Effect of pig growth rate and health status on meat eating quality

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Summary

This study examined meat quality, with emphasis on tenderness and boar taint, in 225 pork loins from male and female pigs slaughtered at either 90 or 110kg live weight. The Large White x Landrace pigs were fed *ad libitum* at the University of Leeds and were subsequently divided into 3 'growth categories' Fast, Slow and Interrupted. Average growth rate between weaning and finishing was 0.68, 0.54 and 0.49 kg/d for the Fast, Slow and Interrupted groups respectively (slightly higher values at 110kg than 90kg). Growth rate had a marked effect on meat quality. The Fast group had more tender pork when this was measured objectively or subjectively using a taste panel. The effect was present at both slaughter weights and in both sexes although it was more marked at 110kg and in males. There was no evidence that slow or interrupted growth adversely affected odours or flavours associated with boar taint. In fact the concentrations of both skatole and androstenone were higher in the faster growing male pigs. Muscle colour was less red in the Fast growth group and drip loss was high in the pigs whose growth had been interrupted.

The results should encourage producers to aim for growth rates above 0.7kg/d from weaning to slaughter for reasons of both lower production costs and better eating quality. Comparison with previous results suggests that the eating quality effects will improve further at higher growth rates than were seen here.

Introduction

Growth rate is an important performance indicator in pig production. Herds with high growth rates normally achieve higher profitability than those with low growth rates. There is also evidence that faster growing pigs have superior tenderness. This was shown in work conducted by MLC at Stotfold (MLC, 1989) where pigs fed *ad libitum* had more tender pork and bacon than those fed a restricted diet. Physiological studies suggest that the higher tenderness is linked to faster muscle protein deposition through the activity and expression of proteolytic enzymes.

It is often speculated that slow growth is likely to result in higher boar taint levels in entire male pigs because they will be older and sexually more mature at slaughter. In fact, the early Stotfold study showed this was unlikely to be the case because higher skatole and androstenone concentrations were found in the *ad libitum* fed pigs (MLC, 1989). However, the growth rates recorded in the Stotfold trial were much higher than current values and the pigs were taken to lower live weights.

Variability in current growth rates in the national herd is high and anecdotal evidence shows variation in pork tenderness and flavour is also high. Part of the variation in growth rate and potentially in quality is linked to the interrupted growth caused by infection. The current project was therefore undertaken to investigate the effect of the

variations in current growth rate, whether fast, slow or interrupted on tenderness, boar taint and other aspects of meat quality in pork.

Materials and methods

Two hundred and twenty five loins were examined from Large White x Landrace pigs involved in a 3 x 2 x 2 factorial experiment based at the University of Leeds. Factors were 3 growth categories (Fast, Slow and Interrupted), 2 sexes and two final live weights, 90 and 110kg. Growth rate was measured between weaning and slaughter, the pigs being fed *ad libitum.* At the outset, guidelines for Fast growth were >600 g/d to 90kg and >700 g/d to 110kg. Guidelines for Slow growth were around 500 g/d to 90kg and 590 g/d to 110kg. Interrupted growth pigs were those that had suffered a period of weight loss presumed to be due to infection. Final numbers in the growth categories were 96 Fast, 86 Slow and 43 Interrupted. Loins were delivered from George Adams abattoir in Spalding to Avonmouth near Bristol and picked up by Bristol staff 2 days after slaughter. The first loins were delivered on 26/1/07 and the last on 17/1/08. On arrival, pH in *longissimus* was measured with a Testo 230 pH meter. A steak was removed, placed with the cut surface uppermost on a foam tray, overwrapped with cling film and bloomed for 2 hr in a walk-in chiller maintained at 1ºC. Colour was then recorded using a Minolta colour meter. To measure drip loss, the muscle from a 25mm thick loin steak was suspended in a plastic bag in a cabinet maintained at 1ºC and the drip collected over 48 hr was recorded. The remainder of the loin was then conditioned at 1ºC so that the period from slaughter to the end of conditioning was 10 days. Loins were then blast frozen at -80ºC and stored at -20ºC before analysis. Toughness was measured following cooking a 10cm piece of loin in a waterbath at 80ºC to an internal temperature of 78ºC. After cooling in ice, 10 cores of muscle 20mm long and 10mm x 10mm in cross section were sheared using a Stable Microsystems Texture Analyser fitted with a Volodkevitch jaws. Average peak shear force of these 10 samples was the measure of toughness recorded.

Skatole and androstenone concentrations in subcutaneous fat from the loin region were measured using the procedures of Whittington et al (2004).

On the day before sensory analysis, loins were thawed at room temperature then kept in a chiller at 1ºC. Steaks 2.5cm thick were griddled to an internal temperature of 72ºC, then cubes of cooked muscle were presented to the 10-member taste panel for analysis of the following attributes on 8-point scales: pork odour of fat, abnormal odour of fat, tenderness, juiciness, pork flavour and abnormal flavour of lean. Finally, the panellists were asked to score flavour liking and overall liking.

Data were statistically analysed using general linear models (GLM), with growth category, carcass weight group and sex as factors and including interaction terms.

Muscle pH was measured in a further 50 pigs from the different groups hourly during the first 6 hours post mortem to determine whether growth rate had affected the rate of pH fall in the *longissimus, vastus* and *semimembranosus* muscles.

Results

The overall growth rates and fat thickness measurements of the pigs on which meat quality measurements were made are in Table 1. The weaning to finishing ADG on which the classification into growth categories was made, was for the Fast growth category 0.66kg/d up to 90kg and 0.70kg/d up to 110kg (average 0.68kg/d). These values are as originally planned. For the Slow category, the ADG was 0.52kg/d to

90kg and 0.55kg/d to 110kg (average 0.54kg/d). These values are again similar to those planned. Average growth rate was lower in the Interrupted than the Slow category. P_2 fat thickness was approximately 1mm greater in the Fast than the Slow and Interrupted groups.

Tables 2, 3, 4 and 5 show the mean slaughter weights and weaning to finishing ADG (basis for classification into growth categories) by gender (male or female) and target slaughter weight (90 or 110 kg). Mean slaughter weights were close to target and similar for all groups other than males to 110 kg. For this group, Interrupted pigs were heavier at slaughter than Fast growing pigs, but the Fast and Slow growing pigs were similar. For all groups, unsurprisingly, Fast growing pigs had higher weaning to finishing ADG than Slow growing or Interrupted pigs. Generally, Slow pigs grew faster than Interrupted pigs, although this wasn't the case for 110 kg males, where the ADGs were similar.

The meat quality measurements recorded on the *longissimus* (loin) muscle are in Table 6. For some characteristics, there were carcass weight group x growth category interactions indicated by †. There were small differences in colour and drip loss between the growth categories, the samples from Fast growing pigs tending to be less red and those from Interrupted pigs more red. There was a strong tendency for toughness to be lower in the Fast growing group but the interaction prevented this being a statistically significant effect. The concentration of skatole in loin backfat was highest in the Fast growth group and similar in the Slow and Interrupted groups. These values are the average for males and females.

The reasons for the interactions between carcass weight group and growth category are explained in Table 7 (as for Table 6, these are mean values for males and females, between which there were few differences). Differences were much more marked in the 110kg pigs. In these pigs, the Fast growth group had less drip, less intensely coloured muscle and higher skatole concentrations. Toughness was much higher in the Slow and Interrupted growth groups than in the Fast group. The Interrupted group had redder colour parameters and the most drip. In the 90kg pigs, toughness was also higher in the Slow and Interrupted groups, particularly in the latter, although growth category differences were smaller than at 110kg. Drip and colour parameters were not different although muscle pH was lower in the Fast growth category group.

The concentrations of skatole and androstenone in backfat of males only are shown in Tables 8 and 9. Table 8 shows that the concentrations of both compounds were highest in the Fast growth category group as was the case when the results from both sexes were combined in Tables 6 and 7. Average concentrations of skatole in females were 0.056, 0.048 and 0.048μg/g in Fast, Slow and Interrupted growth groups respectively, showing that in these Large White x Landrace pigs the concentration of skatole was not very different between the sexes. There were no significant differences in taint compound concentrations between 90 and 110kg carcass weight groups in males (Table 9).

The results for eating quality are in Table 10 which shows the pooled results for sexes and carcass weight groups. The score for tenderness was higher in the Fast growing pigs than in the Slow and Interrupted groups, however the carcass weight group x growth category interaction prevented this being expressed as a statistically

significant effect. Juiciness was significantly higher in the Fast growth group and overall liking tended to be higher.

The eating quality results for the 90 and 110 kg carcass weight groups are in Table 11. The differences between growth categories were greater in the 110 kg group which explains the interaction between carcass weight group and growth category group noted in Table 10. At 110kg, juiciness and overall liking were significantly greater in the Fast group than in the Slow and Interrupted groups. Numerical differences were even greater for tenderness but the sex x carcass weight group interaction prevented a statistically significant result being expressed. The means for tenderness and juiciness were in the same direction in the 90kg pigs (higher values in the Fast group) but differences were not significant.

Comparisons between Fast and Slow growth category groups were more balanced than those between all 3 growth groups because of the low number of Interrupted pigs. Table 12 shows the results for Fast and Slow growth category groups for males only. This analysis allows the growth rate effects on boar taint to be discerned. The Fast group had more tender, juicy meat with a higher score for overall liking. Pork odour of fat was significantly lower in the Fast group in line with the higher skatole and androstenone concentrations but no other measures of odour or flavour were different between the groups. Results for females at 110kg are in Table 13. Juiciness and overall liking were significantly higher in the Fast group and the difference in tenderness just escaped significance. There was no effect of growth rate on odours or flavours and differences in odour and flavour scores between males and females when comparing Tables 12 and 13 were small.
The rates of fall of muscle pH in the first 6 hours post mortem in the 3 muscles measured were not discernibly different between the growth rate, carcass weight and sex groups.

Discussion and conclusions
This study has shown important differences in eating quality between pigs allowed to feed *ad libitum* and differing naturally in growth rate. Pigs growing fast between weaning and slaughter ie at around 0.68 kg/d, had significantly more tender pork than those growing at 0.54 kg/d. The difference was more marked in pigs slaughtered at the heavier weight of 110 kg but was also present at 90kg. Juiciness of pork was also increased by faster growth and as a result the overall liking score for eating quality was higher. There was no evidence that slower growth increased boar taint. Concentrations of both androstenone and skatole were higher in the fast growth groups and scores for flavour attributes were not different between the groups. These conclusions concerning tenderness are similar to those reached in the Stotfold study of genotypes and growth rates (MLC,1989) although the absolute values for growth rate here are lower and more relevant to modern commercial conditions. The results for skatole and androstenone are also similar to those in the Stotfold trial as reported by Patterson et al (1990). Their values for skatole in entire males fed *ad libitum* or restrictedly were 0.08 and 0.048 µg/g, compared with 0.08 and 0.056 for the Fast and Slow groups here.

Use of the results to develop premium markets for British pork

As part of the project, muscle pH fall was recorded in the loin muscle of 50 pigs from the 4 main treatments every hour for 6 hours from slaughter and again at 24 hours. It was postulated that the rate of pH fall might vary in pigs growing at different rates, being faster in those having a high growth rate and more active muscle metabolism. The results (figure below) showed no clear separation between groups meaning that measurement of muscle pH could not be used to distinguish between fast growing tender pigs and slow growing tough ones.

The most effective way to utilise these results is for producers to ensure, through genetic, nutrition, health and management improvements, that growth rate in all pigs is above 600g/d from weaning to slaughter. The actual target value is expected to be genotype dependant, 600g being appropriate for the Large White x Landrace genotype used in this study. Particular attention should be paid to animal health because the highest values for toughness were found in the Interrupted group whose overall growth rate was low probably because of subclinical infections.

Growth rate could be included as a positive indicator of health and welfare linked to eating quality along the lines of: 'Better tasting pork from farms with the highest husbandry standards'.

This approach to the production of high eating quality linked to better animal health and welfare is likely to be more effective, in our view, than attempts to measure toughness in the abattoir. Work with beef has shown that extreme differences in toughness can be identified using near infrared reflectance spectroscopy (NIRS) on line because of differences in muscle lipid/protein ratios or muscle fibre characteristics. However this technology, even if it could be applied to pigs, is unlikely to separate individuals expressing the differences in toughness associated with growth rate found here, even though these would be easily detectable by consumers.

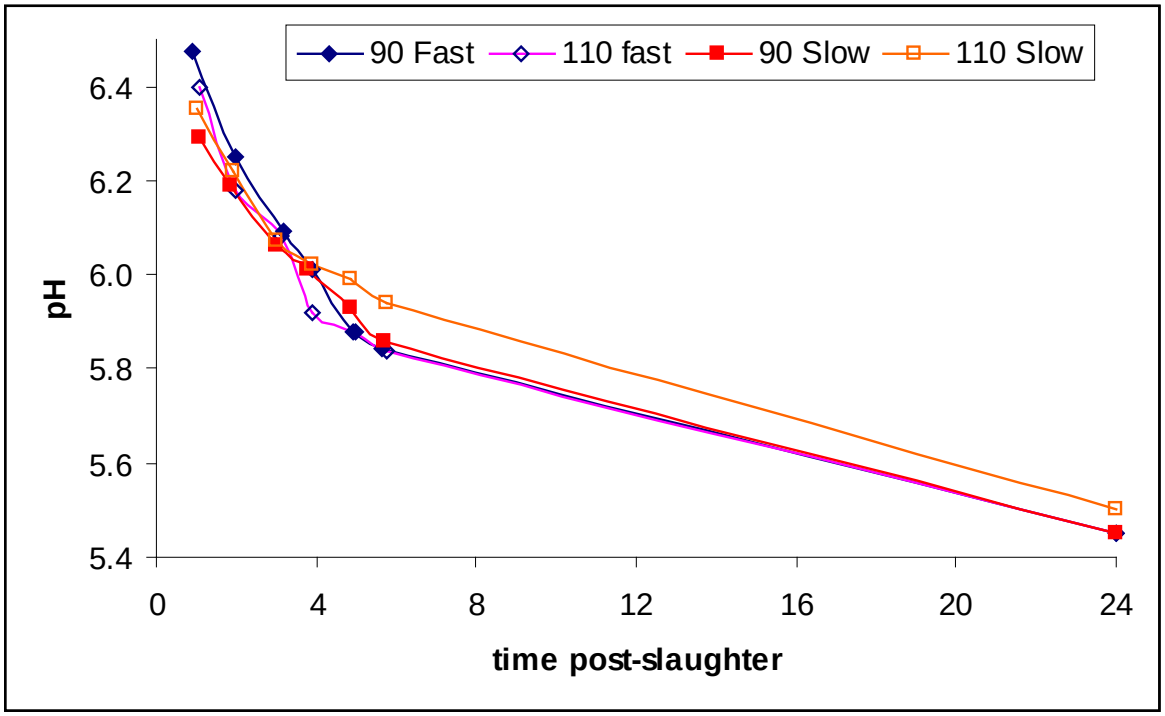

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Table 1. Overall growth rate and P_2 fat thickness in growth category groups.

	Growth category			vr	p-value	sig	sed
	Fast	Slow	Interr				
Finisher ADG (kg)	0.74a	0.57b	0.56b	18.78	†	*	0.036
Wean to finish ADG (kg)	0.68a	0.54b	0.49c	42.6	†	*	0.023
AF P_2 (mm)	10.13a	9.06b	8.43b	14.59	<0.001	***	0.351

†Significant sex x growth category interaction therefore vr, sed and significance recalculated using interaction error term.

Table 2. Growth rate and mean slaughter weight for females to a target slaughter weight of 90 kg.

	Growth category			p-value	sig	sem
Females (n=53)	Fast	Slow	Interr			
Mean slaughter weight (kg)	93.2	91.7	90.8		ns	1.56
Wean to finish ADG (kg)	0.639a	0.524b	0.459c	<0.001	***	0.01

Table 3. Growth rate and mean slaughter weight for males to a target slaughter weight of 90 kg.

	Growth category			p-value	sig	sem
Males (n=55)	Fast	Slow	Interr			
Mean slaughter weight (kg)	93.2	93.6	90.3		ns	1.31
Wean to finish ADG (kg)	0.680a	0.519b	0.465c	<0.001	***	0.01

Table 4. Growth rate and mean slaughter weight for females to a target slaughter weight of 110 kg.

	Growth category			p-value	sig	sem
Females (n=59)	Fast	Slow	Interr			
Mean slaughter weight (kg)	110.3	109.0	110.3		ns	1.04
Wean to finish ADG (kg)	0.673a	0.556b	0.480c	<0.001	***	0.01

Table 5. Growth rate and mean slaughter weight for males to a target slaughter weight of 110 kg.

	Growth category			p-value	sig	Sem
Males (n=58)	Fast	Slow	Interr			
Mean slaughter weight (kg)	108.4a	110.1ab	113.5b	0.039	*	1.65
Wean to finish ADG (kg)	0.734a	0.553b	0.542b	<0.001	***	0.01

Table 6. Effects of growth category on meat quality in the loin muscle

	Growth category			vr	p-value	sig.	sed
Variable	Fast	Slow	Interr				
pH	5.40b	5.43a	5.45a	6.92	0.001	***	0.017
Drip †	4.34	4.45	5.08	2.02		ns	0.354
L*	54.1b	54.5b	55.6a	6.05	0.003	**	0.457
a*	5.89	5.91	6.35	1.84	0.161	ns	0.254
b* †	3.90	4.01	4.64	1.34		ns	0.431
c †	7.09	7.17	7.89	0.84		ns	0.594
h	33.1b	34.3ab	35.7a	3.62	0.029	*	1.01
Toughness †	4.40	5.22	5.41	3.92		ns	0.405
Skatole	0.068a	0.052b	0.054ab	5.36	0.005	**	0.007

† Significant carcass weight group x growth category interaction. Therefore vr, sed and significance recalculated using interaction error term
Units: Drip %, Toughness kg, Skatole µg/g.

Table 7. Effects of growth category on meat quality in the loin muscle in 90 and 110 kg carcass weight groups.

90 kg Pigs

	Growth category			vr	p-value	sig.	sed
Variable	Fast	Slow	Interr				
pH	5.38b	5.43a	5.47a	8.71	<0.001	***	0.023
Drip	4.58	4.30	4.91	2.34	0.102	ns	0.284
L*	54.3	55.0	55.3	1.89	0.157	ns	0.627
a*	6.01	5.52	6.02	1.71	0.186	ns	0.353
b*	4.07	3.71	4.31	2.35	0.101	ns	0.292
c*	7.28	6.69	7.44	2.11	0.127	ns	0.424
h	33.9	34.1	35.1	0.34	0.716	ns	1.537
Toughness	4.49b	4.81ab	5.35a	4.13	0.019	*	0.305
Skatole	0.062	0.056	0.056	0.56	0.573	ns	0.008

110 kg Pigs

	Growth category			vr	p-value	sig.	sed
Variable	Fast	Slow	Interr				
pH	5.42	5.44	5.44	0.77	0.467	ns	0.025
Drip	4.09b	4.59ab	5.24a	7.23	0.001	***	0.315
L* †	53.9	53.9	55.9	1.12		ns	1.375
a*	5.78b	6.30ab	6.67a	3.56	0.032	*	0.367
b*	3.73b	4.32ab	4.97a	7.97	0.001	***	0.326

c*	6.90b	7.66ab	8.33a	5.47	0.005	**	0.463
h	32.3b	34.4ab	36.3a	5.32	0.006	**	1.32
Toughness	4.32b	5.63a	5.47a	22.16	<0.001	***	0.272
Skatole	0.074a	0.048b	0.052ab	6.02	0.003	**	0.011

† Significant growth category x sex interaction so vr, sed and significance recalculated using interaction error term.

Table 8. Effects of growth category on skatole and androstenone concentrations in males.

	Growth category			vr	p-value	sig.	sed
Variable	Fast	Slow	Interr				
Androstenone	0.500	0.383	0.397	3.21	0.045	*	0.062
Skatole	0.080a	0.056b	0.060ab	4.90	0.009	**	0.011

Table 9. Effects of carcass weight group on skatole and androstenone concentrations in males.

	Weight group (kg)		vr	p-value	sig.	sed
Variable	90	110				
Androstenone	0.414	0.439	0.27	0.602	ns	0.047
Skatole	0.066	0.065	0.01	0.925	ns	0.008

Table 10. Effects of growth category on eating quality of griddled loin steaks (1 to 8 scales) in all pigs.

	Growth category						
	Fast	Slow	Interr	vr	Probability	sig.	sed
Pork odour of fat	4.22	4.07	4.07	1.22	0.297	ns	0.112
Abnormal odour of fat	2.23	2.39	2.23	1.38	0.251	ns	0.112
Tenderness †	4.36	4.01	3.97	2.15		ns	0.206
Juiciness	4.59^{a}	4.34^{b}	4.37^{b}	4.32	0.013	*	0.091
Pork Flavour	4.41	4.39	4.31	0.54	0.585	ns	0.103
Abnormal Flavour	2.65	2.68	2.64	0.05	0.948	ns	0.124
Hedonic							
Flavour liking	4.68	4.56	4.64	0.89	0.413	ns	0.095
Overall liking	4.43	4.19	4.27	2.94	0.053	ns	0.100

†Significant carcass weight group x growth category interaction, so vr, sed and significance recalculated using interaction error term.

Table 11. Effects of growth category on eating quality of griddled loin steaks (1 to 8 scales) in 90 and 110kg carcass weight groups.

90kg Pigs

	Growth Category						
	Fast	Slow	Interr	vr	Probability	sig.	sed
Pork odour of fat	4.16	3.97	4.15	0.98	0.375	ns	0.160
Abnormal odour of fat	2.17	2.43	2.21	1.48	0.228	ns	0.159
Tenderness	4.26	4.19	4.05	1.19	0.304	ns	0.136
Juiciness	4.44	4.38	4.35	0.27	0.764	ns	0.128
Pork Flavour	4.3	4.35	4.28	0.11	0.897	ns	0.146
Abnormal Flavour	2.71	2.72	2.59	0.33	0.721	ns	0.248
Hedonic							
Flavour liking	4.56	4.59	4.66	0.33	0.718	ns	0.136
Overall liking	4.31	4.29	4.33	0.03	0.968	ns	0.140

110kg Pigs

	Growth Category						
	Fast	Slow	Interr	vr	Probability	sig.	sed
Pork odour of fat	4.27	4.17	4.00	1.44	0.238	ns	0.158
Abnormal odour of fat	2.29	2.36	2.25	0.24	0.790	ns	0.159
Tenderness†	4.46	3.82	3.89	4.47		ns	0.496
Juiciness	4.74^{a}	4.31^{b}	4.39^{b}	6.10	0.002	**	0.129
Pork Flavour	4.53	4.43	4.34	0.81	0.444	ns	0.144
Abnormal Flavour	2.59	2.64	2.69	0.17	0.844	ns	0.175
Hedonic							
Flavour liking	4.81	4.53	4.61	2.29	0.102	ns	0.134
Overall liking	4.55^{a}	4.10^{b}	4.21^{b}	5.46	0.004	**	0.143

†Significant sex x growth category interaction so vr, sed and significance recalculated using interaction error term.

Table 12. Eating quality of griddled loin steaks (1 to 8 scales). Comparison of Fast and Slow growth category groups in males of 110kg.

	Growth category					
	Fast	Slow	vr	Probability	sig.	sed
Pork odour of fat	3.73	4.20	5.19	0.025	*	0.205
Abnormal odour of fat	2.69	2.50	0.61	0.438	ns	0.241
Tenderness	4.22	3.81	8.57	0.004	**	0.139
Juiciness	4.88	4.47	6.38	0.013	*	0.161
Pork Flavour	3.95	3.91	0.06	0.804	ns	0.189
Abnormal Flavour	2.86	3.05	0.75	0.390	ns	0.217
Hedonic						
Flavour liking	4.50	4.20	2.64	0.107	ns	0.183
Overall liking	4.33	3.91	5.56	0.020	*	0.179

Table 13. Eating quality of griddled loin steaks (1 to 8 scales). Comparison of Fast and Slow growth category groups in females of 110kg

	Growth category					
	Fast	Slow	vr	Probability	sig.	sed
Pork odour of fat	4.31	4.29	0.02	0.879	ns	0.164
Abnormal odour of fat	2.29	2.49	0.98	0.323	ns	0.202
Tenderness	4.28	3.92	3.63	0.059	ns	0.184
Juiciness	5.06	4.41	18.41	<0.001	***	0.152
Pork Flavour	3.81	3.75	0.14	0.705	ns	0.165
Abnormal Flavour	2.77	2.76	0.00	0.944	ns	0.177
Hedonic						
Flavour liking	4.61	4.24	4.49	0.036	*	0.177
Overall liking	4.39	4.00	4.80	0.030	*	0.177