Evaluation of the lean meat colour of commercial pigs produced in Quebec

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Hammell, K. L., Laforest, J. P. and Dufour, J. J. 1994. **Evaluation of the lean meat colour of commercial pigs produced in Quebec.** Can. J. Anim. Sci. **74**: 443–449. Data from a total of approximately 2900 commercial pigs tested in 12 trials from 1987 to 1990 at the Beaumont test station in Quebec were used to determine the effect of sex, sire breed, cross type and parity number of the dam on meat colour. Pigs were housed four to a pen and fed commercial diets. Meat colour measurements were taken 24 h or 72 h after slaughter in a commercial abattoir. The sex of the pigs had no major effect on any of the meat colour measurements. Commercial pigs sired by Hampshire or Hampshire-Duroc boars had characteristics of the loin and ham associated with a paler meat (lower ultimate pH and a higher Luminosity L*) than pigs sired by Landrace, Yorkshire or Duroc boars. A Chi-square analysis of the data indicates that the meat from pigs sired by Hampshire or Hampshire-Duroc boars was more often classified within the colour standards 1 and 2, and less often classified within the colour standards 4 and 5 than the meat from pigs sired by Landrace, Yorkshire or Duroc boars. Four-way cross and especially synthetic cross pigs had a paler meat than single cross, backcross and three-way cross pigs. Overall, less than 3% and less than 1% of the pigs produced meat with a colour standard of 1 (extremely pale) or 5 (extremely dark), respectively. Parity number of the dam did not affect meat colour. A factor analysis and Pearson's coefficients of correlation between the meat colour characteristics indicate that taking the same measurements on both the loin and ham muscle add relatively little information on meat colour. It appears that measuring the pH, the luminosity L* and the chromaticity value a* on either the loin or the ham muscle could be sufficient for an acceptable estimation of meat colour of commercial pigs from the present study.

Key words: Pig, meat colour, pH

Hammell, K. L., Laforest, J. P. and Dufour, J. J. 1994. **Évaluation de la couleur de la viande des porcs commerciaux au Québec.** Can. J. Anim. Sci. **74**: 443–449. Environ 2900 porcs commerciaux ont été évalués à la Station d'épreuve de Beaumont, Québec, à l'intérieur de 12 tests effectués entre 1987 et 1990. Les porcs étaient groupés à quatre par parquet et alimentés d'une moulée commerciale. Les mesures de couleur de la viande ont été prises 24 et 72 h après l'abattage dans un abattoir commercial. Le sexe de l'animal n'a pas eu d'effet substantiel sur les mesures de qualité de la viande. Les porcs commerciaux issus de verrats Hampshire ou Hampshire-Duroc présentaient une viande de la longe et du jambon plus pâle (pH ultime plus bas et une luminosité L* plus élevée) que ceux issus de verrats Landrace, Yorkshire ou Duroc. Une analyse du chi-carré montre que la viande des porcs issus de verrats Hampshire et Hampshire-Duroc présente plus fréquemment une norme de couleur 1 et 2 et moins fréquemment une norme de couleur 4 et 5 que la viande des porcs issus de verrats Landrace, Yorkshire ou Duroc. Les porcs provenant d'un croisement de quatre races et surtout les porcs provenant d'un croisement synthétique ont une viande légèrement plus pâle que ceux issus d'un croisement simple, croisement de retour ou croisement de trois races. Globalement, moins de 3% et moins de 1% des porcs étudiés donnaient une viande dont la norme de couleur était de 1 (très pâle) ou de 5 (très foncée), respectivement. Le numéro de portée n'avait pas d'effet notable sur la couleur de la viande. Les mesures effectuées sur le muscle de la longe et du jambon sont partiellement redondantes, comme le montre l'analyse de variance et les corrélations de Pearson. Il semble que les mesures du pH, de la luminosity L* et de la valeur de chromaticité a*, prises soit à la longe ou au jambon, décrivent adéquatement la qualité de la viande des porcs commerciaux de la présente étude.

Mots clés: Porcs, couleur de la viande, pH

Production efficiency providing pigs of good carcass and meat quality determines the viability and competitiveness of the swine sector. The swine industry must not only be efficient in pig production, it has to also produce the best possible meat quality. Quebec, through its Ministry of Agriculture (MAPAQ), implemented during the 1980's an evaluation program for commercial pigs produced in Quebec, the "Programme d'évaluation des porcs commerciaux, inc." (PEPC). One of the mandates of this program is to evaluate the meat quality of commercial pigs raised in a test station. The program takes into account factors that could have an effect on meat quality such as the sex and genotype of an animal. The main objective of the program is to propose future production guidelines in order to improve swine production and the quality of the meat produced.

The term "meat quality" is relatively hard to define and can cover a vast number of characteristics that vary according

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to user categories. Consumers prefer meat with low amounts of fat and an appetizing appearance, whereas the meat processing industry values meat that keeps well and that can be processed into many different meat end-products (ITP France 1987). Therefore, handling and eating quality characteristics of pork are likely to become increasingly important economic traits in the future (Lo et al. 1992).

Good water retention, colour, texture and preservation are all characteristics of a meat that will give the best possible results in terms of yield and meat quality (ITP France 1987). In the present study, the ultimate pH (24 h), the colour, as measured by the Minolta Chroma meter (luminosity L* and chromaticity values a* and b*), as well as a visual appraisal according to the colour standards of Agriculture Canada (1984; scale 1–5) were used to evaluate lean meat colour of market pigs of different sexes, genetic breeds and crosses and from different parity sows. Knowledge of breed effects on carcass and quality traits is required for the development of commercial crossbreeding programs that emphasize product quality (Lo et al. 1992).

MATERIALS AND METHODS

Description of the Tests

Between January 1987 and November 1990, 12 trials (trials 3–14) were conducted at the test station, Beaumont, Quebec, using 112–318 pigs in each trial. Approximately 2900 pigs from different farms, breeds and sexes were used during different periods of the year. Each participant or farm generally provided 16 pigs that were housed four to a pen. Within each pen, the pigs were full-sibs of the same sex. The breed of the sire and dam, the birth date and the parity number were known for each pig tested. The animals used in our experiment were cared for under guidelines comparable to those laid down by the Canadian Council of Animal Care.

All pigs were fed ad libitum a pelleted starter diet (3220 kcal kg^{-1} DE, 17.9% or 19.7% protein for trials 3–5 and 6–14, respectively) for a period of 3–6 weeks (3 wk: trials 13–14; 4 wk: trial 7; 5 wk: trials 3, 8–12; 6 wk: trials 4–6), and then a grower diet (3,250 kcal kg^{-1} DE, 16.9% protein for all trials) until the end of test. Average feed intake was measured weekly on a per-pen basis. Pigs had free access to drinking water.

At the end of test, the pigs were trucked to a commercial abattoir, slaughtered the next day, chilled for 24 h, then cut-up the day following slaughter, according to standard commercial slaughter practices (Anonymous 1972). Measurements were made on the meat the day after slaughter (24 h after slaughter: trials 3–8; 72 h: trials 9–14). All the measurements were taken by the same technician. The pH (pH meter Fisher model 119 3D, electrode orion #H5815-9) was taken on the longitudinal surface of the loin (Longissimus dorsi), at the same location where fat thickness was measured on the carcass (between the last third and fourth ribs, 7 cm from the dorsal median line of the carcass), and on a freshly exposed longitudinal section of the ham muscle (Semi membranosus). Luminosity L* and chromaticity values a* and b* (Minolta Chroma meter CR-200b) were also measured adjacent to where the pH was taken. High luminosity L* indicates a paler muscle, whereas a low value is associated with darker muscles. Chromaticity values a* and b* represent, respectively, the hue and chroma of the meat. Meat colour was also assessed visually on the exposed surface of the loin and scored according to the standards of Agriculture Canada (1984: values of 1–5). A colour standard of 1 corresponds to an extremely pale coloured meat, whereas a colour standard of 5 corresponds to an extremely dark coloured meat. Since the texture of the meat was not evaluated in the present study it is not possible to assume that meat with a colour standard of 1 is PSE and that meat with a colour standard of 5 is DFD.

Measurements and Statistical Analysis

Meat colour and pH measurements were recorded on each pig. For the first part of the analysis, factors of variation studied were sex and sow parity. Also, the effect of different sire breeds bred to Landrace × Yorkshire crossed sows was analyzed (in order of decreasing number of breeds of boars used these were DDLY, HDLY, LLLY, YYLY and HHLY). Finally, the effect of different types of genetic crosses was also analyzed. Six types were kept: no cross (purebred: LLLL, DDDD); single cross (two breeds: YYLL, LLYY, DDLL, LLWW, WWLL); backcross (two breeds: LLLY, LLHL, HHHL, YYLY); Three-way cross (three breeds: HHLY, DDLY, BBLY); four-way cross (four breeds: HDLY); and a synthetic cross (S9S9). The first two letters for each genetic type correspond to the breed of the boar, the other two to the breed of the sow (B, Berkshire; D, Duroc; H, Hampshire; L, Landrace; S9, Synthetic; Y, Yorkshire; W, Large White).

The general linear model procedure of the Statistical Analysis System Institute, Inc. (1985) was used for statistical analysis. The model used for analyzing the effect of sex, parity number, sire breed and cross type was the following:

$$Y_{ijk} = \mu + T_i + V_j + (TV)_{ij} + e_{ijk}$$

where Y_{ijk} is the individual observation of the ith trial (T), the jth factor of variation (V) and the kth animal and μ is the overall mean. All main effects are fixed except for the error e_{ijk}, which is an independent random variable normally distributed with mean of 0 and variance σ^2. The proportions of pigs with meat classified in each of the 5 colour standards were compared with a Chi-square for each effect studied. Certain trials were eliminated in the statistical analysis so that each level of each source of variation (e.g. castrated males and females for the variable of sex), was represented in all trials.

For the second part of the analysis, a factor analysis for principal components followed by a varimax rotation using the factor procedure of SAS Institute, Inc. (1985) was applied to all the variables used to estimate meat colour, including also the pH. Pearson's correlation coefficients were also taken to study the relation between the different measures of meat colour. Trials kept to analyze the meat colour data are shown in Table 1.

Table 1. Trials kept for the statistical analysis according to the effect analyzed (trials number 1 and 2 were not kept for any of the analysis)

	Factor of variation			
Trial	Sex[z]	Parity number[y]	Sire breed[x]	Cross type[w]
3		X	X	
4			X	X
5		X	X	
6	X		X	X
7		X	X	
8		X		X
9	X		X	
10	X	X	X	X
11		X		X
12			X	X
13			X	
14		X	X	

[z] Trials, 6, 9 and 10 had approximately the same number of castrated males and females, whereas the others had either only castrated males or only females.
[y] In the discarded trials, at least one of the parity numbers to be compared was missing.
[x] In the discarded trials at least one sire breed to be compared was missing.
[w] In the discarded trials at least one genetic type to be compared was missing.

RESULTS AND DISCUSSION

Effects of Variation Factors on Meat Colour

SEX. There was no difference ($P > 0.05$) between trials for all the meat colour variables, nor was there a difference between sexes ($P > 0.05$; Table 2). Langlois and Minvielle (1989) reported a higher pH and a darker meat colour for the females. Sather et al. (1991) also reported a darker meat colour for the gilts, but no difference between the sexes for the pH. In contrast, Gueblez et al. (1990) reported that the castrated males had a higher pH than the females. Christian et al. (1980), Schneider et al. (1982) and Murray et al. (1989) did not find a difference between sexes for the meat colour, as in the present study. Christian et al. (1980) and Schneider et al. (1982) used a visual colour scale from 1 to 5 as in the present study. Langlois and Minvielle (1989), as well as Murray et al. (1989), used reflectance metres different from the one used in the present study, whereas Sather et al. (1991) used the same type of reflectance metre, but obtained results different from those of the present study concerning the effect of sex on meat colour. Langlois and Minvielle (1989) suggested that the paler meat from castrated males is partly due to the higher fat content in the loin than for the females (Bereskin and Frobish 1982; Martel et al. 1988). The castrated males used in the present study had thicker backfat than the females but intramuscular fat content was not evaluated (Hammell et al. 1993).

Castrated males and females presented the same proportions of animals with pale and dark meat (Table 3; $\chi^2 = 3.445$; $P = 0.4864$). When the results from both sexes were put together, only 1.1% of the pigs kept to evaluate the effect of sex on meat colour had extremely pale meat and only 0.7% had extremely dark meat.

SIRE BREED. Independent of sire breed, there was a difference ($P < 0.0001$) between trials for all the meat colour variables. Sire breeds influenced ($P < 0.05$) the pH of the loin and ham, the luminosity L* of the loin, the chromaticity values a* and b* of the loin and ham and the colour standard (Table 2).

The YYLY, LLLY and DDLY pigs had a darker meat colour, measured with the colour standards, than the HHLY and HDLY pigs. The DDLY and LLLY pigs had a higher loin pH than the HHLY and the HDLY pigs; the YYLY pigs being intermediate. Results for the pH of the ham were similar to those for the pH of the loin, except for the YYLY which had the same pH as the LLLY and DDLY pigs. Minvielle and Savoie (1986) reported that in general, the pH was lower for the HHLY and higher for the YYLY pigs, which resembles what was observed in the present study. Langlois and Minvielle (1989) did not find, however, any breed difference for the pH of the loin or ham measured 24 h after slaughter. Nevertheless, they did report that the pH measured 45 min after slaughter was lower for Landrace than Duroc or Hampshire pigs; Yorkshire pigs being intermediate. Lo et al. (1992) found no difference in pH of the loin between Duroc and Landrace pigs. Similarly, the meat pH of commercial pigs with Duroc and Landrace sires was not different in the present study.

The HHLY pigs produced a paler loin colour (luminosity L*) than the other sire breeds. Chromaticity values a* for the loin were higher for HDLY than for DDLY, LLLY and YYLY pigs; HHLY pigs being intermediate. Chromaticity values a* for the ham were higher for HHLY and HDLY pigs; the other pigs thus having lower values. Chromaticity values b* for the loin were higher for HHLY and HDLY pigs. The DDLY and YYLY pigs had the lowest chromaticity values b* with LLLY pigs being intermediate. Finally, the chromaticity values b* for the ham were superior for the HHLY than for all the other breeds, except HDLY pigs which were intermediate. Langlois and Minvielle (1989) found Hampshire and Duroc breeds generally had a darker meat colour than Yorkshire and Landrace breeds. On the contrary, the results of Sellier (1981) and ITP France (1987), as in the present study, reported that Hampshire boars produced progeny having lower ultimate pH and paler meat colour than the other breeds, although sows in the study of Sellier (1981) were a French Landrace × Large White cross. In the present study, commercial pigs from Hampshire and Hampshire × Duroc crosses had a paler meat colour, a lower pH, a higher luminosity L*. They also had higher chromaticity values a* and b* than for the other breeds.

In proportion to the global population of pigs retained for the analysis of the effect of sire breed on meat colour, pigs from Hampshire and Hampshire-Duroc boars had paler meat than pigs from Landrace, Yorkshire and Duroc boars (Table 3; $\chi^2 = 35.783$; $P = 0.0031$). Nevertheless, when the results from all sire types are put together, only 4.3% of the pigs sired by Hampshire boars and 5.3% of the pigs sired by Hampshire-Duroc boars had extremely pale meat compared with 1.8% for the pigs sired by Landrace, Yorkshire and Duroc boars.

CROSS TYPE. Independent of cross type, there was a difference ($P < 0.0001$) between trials for all the variables.

Table 2. Effect of sex, sire breed and cross type[z] on meat colour of commercial pigs in Québec

	pH loin[y]	pH ham	Colour standard	Luminosity L* loin	Chromaticity a* loin	Chromaticity b* loin	Luminosity L* ham	Chromaticity a* ham	Chromaticity b* ham
				Experiment I: sex					
Castrated male	5.67	5.76	2.95	50.4	4.60	4.25	51.2	4.62	3.90*f*
	(261)	(261)	(288)	(276)	(168)	(168)	(276)	(168)	(168)
Gilt	5.68	5.80	3.00	50.6	4.43	4.04	50.7	4.58	3.51*g*
	(262)	(261)	(279)	(261)	(159)	(159)	(261)	(159)	(159)
SE LSM	0.01	0.02	0.04	0.27-0.28	0.11-0.12	0.13-0.14	0.27-0.29	0.13-0.14	0.13-0.14
				Experiment II: sire breed (dam LY)					
LL	5.67*c*	5.82*b*	3.03*b*	49.9*a*	4.48*a*	4.05*bc*	49.5	4.76*a*	3.13*ab*
	(131)	(131)	(138)	(90)	(64)	(64)	(96)	(70)	(70)
YY	5.66*bc*	5.84*b*	3.05*b*	49.4*a*	4.08*a*	3.29*a*	50.5	4.50*a*	3.01*a*
	(144)	(143)	(150)	(116)	(89)	(89)	(122)	(95)	(95)
HD	5.60*ab*	5.67*a*	2.75*a*	50.0*a*	5.32*b*	4.28*c*	50.7	5.39*b*	3.59*bc*
	(164)	(164)	(189)	(135)	(98)	(98)	(136)	(99)	(99)
HH	5.58*a*	5.68*a*	2.58*a*	52.0*b*	5.10*b*	4.64*c*	51.6	5.89*b*	4.22*c*
	(155)	(155)	(162)	(112)	(61)	(61)	(112)	(61)	(61)
DD	5.70*c*	5.81*b*	2.92*b*	49.3*a*	4.62*a*	3.63*ab*	50.4	4.55*a*	3.00*a*
	(205)	(205)	(223)	(201)	(108)	(108)	(202)	(108)	(108)
SE LSM	0.02	0.02-0.03	0.04-0.06	0.27-0.44	0.12-0.19	0.12-0.19	0.25-0.42	0.11-0.17	0.11-0.17
				Experiment III: cross type					
Purebred	5.62*abc*	5.74*bc*	2.73*ab*	50.6	4.77*ab*	4.15*ab*	52.1	5.26*ab*	4.37*c*
	(40)	(40)	(41)	(38)	(24)	(24)	(38)	(24)	(24)
Single	5.61*ab*	5.73*bc*	2.90*bc*	50.4	4.46*a*	3.88*a*	51.0	4.68*a*	3.54*a*
	(194)	(193)	(198)	(190)	(152)	(152)	(190)	(152)	(152)
Backcross	5.63*bc*	5.77*c*	3.00*c*	50.4	4.38*a*	4.19*ab*	51.1	4.71*a*	3.56*ab*
	(155)	(154)	(157)	(148)	(95)	(95)	(147)	(94)	(94)
Three-way	5.69*c*	5.77*c*	2.94*bc*	50.2	4.77*a*	4.29*ab*	50.7	4.93*ab*	3.44*a*
	(234)	(234)	(239)	(236)	(82)	(82)	(237)	(82)	(82)
Four-way	5.60*ab*	5.69*ab*	2.81*b*	50.5	5.50*bc*	4.74*bc*	51.5	5.35*b*	4.08*bc*
	(114)	(114)	(117)	(117)	(80)	(80)	(117)	(80)	(80)
Synthetic	5.56*a*	5.63*a*	2.60*a*	51.2	5.72*c*	5.18*c*	52.2	5.55*b*	4.35*c*
	(215)	(213)	(211)	(215)	(155)	(155)	(213)	(153)	(153)
SE LSM	0.01-0.02	0.02-0.04	0.05-0.10	0.28-0.65	0.12-0.30	0.14-0.33	0.29-0.65	0.13-0.32	0.12-0.29

[z] Purebred: LLLL, DDDD; single: YYLL, LLYY, LLWW, WWLL; backcross: LLLY, LLHL, HHHL, YYLY; three-way cross: HHLY, DDLY, BBLY; four-way cross: HDLY; synthetic cross: S9S9. B, Berkshire; D, Duroc; H, Hampshire; L, Landrace; S9, Synthetic; W, Large White; Y, Yorkshire.
[y] Least square means are presented. The number of pigs per treatment is in parentheses.
SE LSM, Standard error of the least square means. The lowest and highest SE LSM among treatments are presented.
a-d Means with different letters in the same column, for each experiment, differ using pairwise LSM comparisons ($P < 0.05$).
f-h Means with different letters in the same column, for each experiment, differ using pairwise LSM comparisons ($P < 0.10$).

The pH of the loin and ham the chromaticity values a* and b* of the loin and ham and the colour standard were different ($P < 0.05$) between cross types (Table 2).

The pH of the loin was the lowest for the synthetic cross pigs. The three-way and backcross had the highest pH values; the four-way cross, single cross and the purebreds were intermediate. The synthetic cross pigs had the lowest pH value of the ham, except for the four-way cross. The synthetic cross pigs had a higher chromaticity value a* of the loin (indiction of a "redder" meat) than the other cross types, except for the four-way cross. The highest chromaticity value a* for the ham was observed in pigs of the synthetic and four-way crosses and the lowest in pigs of single or backcrosses. The three-way cross and purebreds were intermediate. The chromaticity values b* of the loin were the highest for the purebred and four-way cross and the lowest for the single cross; the other breeds being intermediate. A similar pattern was observed for the chromaticity values b* of the ham, except that both the single and the three-way cross had the lowest values. Even if the meat for all the different cross types was classified as normal, commercial pigs produced from a synthetic cross had a paler meat colour than those from other crosses, except for the purebred and the four-way cross pigs, which were intermediate. Lo et al. (1992) found that in general purebred Duroc and Landrace had a paler meat than crossbreds of the same two breeds. It is possible that purebred animals, no matter what the breed, generally present a paler meat than crossbred pigs, which would explain the relatively light red meat of the purebred in the present study. Johnson et al. (1978) did not report a significant difference between the meat colour of the three-way cross and the single cross, when using the Duroc, Hampshire and Yorkshire breeds. In contrast, the contribution of the Hampshire breed to a paler meat has been shown in the present study and others (Sellier 1981; ITP France 1987). The four-way cross also includes the Hampshire as one of the parents, which could explain paler meat values for that cross. The breeds that contributed to the synthetic cross can not be obtained, but since that synthetic cross was created to improve growth and carcass performances, it is possible that Hampshire was one of them.

Table 3. Effect of sex, sire breed and cross type[z] on meat colour of commercial pigs in Quebec

	Colour standard				
	Experiment I: sex				
Castrated male	2[y] (0.7)	47 (16.3)	207 (71.9)	31 (10.8)	1 (0.3)
Gilt	4 (1.4)	37 (13.3)	198 (71.0)	37 (13.3)	3 (1.1)
	Experiment II: sire breed (dam LY)				
LL	4 (2.9)	35 (25.4)	75 (54.3)	22 (15.9)	2 (1.4)
YY	3 (2.0)	31 (20.7)	83 (55.3)	31 (20.7)	2 (1.3)
HD	10 (5.3)	53 (28.0)	108 (57.1)	17 (9.0)	1 (0.5)
HH	7 (4.3)	62 (38.3)	76 (46.9)	17 (10.5)	0 (0.0)
DD	2 (0.9)	51 (22.9)	136 (61.0)	32 (14.3)	2 (0.9)
	Experiment III: cross type				
Purebred	0 (0.0)	10 (24.4)	29 (70.7)	2 (4.9)	0 (0.0)
Single	1 (0.5)	44 (22.2)	125 (63.1)	28 (14.1)	0 (0.0)
Backcross	2 (1.3)	33 (21.0)	95 (60.5)	26 (16.6)	1 (0.6)
Three-way	4 (1.7)	66 (27.6)	137 (57.3)	31 (13.0)	1 (0.4)
Four-way	1 (0.9)	30 (25.6)	70 (59.8)	15 (12.8)	1 (0.9)
Synthetic	9 (4.3)	68 (32.2)	111 (52.6)	21 (10.0)	2 (0.9)

[z]Purebred: LLLL, DDDD; single: YYLL, LLYY, LLWW, WWLL; backcross: LLLY, LLHL, HHHL, YYLY; three-way cross: HHLY, DDLY, BBLY; four-way cross: HDLY; synthetic cross: S9S9. B, Berkshire; D, Duroc; H, Hampshire; L, Landrace; S9, Synthetic; W, Large White; Y, Yorkshire.

[y]For every category within a source of variation (experiment), the number of pig classified in each colour standard are given (percentages in parentheses).

In proportion to the global population of pigs retained for the analysis of the effect of cross type on meat colour, there was no difference between cross types for the incidence of pale meat (Table 3; $\chi^2 = 27.643$; $P = 0.1181$). When the results from all cross types are put together, only 1.8% of the pigs had extremely pale meat and 0.5% had extremely dark meat.

PARITY NUMBER. Independent of parity numbers there were differences ($P < 0.001$) between trials for all the meat colour variables. However, there was no difference ($P > 0.05$) between parity numbers for any of the meat colour variables (data not shown). Parity number, therefore, does not seem to greatly affect meat colour, and to our knowledge, this factor has not been examined in other studies.

Factor Analysis and Correlations

The factor analysis demonstrates two distinct factors. The first factor is composed of the luminosities L* of the loin and ham, the chromaticity values b* of the loin and ham, the pH of the loin and ham, as well as the colour standard. The second factor only includes the chromaticity values a* of the loin and ham. A varimax orthogonal rotation shows that all the variables in both factors are situated very closely to either one of the two axes, with each axis representing one of the two factors. This indicates that those two factors are very distinct and that none of the variables belongs to both factors at the same time. Langlois and Minvielle (1989), using a similar approach, also reported two distinct factors. One factor was represented by the pH of the ham at 45 min, the reflectance of the loin and the water holding capacity of the meat, while the other factor included the ultimate (24 h) pH of the loin and ham. In the present study, all the measures taken on the loin and ham have coordinates that are grouped quite closely together indicating that they all contribute fairly equally in characterizing a factor. Furthermore, all the measures taken on the loin and ham are correlated to each other (r values for the pH, L*, a* and b*: 0.791, 0.600, 0.499 and 0.577, respectively; $P < 0.0001$; Table 4), which corroborates the results from the factor analysis. These results agree with the results of Langlois and Minvielle (1989) who reported a correlation ($r = 0.46$; $P < 0.0001$) between the ultimate pH of the ham and loin. In the study of Langlois and Minvielle (1989), it was reported that the correlation was greater between the pH of two muscles at the same time (45 min or 24 h postmortem) than between the same muscles (or both muscles, ham and loin) at different times. Therefore, measurements either on the loin or ham give a relatively good assessment of the meat colour of the carcass.

The saturation matrix of the factorial analysis indicates in what proportion each one of the variables contributes to characterize a factor. For the first factor, the luminosity L*, followed by the chromaticity value b* presented the highest coefficients (data not shown). The luminosity L* was highly correlated to the chromaticity value b* for the loin ($r = 0.708$; $P < 0.0001$) and the ham ($r = 0.566$; $P < 0.0001$).

For the colour standard and the pH, the coefficients of the saturation matrix were relatively high, but negative. Correlations between the pH and the colour standard on one hand and the luminosity L* and the chromaticity value b* on the other hand were also negative (Table 4). This agrees with the results of Langlois and Minvielle (1989) and Lundström et al. (1979) who noted that the pH was negatively correlated with reflectance. Barton-Gade (1979), Martin et al. (1981) and Swatland (1982) have also reported an important negative relationship between pH at 24 h and reflectance. Results from the present study confirm these observations.

The second factor obtained from the factorial analysis was entirely defined by two variables correlated to each other: the chromaticity values a* of the loin and ham. The chromaticity values a* were the only measurements for which the Pearson correlation coefficients were not significantly different from zero ($P > 0.10$; L* loin vs. a* ham; a* loin vs. L* ham and a* ham vs. colour standard; Table 4). The factorial analysis, as well as the Pearson correlations indicate that the chromaticity value a* provides additional information distinct enough from the other measurements to be considered as a separate factor and does not tend to duplicate the same information on meat colour.

Table 4. Pearson's coefficient of correlation between the meat colour variables

	pHh	L*l	a*l	b*l	L*h	a*h	b*h	CS
Ultimate pH of the loin	0.791 (2048)[z]	−0.435 (1738)	−0.273 (1126)	−0.506 (1122)	−0.313 (1731)	−0.152 (1119)	−0.446 (1019)	0.493 (2031)
Ultimate pH of the ham (pHh)		−0.465 (1736)	−0.260 (1124)	−0.470 (1120)	−0.406 (1864)	−0.218 (1252)	−0.468 (1145)	0.518 (2029)
Colour of the loin								
Luminosity (L*l)			0.116 (1238)	0.708 (1234)	0.600 (1876)	−0.014[y] (1230)	0.526 (1081)	−0.491 (1876)
Chromaticity value a* (a*l)				0.534 (1234)	0.021[y] (1230)	0.499 (1230)	0.224 (1081)	−0.080 (1229)
Chromaticity value b* (b*l)					0.456 (1226)	0.212 (1226)	0.577 (1080)	−0.349 (1225)
Colour of the ham								
Luminosity (L*h)						−0.286 (1405)	0.566 (1228)	−0.377 (1870)
Chromaticity value a* (a*h)							0.232 (1228)	−0.020[y] (1223)
Chromaticity value b* (b*h)								−0.345 (1075)
Colour standard (CS)								1.000 (2211)

[z]Number of pigs per treatment.
[y]Not significantly different from zero ($P > 0.10$). All the other correlations are significantly different from zero ($P < 0.01$).

CONCLUSION

The meat from commercial pigs evaluated in the present study had on average a normal pH. The luminosities L* of the loin and ham were also situated in the range characteristic of a normal meat colour, but the chromaticity values a* were more indicative of a meat that is less red. This effect was not visually noticeable, as the colour standard of the meat was for a normal meat colour.

There was no effect of sex or parity number on meat colour measurements. Generally, commercial pigs from Hampshire and Hampshire × Duroc crosses produced a paler meat (determined by luminosity L* and colour standard) and a lower pH than the other breeds. Pigs from the synthetic cross produced a paler meat with a lower pH than the backcross, three-way and single crosses.

Measurements taken on either the loin or ham allow estimations of lean meat colour that are relatively comparable. The duplication of these measurements, therefore, may not always give enough additional information to justify the time and effort required to take them. Furthermore, the factorial analysis and Pearson's correlations indicate that the luminosity L* and the chromaticity value a* could be the only parameters used to describe the meat colour of the commercial pigs from the present study. The ultimate pH provides slightly more additional information and could be used as a method of control, since it is negatively correlated to the luminosity L* and the chromaticity value a*. The Minolta Chroma metre did not give much more additional information on meat colour than the colour standard. The two measurements indicated that meat from pigs in the present study was in the range for a normally coloured meat. However, the Minolta Chroma meter has the advantage of quantifying the colour of the meat more precisely than with the naked eye.

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Agriculture Canada, 1984. Pork quality, a guide to understanding colour and structure of pork muscle. Agriculture Canada, Ottawa, ON. Publ. 5180/B.

Anonymous. 1972. Canada Department of Agriculture, Information Canada, Ottawa, ON. Catalogue number A72-3/1.

Barton-Grade, P. A. 1979. Some experience on measuring the meat quality of pig carcasses. Proc. Symp. Muscle Function and Meat Quality. Acta Agric. Scand. (Suppl.) **21**: 61–71.

Bereskin, B. and Frobish, L. T. 1982. Carcass and related traits in Duroc and Yorkshire pigs selected for sow productivity and pig performance. J. Anim. Sci. **55**: 554–564.

Christian, L. L., Strock, K. L. and Carlson, J. P. 1980. Effects of protein, breed cross, sex and slaughter weight on swine performance and carcass traits. J. Anim. Sci. **51**: 51–58.

ITP France. 1987. Mémento de l'éleveur de porc, 4è édition. Institut technique du porc, Paris, France. pp. 217-225.

Johnson, R. K., Omtvedt, I. T. and Walters, L. E. 1978. Comparison of productivity and performance for two-breed and three-breed crosses in swine. J. Anim. Sci. **46**: 69–82.

Hammell, K. L., Laforest, J. P. and Dufour, J. J. 1993. Evaluation of the growth performance and carcass characteristics of commercial pigs produced in Quebec. Can. J. Anim. Sci. **73**: 495–508.

Langlois, A. and Minvielle, F. 1989. Comparisons of three-way and backcross swine: II. Wholesale cuts and meat quality. J. Anim. Sci. **67**: 2025–2032.

Lo, L. L., McLaren, D. G., McKeith, F. K., Fernando, R. L. and Novakofski, J. 1992. Genetic analysis of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs: I. Breed effects. J. Anim. Sci. **70**: 2373–2386.

Martel, J., Minvielle, F. and Poste, L. M. 1988. Effects of crossbreeding and sex on carcass composition, cooking properties and sensory characteristics of pork. J. Anim. Sci. **66**: 41–46.
Martin, A. H., Fredeen, H. T., L'Hirondelle, P. J., Murray, A. C. and Weiss, G. M. 1981. Pork quality attributes: Their estimation and their relationships with carcass composition in commercial pigs. Can. J. Anim. Sci. **61**: 289-298.
Minvielle, F. and Savoie, Y. 1986. Evaluation des porcs commerciaux: Quel type génétique recommander? Colloque sur la production porcine, Conseil des productions animales du Québec, Ministère de l'agriculture, des pêcheries et de l'alimentation du Québec, PQ. pp. 19–27.
Murray, A. C., Jones, S. D. M., Robertson, W. 1989. The effect of pre-slaughter feed restriction and genotype for stress susceptibility on pork lean quality and composition. Can. J. Anim. Sci. **69**: 83–91.
SAS Institute, Inc. 1985. SAS user's guide: Statistics. Version 5th ed. SAS Institute, Inc., Cary, NC.
Sather, A. P., Jones, S. D. M., Tong, A. K. W. and Murray, A. C. 1991. Halothane genotype by weight interactions on pig meat quality. Can. J. Anim. Sci. **71**: 645-658.
Schneider, J. F., Christian, L. L. and Kuhlers, D. L. 1982. Effects of season, parity and sex on performance of purebred and crossbred swine. J. Anim. Sci. **54**: 728–738.
Sellier, P. 1981. Une première évaluation de la race Duroc. J. Rech. Porc. Fr. **13**: 299–306.
Swatland, H. J. 1982. Meat color of pork chops in relation to pH and adductor capacitance of intact carcasses. J. Anim. Sci. **54**: 264-267.