academicJournals

Vol. 8(47), pp. 2281-2288, 18 December, 2013
DOI: 10.5897/SRE11.2195
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Measurement of trimethylamine contents and evaluation of pig meat natural quality by spectrophotometric method

Mohammod Abdul Hamid[1], Xi Wang[1,2] and Xingbo Zhao[1]*

[1]National Engineering Laboratory for Animal Breeding, Ministry of Agriculture, Key Laboratory of Animal Genetics and Breeding, College of Animal Science and Technology, China Agricultural University, 100193, Beijing, China.
[2]Institute of Animal Science and Veterinary Medicine, Shanxi Academy of Agricultural Science, 030000, Taiyuan, China.

Accepted 4 December, 2013

Pig meat off-flavor was attributed to trimethylamine (TMA) contents, and to evaluate pig meat natural quality at different breeds, genders and days is reported. In this study, total 49 leg meat samples were used to assay TMA contents and 18 for measurement of TMA threshold to evaluate the natural quality. Xiang Mini pig contained the lowest TMA value (11.31±0.25 µg/g) in the four tested breeds, whose meat tasted more delicious. The TMA value of uncastrated male was significantly higher than castrated male and female. The TMA threshold for smell-off was about 25 µg/g and it was found at the middle of the 3rd day. The natural quality such as, appearance, flavor, color and overall acceptability scores declined significantly during four days storage time (P<0.01). As a conclusion, native pigs, castrated males, meat storage up to 34 h in room temperature contained lower TMA value, tasted better in flavor and highly acceptable.

Key words: Pig meat, off-flavor, trimethylamine, native breed.

INTRODUCTION

Trimethylamine (TMA), $(CH_3)3N$ is a tertiary amine which is gaseous at normal temperature and has a characteristic smell of rotting fish. Trimethylamine content is an indicator of meat/fish quality, and picric acid reaction to form an intensely yellow coloured pi-complex and is a standard method for its determination (Francisco et al., 2010). Off-flavors in pork can sometimes be described as having a sour, fishy, metallic or other non-typical flavors including boar taint (Jeremiah et al., 1990; Xue et al., 1997). The pig meat have different aroma because of different breeds, genders, age, diet and carcass handling techniques (Cross et al., 1984; Sabine et al., 2005), but the basic factor is the TMA content which determines the flavor of meat and it is also an important fact which determines the natural quality of meat. TMA value is also associated with some genetic factors (Larzul et al., 1997). Loss of function mutations in flavin containing mono-oxygenase 3 (FMO3) are known to be associated with a fishy off-flavor in chicken eggs (Bolton et al., 1976; Honkatukia et al., 2005) and cow's milk (Lundén et al., 2002a, b) and also in humans, which is called Trimethylaminuria (TMAU) or 'fish-odor syndrome' (Zhang et al., 1995; Dolphin et al., 1997).

The consumption of meat and meat products mostly depends on color, appearance, flavor and taste (Risvik, 1994; Van Oeckel et al., 1999; Davoli and Braglia, 2007).Pig meat natural quality such as, color, appearance, flavor and acceptability and TMA content is

*Corresponding author. E-mail: zhxb@cau.edu.cn. Tel: +86-010-62733417. Fax: +86-010-62733417.

mostly dependent on storage time of meat.

In this study we described trimethylamine contents and some natural quality in pig meat, and aims to evaluate the influence of flavor and acceptability of meat storage at room temperature. Different fresh refrigerated leg meat samples from four different breeds and genders were used to test trimethylamine contents and also leg meat samples from three different breeds and genders, storage at room temperature for 1 to 4 days (0 to 72 h) were used for measurement of TMA threshold and natural quality of pig meat. Pig meat of native breeds is fragrant in smell and delicious in taste, and the price is higher than commercial breeds, but the growth is slow. On the other hand, commercial breeds grow fast, but the market price is always low and meat taste poor. In this study we took two native breeds named Xiang Mini pig and Jinhua pig and two commercial breeds named hybrid of Pie train and Landrace and hybrid of Yorkshire, Landrace and Duroc to detect TMA value and to evaluate natural quality. In this paper, we used only 100 mg meat, easy-to-derived and easy to operations.

MATERIALS AND METHODS

Collection of meat samples

Total of 49 leg meat samples from four different breeds and genders were collected including Xiang Mini pig (XM), Jinhua pig (JP), Hybrid of Pie train and Landrace (HPL) and Hybrid of Yorkshire, Landrace and Duroc (HYLD). All pigs were 1 year old with same feedstuff, and collected from Beijing and Hangzhou of China. The meat was obtained within 2 h of slaughter; the separable fat and connective tissue were removed, packed in low density polyethylene (LDPE) bags and transferred to the freezer at -20°C until it was processed. Pig numbers was shown in Table 1.

TMA threshold for pig meat off-flavor

In order to determine the TMA threshold for pig meat smell-off, meat samples were kept at room temperature (13 to 16°C) for different days (1 to 4) (0 to 72 h), scored and measured TMA content for each sample every 24 h and every 2 h at 3rd day from 30 to 40 h. 18 leg meat samples from three different breeds were collected including Xiang Mini pig (XM), female-3, male castrated -3, Jinhua pig (JP), female-3, male castrated -3 and hybrid of Yorkshire, Landrace and Duroc (HYLD), female-3, male castrated -3. Average TMA value was taken for each time.

Measurement of room temperature

For measurement of room temperature, the digital thermometer was used. It was placed on the wall of the room. Every day at the same time, the temperature was measured and recorded properly. The average temperature was 13 to 16°C.

Evaluation of meat appearance, flavor scores and overall acceptability

Meat samples were kept at room temperature (13 to 16°C) for different days (1 to 4) (0 to 72 h), and standard meat appearance, flavor and acceptability scores of meat was evaluated using 8-point descriptive scale, where 8=excellent, 1=extremely poor (Kandeepan et al., 2010). The experienced evaluation panel consisted of 30 scientists and post graduate students of College of Animal Science and Technology, China Agricultural University, Beijing, China, which judged the samples. The panelists were trained according to the guidelines of American Meat Science Association, 1995. The panelists evaluated the samples for flavor scores ranging from 1 to 8. Average scores were taken for each time.

Measurement of meat color

Meat color was measured for different days (1 to 4) (0 to 72 h), using star series equipment [Opto-star (SFK technology A/S, Denmark)] (Zhai et al., 2010). Surface color was measured at different locations. Results for individual meat samples for color showed an average of four readings across each sample surface.

Measurement of TMA content

The procedure for determination of TMA concentration in chicken meat was modified from those reported by Ward et al. (2009). 100 mg meat was collected in a 2-mL tube, 1 mL of 10% trichloroacetic acid (at 4°C) was added and quickly homogenized with homogenizer (PRO SCIENTIFIC INC., USA). The liquid was transferred into a 2-mL tube, 1 mL of 10% trichloroacetic acid with vibration was added, and centrifugated at 3000 g for 3 min. The supernatant was then added to 0.2 mL of 10% formaldehyde solution, 2 mL anhydrous toluene, 0.6 mL 1:1 potassium carbonate (K_2CO_3) solution, shook up and down for 10 min; the liquid of the toluene phase was transferred to a plastic tube and 0.2 g sodium sulfate anhydrous was added and mixed properly. After mixing, 1 mL liquid was transferred to a new plastic tube and 1 mL of 0.02% picric acid was added, forming the yellow TMA-N–picrate complex. 200 uL liquid was then transferred in a 96 well EIA/RIA plate (Corning Incorporated, USA) and measured photometrically at its maximum absorption wavelength of 410 nm in a spectrophotometer (TECAN infinite M200, Switzerland), with 10% trichloroacetic acid solution as blank control.

A standard curve was produced from 14 TMA standard solutions (ranging in concentration from 0 to 50 µg/mL of TMA-N) to calculate the TMA concentration of each meat sample (R^2=0.9984). The method was modified from Kretzschmar et al. (2007). 0.682 g of dry TMAH ($C_3H_9N·HCl$) was collected in a tube, 1 mL of HCl was added and dissolved with double distilled water up to 100 mL. 1.1905 mL was then taken from this solution and mixed with double distilled water up to 100 mL. That was the mother solution, and the concentration was 50 µg/mL TMA-N. The mother solution, was further diluted with double distilled water for 5, 10, 20, 30, 40 and 50 µg/mL respectively, which made the standard solution of TMA-N. The absorbance value obtained was 0.0698, 0.1089, 0.2394, 0.3342, 0.4484 and 0.5751 for each standard solution. The TMA concentration was then calculated from the TMA-N concentration (Figure 1).

Statistical analysis

General Linear Model (GLM) procedure of the SAS 9.1 program (Statistical Analysis System, 1999) was used for association analysis of TMA value, appearance, flavor and color scores and overall acceptability in different breeds, days and genders. The data

Table 1. Pig numbers for different breeds and genders.

Genders / Breeds	Females	Male castrated	Male uncastrated	Total
XM	5	5	-	10
JP	3	3	-	6
HPL	-	2	2	4
HYLD	9	20	-	29
totals	17	30	2	49

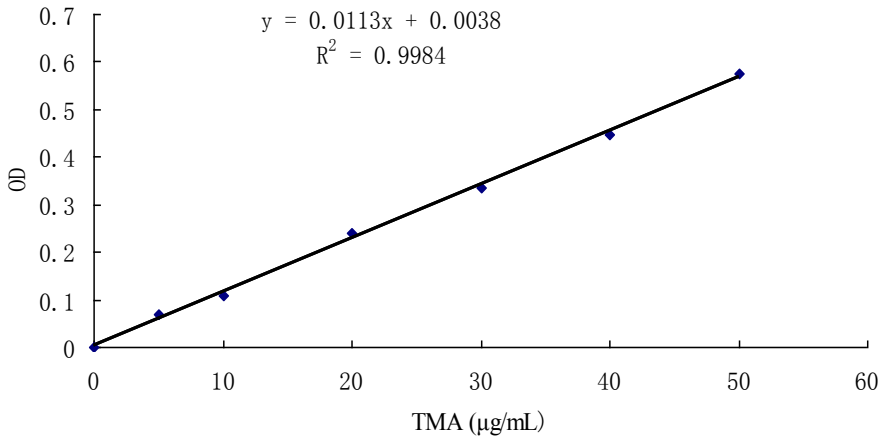

Figure 1. Standard curve for TMA content measurement.

were presented as the least squares means ±SEM (standard error of the mean). The significant difference of least squares means was tested with Bonferroni multiple range tests and P≤0.01 and P≤0.05 were considered statistically significant.

RESULTS

Pictures of pig meat at different days

Figure 2 shows the pictures of pig meat at different day's storage at room temperatures.

Meat TMA contents in different breeds and genders

49 pigs showed that HYLD had significantly higher TMA content (14.86±0.21 μg/g) than HPL (14.44±0.29 μg/g), JP (12.63±0.29 μg/g) and XM (11.31±0.25 μg/g) ($p<0.01$). The LSM difference between breeds HYLD and PHL, HYLD and JP, HYLD and XM was 0.42, 2.23 and 3.55 μg/g, respectively (Table 2).

Association analysis on genders showed that males uncastrated (17.02±0.48 μg/g) had significantly higher TMA value than males castrated (11.97±0.13 μg/g) and female (10.93±0.17 μg/g). The LSM difference between males uncastrated and males castrated, males uncastrated and female, males castrated and female was 5.05, 6.09 and 1.04 μg/g, respectively.

Threshold of TMA content to be off-flavor

The threshold TMA value of different breeds and days was analyzed and the least squares means (LSM), standard errors (ES) and levels of significance are presented in Tables 3 and 4. Association analysis showed that concentration of TMA in pig meat had significant associations with different days.

Association analysis on different days showed that day 1 (11.80±0.13 μg/g) had significantly lower TMA value than day 2 (16.82±0.13 μg/g), day 3 (29.65±0.13 μg/g) and day 4 (55.86±0.13 μg/g) ($p<0.05$). The LSM difference between days 1 and 2, 1 and 3, 1 and 4 was 5.02, 17.85 and 44.06 μg/g, respectively.

The average TMA value on day 1 (0 h) was 11.80±0.13 μg/g meat and the flavor was quite fresh. The 2nd day (after 24 h) TMA value was 16.82±0.13 μg/g meat and the flavor was also fresh. The 3rd day (after 48 h) TMA value was 29.65±0.13 μg/g meat and at this time meat contained off-flavor, something like a rotten fish, so we found out that the point of threshold TMA value would be 20 to 25 μg/g. So, on day 3 we measured TMA value for

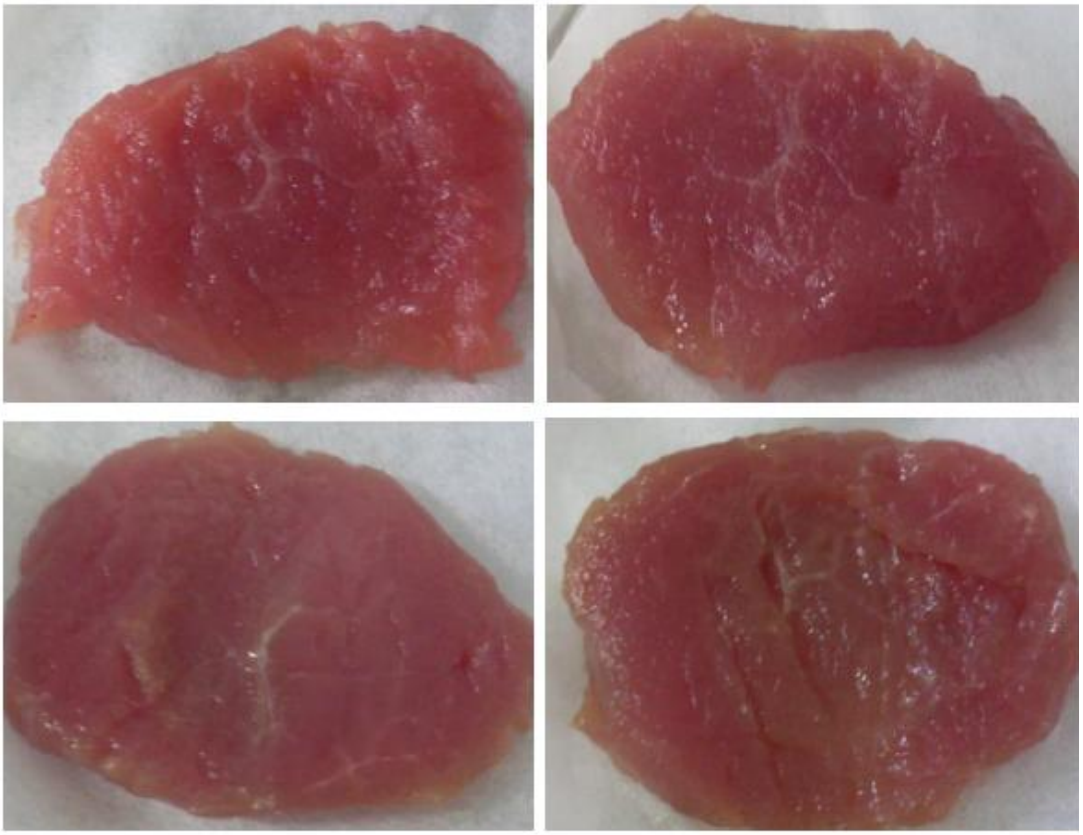

Figure 2. Pig meat of Xiang Mini pig storage at different days (i. left up- fresh refrigerated meat (day 1), ii. right up-day 2 (at 24 h), iii. left down-day 3 (at 48 h), iv. right down-day 4 (at 72 h).

Table 2. Meat TMA contents in different breeds and genders (μg/g).

Genders / Breeds	Females	Males castrated	Males uncastrated	Total
XM	8.76±0.17^{X}	10.14±0.17^{Y}	--	11.31±0.25^{C}
JP	9.85±0.19^{X}	11.07±0.19^{Y}	--	12.63±0.29^{B}
HPL	--	13.10±0.33^{X}	18.15±0.33^{Y}	14.44±0.29^{A}
HYLD	12.71±0.19^{X}	13.42±0.13^{Y}	--	14.86±0.21^{A}
Total	10.93±0.17^{X}	11.97±0.13^{Y}	17.02±0.48^{Z}	

XM=Xiang Mini pig, JP=Jinhua pig, HPL=Hybrid of Pie train and Landrace and HYLD=Hybrid of Yorkshire, Landrace and Duroc. The data were presented as the least squares means (LSM) ±SEM (standard errors of the mean). $^{A, B, C, D}$ means with different superscripts in the same column (column 5) indicated significant difference (P<0.01). $^{X, Y, Z}$ means with different superscripts in the same raw (columns 2, 3 and 4) indicated significant difference (P<0.01).

different hours (30 to 40 h) at 2 h interval.

Association analysis of appearance, flavor scores and overall acceptability in different breeds and days

Association analysis showed that appearance, flavor scores and overall acceptability in pig meat had significant associations with different breeds and days.

Association analysis showed that the appearance of pig meat on day 1(8.0±0.04) and day 2 (7.19±0.04) was better than day 3 (4.06±0.04) and day 4 (2.02±0.04). The LSM difference between days 1 and 2, 1 and 3, 1 and 4 was 0.81, 3.94 and 5.98.

Association analysis on different days showed that day 1 (7.97±0.05) had significantly higher flavor score than

Table 3. TMA contents (µg/g) with stayed meat in different days (every 24 h).

Treats/Breeds \ Days (Hours)		1 (0)	2 (24)	3 (48)	4 (72)
TMA (µg/g)	XM	10.58±0.11^{A}	15.28±0.11^{B}	27.97±0.11^{C}	53.25±0.11^{D}
	JP	11.42±0.12^{A}	16.72±0.12^{B}	29.6±0.12^{C}	55.45±0.12^{D}
	HYLD	13.40±0.15^{A}	18.45±0.15^{B}	31.38±0.15^{C}	58.87±0.15^{D}
	Together	11.80±0.13^{A}	16.82±0.13^{B}	29.65±0.13^{C}	55.86±0.13^{D}

XM=Xiang Mini pig, JP=Jinhua pig, HYLD=Hybrid of Yorkshire, Landrace and Duroc. The data were presented as the least squares means ±SEM (standard errors of the mean). $^{A, B, C, D}$ means with different superscripts in the same raw indicated significant difference (P<0.01).

Table 4. TMA contents (µg/g) with stayed meat in every 2 h (30 to 40 h).

Treats/Breeds \ Hours		30	32	34	36	38	40
TMA (µg/g)	XM	19.93±0.10^{A}	20.90±0.10^{B}	22.65±0.10^{C}	23.98±0.10^{D}	25.90±0.10^{E}	27.08±0.10^{F}
	JP	20.50±0.12^{A}	21.66±0.12^{B}	23.27±0.12^{C}	24.57±0.12^{D}	26.27±0.12^{E}	27.92±0.12^{F}
	HYLD	20.97±0.14^{A}	21.85±0.14^{B}	23.75±0.14^{C}	25.72±0.14^{D}	26.90±0.14^{E}	28.83±0.14^{F}
	Together	20.47±0.08^{A}	21.47±0.08^{B}	23.22±0.08^{C}	24.76±0.08^{D}	26.36±0.08^{E}	27.94±0.08^{F}

XM=Xiang Mini pig, JP=Jinhua pig, HYLD=Hybrid of Yorkshire, Landrace and Duroc. The data were presented as the least squares means ±SEM (standard errors of the mean). $^{A, B, C, D}$ means with different superscripts in the same raw indicated significant difference (P<0.01).

day 2 (6.70±0.05), day 3 (4.53±0.05) and day 4 (2.31±0.05) (p<0.01). The LSM difference between day 1 and 2, 1 and 3, 1 and 4 was 1.27, 3.44 and 5.66.

Association analysis showed that the pig meat had highly overall acceptability on day 1 (8.0±0.04) and day 2 (7.17±0.04) than day 3 (3.85±0.04) and day 4 (0.93±0.04). The LSM difference between days 1 and 2, 1 and 3, 1 and 4 was 0.83, 4.15 and 7.07.

Association analysis of meat color scores in different breeds and days

Association analysis showed that meat color scores had significant associations with different breeds and days.

Association analysis on different day showed that day 1 (53.34±0.39) had significantly higher meat color scores than day 2 (49.91±0.39), day 3 (47.13±0.39) and day 4 (44.51±0.39) (p<0.01). The LSM difference between days 1 and 2, 1 and 3, 1 and 4 was 3.43, 6.21 and 8.83.

The meat color of Xiang Mini pig was bright red, Jinhua pig was white red and Hybrid pig was red. So, the Opto-star value (color scores) was highest in Xiang Mini pig, 2nd highest in Hybrid pig and lowest in Jinhua pig.

DISCUSSION

The pictures of pig meat at different days are presented in Photo 1. Visually, we found out that pig meat changed their color and appearance according to storage time. The meat on day 1 was fresh refrigerated meat and was bright red color and good appearance. The color and appearance changed a little on day 2 (at 24 h). The meat changed more and looked like spoiled meat on day 3 (at 48 h) and day 4 (at 72 h) at room temperatures.

The TMA value of different breeds and genders, the least squares means, standard errors were shown in Table 2. Trimethylamine is a common product of corruption. The quality of meat is mostly dependent on TMA concentration. Ward et al. (2009) showed that the TMA value should be estimated as 4 µg/g in the egg yolk. However, there is variability in the ability of individuals to detect TMA (Griffiths et al., 1979). In this study, the TMA value of different breeds and genders had a wide range from 8.30 to 18.50 µg/g meat. The one reason is that the method of detecting TMA value had some error, and another reason is that there were some amines in the results to amplify the real TMA value.

Xiang Mini pig and Jinhua pig are famous local breeds, due to the fact that its meat is fragrant in smell and delicious in taste. Hybrid of Pie train and Landrace and hybrid of Yorkshire, Landrace and Duroc are cross breeds, and its meat is quite tasty. In this study the result showed that the effect of breed on TMA in pig was significant. Xiang Mini pig and Jinhua pig contains significantly lower TMA value 11.31±0.25 and 12.63±0.29 µg/g which is tastier than other pig meats. On the other hand, hybrid pigs contain significantly higher TMA value 14.44±0.29 and 14.86±0.21 µg/g which is less tasty.

Table 5. Associations of appearance, flavor scores and overall acceptability with different breeds and days.

Treats/Breeds \ Days (Hours)		1 (0)	2 (24)	3 (48)	4 (72)	Average
Appearance	XM	8.0±0.06^{A}	7.3±0.06^{B}	4.45±0.06^{C}	2.0±0.06^{D}	5.45±0.03
	JP	8.0±0.05^{A}	7.15±0.05^{B}	3.95±0.05^{C}	2.0±0.05^{D}	5.28±0.03
	HYLD	8.0±0.04^{A}	7.08±0.04^{B}	3.78±0.04^{C}	2.05±0.04^{D}	5.23±0.02
	Together	8.0±0.04^{A}	7.19±0.04^{B}	4.06±0.04^{C}	2.02±0.04^{D}	
Flavor scores	XM	8.0±0.05^{A}	6.98±0.05^{B}	4.90±0.05^{C}	2.48±0.05^{D}	5.59±0.03
	JP	8.0±0.06^{A}	6.73±0.06^{B}	4.75±0.06^{C}	2.40±0.06^{D}	5.47±0.03
	HYLD	7.93±0.06^{A}	6.38±0.06^{B}	3.95±0.06^{C}	2.05±0.06^{D}	5.08±0.03
	Together	7.97±0.05^{A}	6.70±0.05^{B}	4.53±0.05^{C}	2.31±0.05^{D}	
Overall acceptability	XM	8.0±0.05^{A}	7.35±0.05^{B}	4.15±0.05^{C}	0.98±0.05^{D}	5.12±0.02
	JP	8.0±0.05^{A}	7.15±0.05^{B}	3.75±0.05^{C}	0.92±0.05^{D}	4.95±0.03
	HYLD	8.0±0.06^{A}	7.02±0.06^{B}	3.65±0.06^{C}	0.90±0.06^{D}	4.89±0.03
	Together	8.0±0.04^{A}	7.17±0.04^{B}	3.85±0.04^{C}	0.93±0.04^{D}	

XM=Xiang Mini pig, JP=Jinhua pig, HYLD=Hybrid of Yorkshire, Landrace and Duroc. The data were presented as the least squares means ±SEM (standard errors of the mean). Here, $^{A, B, C, D}$ means with different superscripts in the same row indicate significant difference (P<0.01). *Based on 8 point descriptive scale.

Traditionally in China, people often had male pig castrated to get more delicious meat, and in this study, we got the result that the TMA value of female (10.93±0.17 µg/g) and castrated male (11.97±0.13 µg/g) was significantly lower than uncastrated male (17.02±0.48 µg/g). So more study is needed to prove that the more delicious meat had the less TMA. In 1979, Pearson and Butler found that the TMA oxidation defect is present in both male and female chicks and there is no difference between the genders in regards to their sensitivity to rapeseed meal. More study is needed to collect male and female pig and compare the TMA value of them.

In human, Cashman et al. (2003) found that in unaffected individuals, TMA composes 0 to 9% of total urinary trimethylamines (that is, TMA + TMAO), whereas TMA comprises greater than 40% of the total urinary trimethylamines in individuals with severe trimethylaminuria.

Lundén et al. (2002b) found that TMA concentration in milk from one of the homozygous mutants was shown to vary between 1 and 16 mg TMA/kg milk within a single lactation. They also mentioned that fishy off-flavor was influenced by environmental factors such as the presence of TMA precursors or FMO inhibitors in the feed.

The threshold TMA value of different breeds and days, the least squares means, standard errors were shown in Tables 3 and 4. The result showed that the TMA value increased significantly (P<0.01) for different breeds and days. The TMA value of days 1 and 2 were 11.80±0.13 and 16.82±0.13 µg/g meat, respectively and the flavor was fresh. The TMA value of day 3 was 29.65±0.13 µg/g meat and at this time meat contained off-flavor, something like a rotten fish, so again we measured TMA value for different hours (30 to 40 h) at 2 h interval at 3rd day.

The result showed that the TMA values for 30, 32 and 34 h in room temperature were 20.47±0.08, 21.47±0.08 and 23.22±0.08 µg/gmeat, respectively and the flavor was also fresh. At 36 h, the TMA value was 24.76±0.08 µg/g meat and at this time meat contained off-flavor, something like a rotten fish, so we found out the point of threshold TMA value was about 25 µg/g.

The appearance, flavor scores and overall acceptability in pig meat, the least squares means, standard errors were shown in Table 5. The appearance, flavor scores and overall acceptability of meat declined significantly (P < 0.01) during 4 days storage time. The result showed that the appearance, flavor and overall acceptability of pig meat was 8.0±0.04, 7.97±0.05, 8.0±0.04 on day 1; 7.19±0.04, 6.70±0.05 and 7.17±0.04 on day 2 and 4.06±0.04, 4.53±0.05 and 3.85±0.04 on day 3. The steep decline in flavor scores were attributed to the liberation of fatty acids (Branen, 1979), oxidation of fat (Santamaria et al., 1992). An abrupt reduction in overall acceptability during 4 days storage time was mainly attributed to decline in flavor in pig meat. As our observation, the natural quality of meat was acceptable on day 1, day 2 and early 10 h of 3rd day.

The color scores in pig meat, the least squares means, standard errors were shown in Table 6. The color scores of meat declined significantly (P < 0.01) during four days storage time. The decline in color scores during storage time was due to lipid oxidation and subsequent oxidized compounds reacting with amino acids during non-enzymatic browning of the product (CheMan et al., 1995). In our experiment, the meat color was different according

Table 6. Associations of meat color scores with different breeds and days.

Treats/Breeds \ Days (Hours)		1 (0)	2 (24)	3 (48)	4 (72)	Average
Meat color scores	XM	65.28±0.34^{A}	59.36±0.34^{B}	54.73±0.34^{C}	51.37±0.34^{D}	57.69±0.17
	JP	44.95±0.36^{A}	42.03±0.36^{B}	40.23±0.36^{C}	37.60±0.36^{D}	41.20±0.18
	HYLD	49.78±0.26^{A}	48.33±0.26^{B}	46.42±0.26^{C}	44.57±0.26^{D}	47.28±0.13
	Together	53.34±0.39^{A}	49.91±0.39^{B}	47.13±0.39^{C}	44.51±0.39^{D}	

XM=Xiang Mini pig, JP=Jinhua pig, HYLD=Hybrid of Yorkshire, Landrace and Duroc. The data were presented as the least squares means ±SEM (standard errors of the mean). Here, $^{A, B, C, D}$ means with different superscripts in the same row indicate significant difference ($P<0.01$).

to different breeds. The meat color of Xiang Mini pig was bright red, Jinhua pig was white red and Hybrid pig was red. As our finding, the color scores were changed during storage time.

The advantages of this method is previous methods used more samples (20 g or so), hence it is difficult to collect. Meat samples used in this method was less, only 100 mg, easy-to-derive, reagent used in this process was small amount, hence it is easy to operate and save cost of experiment.

The results implied that the TMA concentration, appearance, flavor and color are most important factors of meat quality. As our result, TMA concentration, appearance, flavor and color were mostly dependent on meat storage time.

Conclusions

This study analyzed the TMA content, appearance, flavor, meat color and overall acceptability in pig meat. The result showed that native breed and fresh meat contained lower TMA value, good flavor and highly acceptable. The acceptable TMA concentration in pig meat was 1 to 23 µg/g. The results supplied valuable information of TMA content and off-flavor which is related to natural meat quality and encourage performing further study of TMA content and off-flavor, which might reveal association to meat quality.

ACKNOWLEDGEMENT

This work was supported by the National Natural Science Foundation of China (Grant No. 31072017).

REFERENCES

Bolton W, Carter TC, Morley JR (1976). The hen's egg: genetics of taints in eggs from hens fed on rapeseed meal. Br. Poult. Sci. 17:313-320.

Branen AL (1979). Interaction of fat oxidation and microbial spoilage in muscle foods. Proceedings of the 31st Annual Reciprocal Meat Conference, pp. 156-161.

Cashman JR, Camp K, Fakharzadeh SS, Fennessey PV, Hines RN, Mamer OA, Mitchell SC, Preti G, Schlenk D, Smith RL, Toja SS, Williams DE, Yannicelli S (2003). Biochemical and clinical aspects of the human flavin-containing monooxygenase form 3 (FMO3) related to trimethylaminuria. Curr. Drug Metab. 4:151-170.

CheMan YB, Bakar J, Mokri AAK (1995). Effect of packaging films on storage stability of intermediate deep fried mackerel. Int. J. Food Sci. Technol. 30:175-179.

Cross HR, Crouse JD, MacNeil MD (1984). Influence of Breed, Sex, Age and Electrical Stimulation on Carcass and Palatability Traits of Three Bovine Muscles. J. Anim. Sci. 58:1358-1365.

Davoli R, Braglia S (2007). Molecular approaches in pig breeding to improve meat quality. Brief. Funct. Genom. Proteom. 6:313-321.

Dolphin CT, Janmohamed A, Smith RL, Shephard EA, Phillips IR (1997). Missense mutation in flavin-containing mono-oxygenase 3 gene, FMO3, underlies fish-odour syndrome. Nat. Genet. 17:491–494.

Francisco P, Isela L, Carlos B (2010). Colorimetric assay for determination of trimethylamine-nitrogen (TMA-N) in fish by combining headspace-single-drop microextraction and microvolume UV–vis spectrophotometry. Food Chem. 119:402–407.

Griffiths NM, Land DG, Hobson-Frohock A (1979). Trimethylamine and egg taint. Br. Poult. Sci. 20: 555-558.

Honkatukia M, Reese K, Preisinger R, Tuiskula-Haavisto M, Weigend S, Roito J, Mäki-Tanila A, Vilkki J (2005). Fishy taint in chicken eggs is associated with a substitution within a conserved motif of the FMO3 gene. Genomics 86:225-232.

Jeremiah LE, Murray AC, Gibson LL (1990). The Effects of Differences in Inherent Muscle Quality and Frozen Storage on the Flavor and Texture Profiles of Pork Loin Roasts. Meat Sci. 27:305–327.

Kandeepan G, Anjaneyulu ASR, Kondaiah N, Mendirattal SK (2010). Quality of buffalo meat keema at different storage temperature. Afr. J. Food Sci. 4(6):410-417.

Kretzschmar K, Reese K, Honkatukia M, Eding H, Preisinger R, Karl H, Danicke S, Weigend S (2007). Effect of flavin containing monooxygenase (FMO3) genotype on trimethylamine (TMA) content in the chicken egg yolk. Arch. Geflugelkd. 71:200-206.

Larzul C, LeRoy P, Gueblez R, Talmant A, Gogue J, Sellier P (1997). Effect of halothane genotype (NN, Nn, nn) on growth, carcass and meat quality traits of pigs slaughtered at 95 kg or 125 kg live weight. J. Anim. Breed. Genet. 114(4):309-320.

Lundén A, Gustafsson V, Imhof M, Gaush R, Bosset JO (2002a). High trimethylamine concentration in milk from cows on standard diets is expressed as fishy off-flavour. J. Dairy Res. 69:383-390.

Lundén A, Marklund S, Gustafsson V, Andersson L (2002b). A nonsense mutation in the FMO3 gene underlies fishy off-flavor in cow's milk. Genome Res. 12:1885-1888.

Pearson AW, Butler EJ (1979). Rapeseed meal and egg taint: Demonstration of the metabolic defect in male and female chicks. Vet. Rec. 104:318-319.

Risvik E (1994). Sensory properties and preferences. Meat Sci. 36:67-77.

Sabine S, Jana P, Eva W (2005). Influence of production system, age and sex on carcass parameters and some biochemical meat quality

characteristics of rein deer (*Rangifer tarandus tarandus* L.). Rangifer. 25(2):85-96.
Santamaria L, Lizarraga T, Astiasaran I, Bello J (1992). Characterization of pamplona chorizo sausages, physico-chemical and sensory studies. Revists-Espanole-de-Ciencis-y-Technologis-de-Alimentos 32:431-445.
Van Oeckel MJ, Warnants N, Boucque ChV (1999). Measurement and prediction of pork colour. Meat Sci. 52:347-354.
Ward AK, Classen HL, Buchanan FC (2009). Fishy-egg tainting is recessively inherited when brown-shelled layers are fed canola meal. Poult. Sci. 88(4):714-21.
Xue JL, Dial GD (1997). Raising intact male pigs for meat: Detecting and preventing boar taint. Swine Health Prod. 5(4):151-158.
Zhai LW, Wang LX, Zhou WL, Wang CD (2010). Association of the MTPN gene polymorphisms with meat quality in commercial pigs. J. Anim. Vet. Adv. 9(4):705-709.
Zhang AQ, Mitchell S, Smith R (1995). Fish odour syndrome: Verification of carrier detection test. J. Inherit. Metab. Dis. 18:669-674.