After the temperature of the broth reached 85℃, which was monitored using a thermometer (SN3000, Netsuken, Tokyo, Japan), the broth was stirred and heated for another 60 min. The beakers were then removed from the pot, cooled under running water for 1 h, and stored in a refrigerator at 4℃ for 18 h. After that, the oil layer was removed from the broth using a 0.3-mm mesh sieve. Next, the obtained chicken broth was filtered through two layers of paper towels (NIPPON PAPER CRECIA, Tokyo, Japan) to remove the meat residues. Finally, the volume of the filtered samples was adjusted to 250 mL with purified water and stored in polypropylene bottles (250 mL; AS ONE, Osaka, Japan) at −30℃ until sensory evaluation and chemical component analysis.

General Procedures for the Sensory Evaluation

The temperature of the test room was maintained at 21℃ using an air conditioner. The room was illuminated with fluorescent light. The panelists sat at a long table 2 m apart. The sensory panelists were informed of the safety of the chicken meat samples according to the National Livestock Breeding Center (2005).

Screening of Candidates

Descriptive sensory evaluation was performed using a screened and trained panel. This method helps quantify the intensity of sour taste and confirms that sour taste is a characteristic of *Choshu-Kurokashiwa* broth. In addition, this method prevents the "damping effect" and allows the panel to evaluate the appropriate attribute intensities (Lawless and Heymann, 2013).

Sensory panel screening was performed according to the method described by Sasaki *et al*. (2012). Forty-five candidates were recruited from the Yamaguchi Prefectural Technology Center for Agricultural and Forestry (Yamaguchi-shi, Yamaguchi, Japan). The screening was performed in three substages: (1) recognition test of five basic tastes, (2) discrimination test of different seasoning concentrations, and (3) discrimination test of differences in food and characteristics of odors. As a result, 11 members (six males and five females, aged 28–61 years) were screened. All participants took part in three training sessions and three evaluation sessions.

Generation of Descriptors and References

The panel developed sensory attributes, definitions, and references in three training sessions according to Lawless and Heymann (2013), with some modifications. All training sessions were performed for 1 h each. In the first training session, the panel generated a lexicon of sensory attributes using Kelly's repertory grid method (Moskowitz, 1983). The sensory panel received three pairs of chicken broths randomly combined from six different broths (two muscle parts × three chicken breeds) and were asked to describe the similarities and differences between the pairs using a Japanese candidate lexicon for the descriptive sensory evaluation of meat (Sasaki *et al*., 2018). In the second training session, the panelists were exposed to the samples and potential reference foods and reached a consensus on the definition of attributes using the potential references (Table 1). In the final training session, six different samples (two muscle parts × three chicken breeds) and references were provided under the actual testing conditions. The panelists evaluated the samples and received

Table 1. **Sensory Attributes, Definitions, and References Used in the Descriptive Analysis**

Attribute	Definition	Reference
Odor		
Odor intensity	Total intensity of the odors	Nr
Roasted-like odor	Roasted-like odor	Chicken breasts cooked in a pan on the gas stove until browned and charred
Chicken meat-like odor	Chicken meat-like odor	Chicken breasts cooked in water (85℃) for 15 min
Sour odor	Sour odor	Yogurt (Meiji Bulgaria Yogurt LB81, Meiji, Tokyo, Japan)
Baked odor	Baked odor	Baked cookie (Mitsubishi Shokuhin, Tokyo, Japan)
Flavor/taste		
Flavor/taste intensity	Total flavor/taste intensity	Nr
Vegetable soup like flavor	Vegetable soup like flavor	Vegetable soup made by simmering 380 g onions, 260 g carrots, 340 g Chinese cabbage, and 2 L water for 30 min
Sour taste	Sour taste	0.03 g citric acid per 100 mL of chicken stock
Umami taste	Umami taste	0.13 g MSG per 100 mL of chicken stock
Salty taste	Salty taste	0.16 g NaCl per 100 mL of chicken stock
Sweet taste	Sweet taste	0.5 g sucrose per 100 mL of chicken stock
Koku taste	Complexity, body, mouthfulness, and/or continuity	0.01 g γ-Glu-Val-Gly per 100 mL of chicken stock

Nr, no reference

feedback on the results.

Evaluation of Chicken Broth

Frozen chicken broth was reheated in a boiling pot to 85℃ for the evaluation sessions and was incubated in a water bath set at 68℃ until just before being presented to the sensory panel. Forty milliliters of chicken broth was served in a plastic cup to each panelist (SUNNAP, Tokyo, Japan) with three-digit random codes. Reference foods were also presented to each panelist and used just prior to evaluation to confirm the evaluation terms. Intervals of at least 1 min were provided between sample tasting, during which the panelists rinsed their mouths with purified water.

The sample set for the descriptive analysis consisted of six different samples, namely, the broths of the three breeds, a male and female of *Choshu-Kurokashiwa*, broiler, and breast and leg meat. This sample set was assessed by each of the 11 panelists using three replicates. The serving order was determined using a Latin square design. Unstructured lined scales of 15 cm with the left side termed as "not perceived" and the right side termed as "extremely strong" were used to score each sensory attribute. The panelists marked the relevant position on the line and used the length from the end to the marked point as the data for stimulus intensity.

Determination of pH and Organic Acids, Phosphoric Acid, Glutamic Acid, and Aspartic Acid Contents

The pH and lactic acid, citric acid, pyruvic acid, malic acid, succinic acid, acetic acid, phosphoric acid, glutamic acid, and aspartic acid in the broth samples were also measured. These affect the sour taste of food (Neta *et al*., 2007; Kawai *et al*., 2012).

The pH of the broth was measured using a pH meter (DKK-TOA, Tokyo, Japan). For the organic acid and phosphoric acid content measurements, 10 mL of broth was mixed with 14 mL of dH_2O and 6 mL of 10% (w/v) sulfosalicylic acid. The mixture was centrifuged at 10,000×*g* for 15 min. Six milliliters of the supernatant was adjusted to pH 6.8 with KOH and diluted to 20 mL with dH_2O. The solution was filtered through a 0.45-µm membrane (DISMIC 13HP045AN, Toyo Roshi Kaisha, Tokyo, Japan). The organic and phosphoric acid contents were analyzed using high-performance liquid chromatography (LC20AD; Shimadzu, Kyoto, Japan), using a Shim-pack SCR-102(H) column (Shimadzu, Kyoto, Japan). The mobile phase and reaction solution used for the experiment were 5 mM *p*-toluene sulfonic acid, 100 µM EDTA, and 20 mM Bis-Tris, respectively. The flow rate and oven temperature were 0.8 mL/min and 45℃, respectively.

Free amino acid levels were assessed according to Qi *et al*. (2017), with some modifications. After protein precipitation and centrifugation using the method used for organic acid analysis, 6 mL of the supernatant was mixed with 2 mL of *n*-hexane. The water phase was adjusted to pH 3.0 with KOH and diluted to 20 mL with dH_2O. The solution was filtered through a 0.45-µm membrane (DISMIC 13HP045AN, Toyo Roshi Kaisha, Tokyo, Japan) before free amino acid analysis. Free amino acids were analyzed using an automatic amino acid analyzer (L-8900; Hitachi, Tokyo, Japan).

Statistical Analysis

All statistical analyses were performed using R version 3.6.1 (R Core Team, 2019). The descriptive sensory score was analyzed using a linear mixed model with the package 'lme4'. The type of chicken (male or female *Choshu-Kurokashiwa* or broiler), muscle parts (breast or leg), serving order, and sessions were used as fixed effects. Panelists were used as random effects.

The chemical component characteristics were analyzed by two-way analysis of variance, including variables such as the type of chicken, muscle parts, and interaction. In addition, multiple comparisons were performed using the Tukey–Kramer test using the package 'multcomp'.

Pearson's correlation coefficients were evaluated using the 'stats' package to determine the relationship between lactic acid and pH or sour taste score of the pooled results for breast meat (n=33) and the pooled results for leg meat (n=33).

Results

Table 2 shows the least-square means of the sensory scores for *Choshu-Kurokashiwa* broth and broiler broth attributes. The sour taste was the only attribute that was significantly higher in the *Choshu-Kurokashiwa* broth than in the broiler broth ($P<0.001$). The effect of breed on sourness was significant, with the sourness of *Choshu-Kurokashiwa* being significantly greater than that of broilers. The effect of the muscle part was also significant, with the breast being significantly more sour than the leg ($P<0.001$). Furthermore, the interaction between chicken breed and muscle part was significant ($P<0.001$), with the *Choshu-Kurokashiwa* breast being significantly more sour than the broiler breast ($P<0.001$), whereas no differences in the sourness of the leg meats were observed among the breeds ($P>0.1$). Except for sourness, the only significant difference among the chicken breeds was umami. Broilers had a stronger umami taste than *Choshu-Kurokashiwa* in breast meat, but there was no difference in the leg meat. Significant differences were found in odor intensity, chicken meat-like odor, baked odor, flavor/taste intensity, umami taste, and sweet taste between the muscle parts, except for the sour taste. In addition, chicken breed and muscle parts interacted with chicken meat-like odor.

Table 3 shows the weight of chicken meat, acid composition, and pH of chicken broth. A statistically significant interaction was observed between chicken breed and lactic acid content ($P<0.001$). In the breast meat broth, the lactic acid content was higher in *Choshu-Kurokashiwa* than in broilers ($P<0.001$). In contrast, in the leg broth, the lactic acid content of the male *Choshu-Kurokashiwa* was lower than that of the broilers and female *Choshu-Kurokashiwa* ($P<0.05$), but the difference among the chicken breeds was smaller than that in the breast broth. The other organic acids analyzed, namely citric acid, pyruvic acid, malic acid, succinic acid, and acetic acid, were not detected in any of the broths. Phosphoric acid and glutamic acid contents were higher in the broiler broth than in the *Choshu-Kurokashiwa* broth for both breast and leg meat ($P<0.001$). In the breast broth, the aspartic acid content was not significantly different ($P>0.1$), and in the leg broth, it was higher in the broiler and female *Choshu-Kurokashiwa* broths ($P<0.001$) than in the male *Choshu-Kurokashiwa* broth. Among the different broths, the pH was the lowest for the *Choshu-Kurokashiwa* breast broth, and the leg broth was almost neutral. The breast meat of male and female *Choshu-Kurokashiwa* was more than 100-g lighter than that of the broilers ($P<0.001$), whereas the leg meat did not differ significantly among the breeds ($P>0.05$). Fig. 1 shows the relationship between the lactic acid content and the pH of each broth. The *Choshu-Kurokashiwa* breast broth had a higher lactic acid content and lower pH than the broiler breast broth. The pH of the leg broth decreased as the lactic acid content increased in both the *Choshu-Kurokashiwa* and broilers.

Figure 2 shows the relationship between the lactic acid content and the sour taste score of each broth. The *Choshu-Kurokashiwa* breast broth had a higher lactic acid content and a higher sour taste score than broiler breast broth. *Choshu-*

Table 2. **Descriptive Sensory Characteristics of *Choshu-Kurokashiwa* Broth and Broiler Broth**[1]

Attribute	Breast			Leg			SEM[3]	Breed	Part	Breed × Part
	CK[2]		BR	CK		BR				
	Male	Female		Male	Female					
Odor										
Odor intensity	9.7^{a}	9.7^{a}	9.5^{a}	9.1^{a}	9.2^{a}	9.3^{a}	0.5	ns[4]	*	ns
Roasted-like odor	7.9^{a}	8.2^{a}	7.4^{a}	7.1^{a}	7.4^{a}	7.8^{a}	0.6	ns	ns	ns
Chicken meat-like odor	6.1^{bc}	6.0^{c}	7.4^{ab}	7.7^{a}	7.5^{ab}	6.9^{abc}	0.7	ns	**	**
Sour odor	6.1^{a}	5.2^{a}	6.2^{a}	5.3^{a}	5.4^{a}	5.5^{a}	0.9	ns	ns	ns
Baked odor	7.3^{ab}	7.6^{a}	6.7^{ab}	6.0^{b}	6.2^{b}	6.4^{ab}	0.7	ns	***	ns
Flavor/taste										
Flavor/taste intensity	9.1^{a}	8.5^{a}	8.6^{a}	7.6^{a}	8.3^{a}	8.2^{a}	0.6	ns	*	ns
Vegetable soup like flavor	4.9^{a}	4.8^{a}	5.4^{a}	5.2^{a}	5.0^{a}	5.1^{a}	0.9	ns	ns	ns
Sour taste	9.0^{a}	8.6^{a}	5.1^{b}	3.3^{c}	3.8^{bc}	4.0^{bc}	0.8	***	***	***
Umami taste	6.3^{bc}	6.0^{c}	7.5^{ab}	7.1^{abc}	7.4^{ab}	8.0^{a}	0.7	***	***	ns
Salty taste	4.8^{a}	4.4^{a}	4.9^{a}	4.5^{a}	4.5^{a}	5.1^{a}	0.8	ns	ns	ns
Sweet taste	3.7^{a}	3.6^{a}	4.3^{a}	4.4^{a}	4.3^{a}	4.3^{a}	0.7	ns	*	ns
Koku taste	6.2^{a}	5.8^{a}	6.7^{a}	6.1^{a}	6.9^{a}	6.8^{a}	0.6	ns	ns	ns

[a–c] Values with different superscripts within a row differ significantly ($P<0.05$).
[1] Samples were evaluated using 15-cm lined scales from 0 cm (not perceived) to 15 cm (extremely strong). Values are expressed as least-square means.
[2] CK, *Choshu-Kurokashiwa*; BR, broiler.
[3] Standard error of the mean.
[4] ns, not significant; *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$.

Table 3. **Weight of Chicken Meat, and Acid Composition and pH of *Choshu-Kurokashiwa* Broth and Broiler Broth[1]**

	Breast			Leg			SEM[2]	Breed	Part	Breed × Part
	CK[3]		BR	CK		BR				
	Male	Female		Male	Female					
Weight (g)	219.5[b]	205.8[b]	330.6[a]	342.5[a]	315.2[a]	310.3[a]	16.49	***[4]	***	***
Acid composition (mg per 100 mL)										
Lactic acid	254[a]	254[a]	209[b]	103[d]	127[c]	121[c]	4.74	***	***	***
Citric acid	nd[5]	nd	nd	nd	nd	nd	—	—	—	—
Pyruvic acid	nd	nd	nd	nd	nd	nd	—	—	—	—
Malic acid	nd	nd	nd	nd	nd	nd	—	—	—	—
Succinic acid	nd	nd	nd	nd	nd	nd	—	—	—	—
Acetic acid	nd	nd	nd	nd	nd	nd	—	—	—	—
Phosphoric acid	101[c]	100[c]	127[a]	114[b]	113[b]	125[a]	3.15	***	***	**
Aspartic acid	1.37[c]	1.54[c]	1.96[c]	2.61[b]	3.28[a]	3.33[a]	0.21	***	***	ns
Glutamic acid	4.52[d]	2.89[d]	6.09[c]	9.69[b]	10.2[b]	12.6[a]	0.66	***	***	ns
pH	6.23[d]	6.24[d]	6.44[c]	6.95[a]	6.83[b]	6.86[b]	0.02	***	***	***

[a–d] Values with different superscripts within a row differ significantly ($P<0.05$).
[1] Values are expressed as means ($n=11$ each).
[2] Standard error of the mean.
[3] CK, *Choshu-Kurokashiwa*; BR, broiler.
[4] ns, not significant; **, $P<0.01$; ***, $P<0.001$.
[5] nd, the compound was below the limit of quantification in the sample.

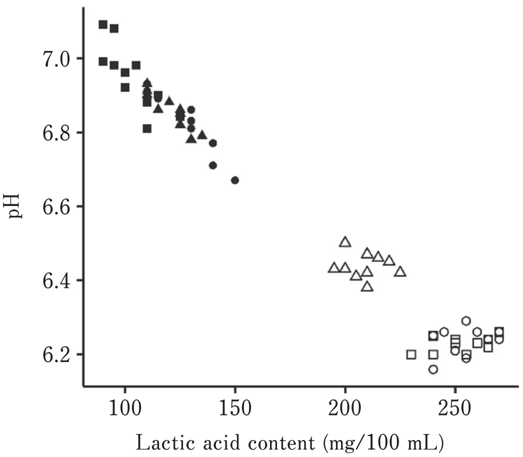

Fig. 1. **Relationship between the lactic acid content and the pH of chicken broth.** Open squares, circles, and triangles indicate the breasts of *Choshu-Kurokashiwa* male, *Choshu-Kurokashiwa* female, and broilers, respectively. Closed squares, circles, and triangles indicate the broths of *Choshu-Kurokashiwa* males, *Choshu-Kurokashiwa* females, and broilers, respectively.

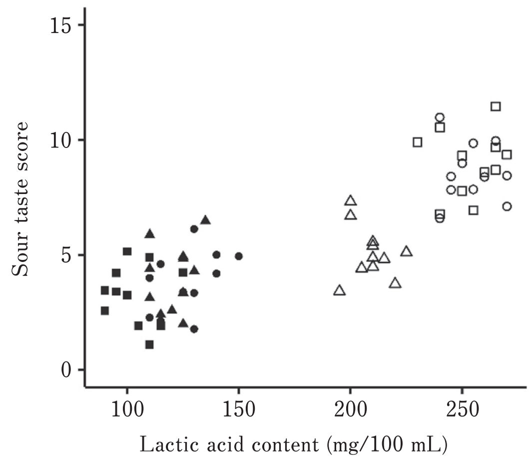

Fig. 2. **Relationship between the lactic acid content and the sour taste score of chicken broth assessed by the trained sensory panel.** Open squares, circles, and triangles indicate the breast meats of *Choshu-Kurokashiwa* male, *Choshu-Kurokashiwa* female, and broilers, respectively. Closed squares, circles, and triangles indicate the broths of *Choshu-Kurokashiwa* males, *Choshu-Kurokashiwa* females, and broilers, respectively. Three trained panelists assessed each sample. The sour taste score is expressed as the least-square means.

Kurokashiwa breast broth and broiler breast broth were plotted for different groups. On the other hand, leg meat broth showed little difference in lactic acid content and sour taste score among the chicken breeds.

As shown in Table 4, negative correlations between lactic acid and pH of the broth were observed for both breast and leg broths ($P<0.001$). Lactic acid content was significantly and positively correlated with the sour taste score for breast broth ($P<0.001$), but not with that for leg broth ($P>0.1$).

Table 4. **Pearson's Correlation Coefficients between Lactic Acid and Ph or Sour Taste Score in Chicken Broth**

	Breast	Leg
Lactic acid - pH	−0.828***	−0.919***
Lactic acid - Sour taste score	0.719***	0.289[ns]

[ns], not significant; ***, $P<0.001$.

Discussion

The sour taste was found to be a crucial characteristic of *Choshu-Kurokashiwa* breast broth, but not of the leg broth (Table 2). This result is consistent with those of other studies (Rikimaru *et al*., 2011; Horinouchi *et al*., 2016). As described above, Horinouchi *et al*. (2016) reported that sour taste is an essential characteristic of the *jidori* breast broth; however, they did not mention why the panel perceived the sour taste to be stronger in the *jidori* breast broth. Rikimaru *et al*. (2011) fed *Hinai-jidori* and broilers raised to 22 weeks in the same environment and performed sensory evaluation by a trained panel. They reported no difference in the intensity of sour taste between chicken thigh meat and soup. The findings of these studies are in accordance with the results of the present study, which indicated that the breed and muscle part interacted with the intensity of the sour taste of chicken broth (Table 2).

The chicken breed and muscle part also interacted with the lactic acid content of the broth and the weight of meat (Table 3). The breast meat of *Choshu-Kurokashiwa* was lighter and had a higher lactic acid content than broilers. Le Bihan-Duval *et al*. (2008) compared chicken traits of approximately 600 chickens and found a positive correlation between breast muscle weight and ultimate pH. The pH of the breast meat of Thai and Taiwan native chickens, which grow more slowly than broilers, was lower than that of broilers (Jaturasitha *et al*., 2002; Chumngoen and Tan, 2015). These chicken breasts presumably had a high lactic acid content, which was highly and negatively correlated with pH. These results are consistent with the results of the present study, where the breast meat of *Choshu-Kurokashiwa* was lighter, and its broth had a higher lactic acid content than broiler breasts.

The relationship between weight and lactic acid content in the leg broth was similar to that in breast broth. The leg meat of male *Choshu-Kurokashiwa* was heavier and had a lower lactic acid content than that of the broiler, even though the weights were not significantly different among the breeds (Table 3). Therefore, the effect of the chicken breed on the lactic acid content depends on the part of the chicken to be cooked, and the weight of each part of the chicken needs to be considered rather than the growth rate of the chicken.

The present study suggests that the high lactic acid content of the *Choshu-Kurokashiwa* breast broth might intensify its sour taste. Chemical components and descriptive analyses showed that the sour taste score was significantly and positively correlated with the lactic acid content in the breast broth (Fig. 2, Table 4). Because the *Choshu-Kurokashiwa* breast broth had 20% more lactic acid than broiler breast broth (Table 3), the trained panel could probably discriminate the difference in the sour taste intensity between the *Choshu-Kurokashiwa* and broiler breast broth. Furthermore, no organic acids, other than lactic acid, were detected in the broths, and phosphoric and glutamic acids were more abundant in the broiler broth than in the *Choshu-Kurokashiwa* broth for breast meat. The aspartic acid content of the breast broth was not significantly different among the breeds. These results suggest that lactic acid is responsible for the sour taste of the *Choshu-Kurokashiwa* breast broth.

Conversely, no significant correlation was observed between lactic acid content and sour taste score in leg broth (Table 4). Although the lactic acid content of the leg broths differed significantly among the chicken breeds, the differences were small (Table 3). Because the taste threshold of lactic acid is 126 mg per 100 mL (Rotzoll *et al*., 2006), the panel felt a slightly sour taste and could not discriminate the intensity of the sour tastes.

The pH and lactic acid content interact to affect the intensity of sour taste in foods. For solutions with the same lactic acid content, the lower the pH, the sourer the solution (Sowalsky *et al*., 1998; Neta *et al*., 2009). In the present study, the broth with a higher lactic acid content had a lower pH (Fig. 1). Therefore, in the *Choshu-Kurokashiwa* breast meat broth, both high lactic acid content and low pH may increase the sour taste. However, in 10 mM lactic acid solution, a change from pH 4.5 to pH 3.5, does not affect sour taste intensity (Neta *et al*., 2009). In addition, the closer the pH of the solution is to neutral, the lower the effect of pH on sour taste intensity (Neta *et al*., 2009). The present study did not demonstrate a change in sour taste when the pH was changed; however, the difference in pH of the broths in the present study was less than 1 and the pH ranged from 6 to 7. Based on a previous report (Neta *et al*., 2009), the effect of pH on the sour taste of chicken broth was smaller than that of lactic acid (Table 3).

The sensory evaluation results in this study showed that the umami taste was stronger in the broiler broth than in the *Choshu-Kurokashiwa* broth for both breast and leg meat (Table 2). This is in agreement with a previous study (Horinouchi *et al*., 2016). There were significant differences in odor intensity, chicken meat-like odor, baked odor, flavor/taste intensity, umami taste, and sweet taste between the parts, except for sour taste. In addition, an interaction between chicken breed and part of the chicken meat-like odor was observed. Future studies should characterize the volatile compounds and sugars that may contribute to the sensory attributes of *Choshu-Kurokashiwa* and broiler meat.

Lopez *et al*. (2011) reported the pH values of breast meat for sexes and showed that female broilers had a slightly lower ultimate pH than males (5.87 vs. 5.94). In the present study, the sex of broilers was unknown. However, because the sex differences in pH of broiler meat broth predicted from the study described by Lopez *et al*. (2011) was smaller than the differences between broiler and *Choshu-Kurokashiwa* (Table 3), the effect of sex differences on the sour taste score is probably negligible.

The effects of fatty acids were not considered in this study. According to Kiyohara *et al*. (2011), arachidonic acid contributes to the palatability of *Hinai-jidori* chickens. Oleic acid is also a preferred fatty acid in meat (Choe *et al*., 2010), while docosahexaenoic acid has been shown to suppress sourness and bitterness and enhance umami intensity (Koriyama *et al*., 2002). In the future, it will be necessary to cook meat with the fat retained and conduct the sensory evaluation.

In conclusion, in the present study, I demonstrated that lactic acid content is an essential indicator for determining the sour taste of *Choshu-Kurokashiwa* breast broth. On the other hand, for leg broth, the lactic acid content is not important for the *Choshu-Kurokashiwa*-like taste because the trained panel could not discriminate the intensity of the sour tastes between the *Choshu-Kurokashiwa* and broiler. Although sour taste in breast meat is one of the major characteristic tastes of *jidori* breast meat, preference of the consumers for the sour taste derived from lactic acid of *jidori* meat is unclear. Future studies should investigate the effect of the lactic acid content of *jidori* meat on consumer preference before using it as an indicator for breeding *jidori*.

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Author Contributions

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Conflict of Interest

The author declares no conflict of interest.

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