SELECTION FOR INTRAMUSCULAR FAT CONTENT AND CORRELATED RESPONSES ON CARCASS AND MEAT QUALITY TRAITS IN RABBITS

M. Martínez-Álvaro[1], S. Agha[1, 2], V. Juste[1], A. Blasco[1] and P. Hernández[1]*

[1]Institute for Animal Science and Technology, Universitat Politècnica de València, Valencia, Spain
[2]Animal Production Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt
*phernan@dca.upv.es

Abstract - A divergent selection experiment for intramuscular fat content (IMF) in *Longissimus* muscle (LM) in rabbits was carried out during 5 generations. Direct and correlated responses in body weight, chilled carcass weight, reference carcass weight, scapular fat, perirenal fat, meat to bone ratio, color parameters in carcass and LM, pH of LM and fatty acid (FA) composition of the LM were estimated as the differences between lines in the fifth generation. Response to selection for IMF was successful, representing the difference between high and low lines 27.7% of the mean. Carcass quality was affected by selection for IMF, producing an increase in dissectible fat content, a slight decrease in meat to bone ratio and modifications in color parameters. Meat quality was also affected showing modifications in color and FA composition of the LM.

I. INTRODUCTION

Intramuscular fat content (IMF) plays an essential role in meat quality. However, few studies have been focused on increasing IMF by selection. Sapp *et al*. (1) in cattle, Schwab *et al.* (2) in pigs and Suzuki *et al*. (3) in a multitrait experiment also in pigs, showed that genetic improvement is feasible, but no experiments in rabbits have been performed hitherto. Selection for IMF can change carcass quality; for example, in pigs, selection for IMF lead to correlated deposition of fat, deteriorating carcass quality (2). Rabbit meat is characterized by its lower fat content and favorable FA composition compared to other meats (4). Moreover, rabbits are an excellent model for genetic studies in other livestock species due to their reduced generation interval and low cost of carcasses. The aims of this study are to evaluate the selection response and correlated responses on carcass and meat quality traits of a divergent selection experiment for intramuscular fat content of the *Longissimus* muscle in rabbits.

II. MATERIALS AND METHODS

Data. A total amount of 986 data from 5 generations of a divergent selection experiment for IMF of *Longissimus* muscle (LM) in rabbits were used in this study. Animals came from a synthetic rabbit line. The base population consisted of 13 males and 83 females. High (H) and low (L) lines had approximately 8 males and 40 females per generation. Selection was based on the phenotypic value of IMF measured in 2 full sibs of the candidate (a male and a female). Selection pressure on females was approximately 20% per generation on average. Males were chosen within families to avoid inbreeding. Litters were homogenized at birth up to 9 kits per litter. Rabbits were reared collectively from weaning to 9 weeks of age and were fed *ad libitum* with a commercial diet. Animals were evaluated after slaughter at 9 weeks of age, and chilled for 24h at 4ºC. Then, LM was excised, minced, freeze-dried and scanned with near infrared spectroscopy (NIRS). The IMF of LM was expressed as g/100g of muscle on a fresh basis. Body weight (BW), chilled carcass weight (CCW) and reference carcass weight (RCW) (5) were recorded. Scapular (SF) and perirenal fat (PF) were excised and weighted. The left leg was dissected to obtain the meat to bone ratio. Color parameters L*, a*, b* of the carcass were measured on the surface of the fourth lumbar vertebra, and color of the meat was measured at the seventh lumbar vertebra transversal section at the LM. Euclidean distance Delta E (ΔE) was calculated (6). Muscle pH was measured 24 hours *post mortem* in the LM at the level of the fifth lumbar vertebra. Fatty acids (FA) composition of the LM was determined by NIRS (7), and was expressed as a percentage of total FA. All experimental procedures involving animals were approved by the Universitat Politècnica de València Research Ethics Committee, according to Council Directives 98/58/EC and 2010/63/EU.

Statistical analysis. Descriptive analyses were performed using the whole data set, after correcting

data by line-generation, sex and parity order effects. Response to selection for IMF and correlated responses were estimated as the differences between H and L lines in the fifth generation (62 and 52 rabbits, respectively). A model with the previous effects and a common litter effect was employed. Bayesian inference was used. Normal priors for the common litter effects and flat priors for the remaining effects were used.

III. RESULTS AND DISCUSSION

Table 1 presents descriptive statistics of the carcass and meat quality traits. Tables 2 and 3 present descriptive statistics for FA composition in LM.

Table 1. Descriptive statistics of IMF, BW and carcass and meat quality traits.

Trait	Mean	SD	CVx100	Nºof animals
IMF[1]	1.08	0.16	14.8	980
BW[2]	1719	156	9.1	986
CCW[3]	988	100	10.1	984
RCW[4]	783	84	10.8	984
SF[5]	4.03	1.22	30.3	980
PF[6]	8.48	3.72	43.9	984
M/B[7]	4.60	0.52	11.3	703
CL*[8]	54.2	2.44	4.5	986
Ca*[9]	3.21	0.86	-*	986
Cb*[10]	0.61	1.37	-*	954
LML*[11]	53.1	2.50	4.7	985
LMa*[12]	3.76	1.01	-*	985
LMb*[13]	1.14	0.76	-*	985
LMpH[14]	5.58	0.10	1.8	981

[1]IMF, intramuscular fat content of the *Longissimus* muscle (g/100g); [2]BW, body weight (g); [3]CCW, chilled carcass weight (g); [4]RCW, reference carcass weight (g); [5]SF, scapular fat content (g); [6]PF, perirenal fat content (g); [7]M/B, meat to bone ratio of the hind leg; [8]CL*, lightness, [9]Ca*, redness and [10]Cb*, yellowness of the carcass surface; [11]LML*, lightness, [12]LMa*, redness, [13]LMb*, yellowness and [14]LMpH, pH of the *Longissimus* muscle. *CV non estimable.

Table 2. Descriptive statistics of SFA, MUFA, PUFA (expressed as a percentage of total fatty acids) and fatty acid ratios of the *Longissimus* muscle.

Trait	Mean	SD	CVx100	No. of animals
SFA[1]	36.0	2.0	5.6	959
MUFA[2]	24.0	2.2	9.1	950
PUFA[3]	38.9	3.5	9.0	959
n-6/n-3[4]	5.69	0.41	7.3	959
PUFA/SFA	1.08	0.11	9.8	959

[1]SFA=C14:0+C15:0+C16:0+C17:0+C18:0; [2]MUFA=C16:1+ C18:1n-7+C18:1n-9; [3]PUFA=C18:2n-6+C18:3n-3+C20:2n-6+ C20:3n-6+CC20:4n-6+C20:5n-3+C22:4n-6+C22:5n-3+C22:6n-3; [4]n-6=C18:2n-6+C20:2n-6+C20:3n-6+C20:4n-6+C20:5n-6+ C22:4n-6; n-3 =C18:3n-3+C20:5n-3+C22:5n-3+C22:6n-3.

Table 3. Descriptive statistics of individual fatty acid composition (expressed as a percentage of total fatty acids) of the *Longissimus* muscle.

Trait	Mean	SD	CVx100	Nºof animals
C14:0	1.29	0.43	33.3	903
C15:0	0.49	0.02	4.3	908
C16:0	19.8	1.7	8.4	959
C16:1	1.33	0.59	44.1	847
C17:0	0.79	0.05	6.6	905
C18:0	8.70	0.59	6.8	959
C18:1 n-7	1.70	0.13	7.4	908
C18:1 n-9	20.7	1.7	8.2	959
C18:2 n-6	25.2	2.0	7.8	959
C18:3 n-3	1.74	0.23	13.0	959
C20:2 n-6	0.32	0.05	15.0	908
C20:3 n-6	0.65	0.12	18.2	908
C20:4 n-6	5.80	0.95	16.4	959
C20:5 n-3	1.80	0.35	19.2	908
C22:4 n-6	2.23	0.36	16.3	908
C22:5 n-3	0.67	0.17	24.9	883
C22:6 n-3	2.23	0.59	26.5	873

Response on IMF and correlated responses in carcass and meat quality traits are shown in Table 4. Response to selection for IMF was successful, being the difference between lines in the fifth generation 0.30g/100g muscle, representing 27.7% of the mean. Other experiments were also successful in cattle (1), in pigs (2), and also in a multitrait selection experiment in pigs (3).

The BW and carcass body weights showed a slightly negative correlated response with IMF. The probability of the difference in BW between H and L lines being different from zero (P) was 0.96, although it represented a low percentage of the mean (3.7%). Schwab *et al*. (2) did not observe response in growth traits when selecting for IMF in porcine.

There are evidences that fat deposits have increased, particularly PF. The difference between lines in PF was 2.61, representing 30.8% of its mean. Schwab *et al.* (2) showed a low positive correlated response in adipose tissues when selecting for IMF in pigs and Sapp *et al.* (1) did not obtained any response in fat deposits when selecting for IMF in cattle. Selection for IMF can deteriorate carcass quality due to correlated increase in adipose deposits. Nevertheless, total dissectible fat content in rabbit carcass is low, about 3% of the carcass at 9 weeks of age (8), thus this correlated response is not relevant in practice. There is some evidence that the meat to bone ratio

was slightly lower in the H line (P=0.96). In pigs, Schwab *et al.* (2) showed a negative correlated response in loin muscle area when selecting for IMF. Nonetheless, Sapp et al. (1) did not find a response in ribeye area trait in cattle after selection for IMF.

Table 4. Responses to selection for IMF and correlated responses on BW and carcass and meat quality traits estimated as the differences between high and low lines in the fifth generation.

Trait	D[1]	P[2]	$HPD_{95\%}$[3]
IMF[4]	0.30	1.00	[0.24, 0.37]
BW[5]	-64.3	0.96	[-139, 8.5]
CCW[6]	-15.5	0.74	[-60.7, 30.9]
RCW[7]	-10.9	0.70	[-50.7, 27.6]
SF[8]	0.31	0.88	[-0.21, 0.82]
PF[9]	2.61	1.00	[0.95, 4.29]
M/B[10]	-0.26	0.96	[-0.54, 0.05]
CL*[11]	-1.18	0.98	[-2.27, -0.05]
Ca*[12]	0.10	0.72	[-0.27, 0.45]
Cb*[13]	-0.27	0.81	[-0.88, 0.34]
CΔE[14]	1.27	1.00	[0.17, 2.39]
LML*[15]	-1.22	0.99	[-2.33, -0.09]
LMa*[16]	0.33	0.95	[-0.05, 0.74]
LMb*[17]	0.00	0.51	[-0.33, 0.31]
LMΔE[18]	1.28	1.00	[0.25, 2.36]
LMpH[19]	0.05	0.99	[0.00, 0.09]

[1]D, median of the marginal posterior distribution of the difference between high and low lines; [2]P, probability of D being greater than zero when D>0 and probability of D being lower than zero when D<0; [3]$HPD_{95\%}$ highest posterior density region at 95% of probability; [4]IMF, intramuscular fat content of the *Longissimus* muscle (g/100g); [5]BW, body weight (g); [6]CCW, chilled carcass weight (g); [7]RCW, reference carcass weight (g); [8]SF, scapular fat content (g); [9]PF, perirenal fat content (g); [10]M/B, meat to bone ratio of the hind leg; [11]CL*, lightness, [12]Ca*, redness, [13]Cb*, yellowness and [14]CΔE, color distance of carcass surface; [15]LML*, lightness, [16]LMa*, redness, [17]LMb*, yellowness, [18]LMΔE, color distance and [19]LMpH, pH of the *Longissimus* muscle.

Rabbit meat is usually commercialized as a whole carcass and to a less extent as retail cuts, thus carcass color is important for consumers. Selection for IMF produced some modifications in carcass and meat color. Carcass and meat lightness were lower in the H line (P=0.98 and P=0.99, respectively). In contrast, Schwab *et al*. (2) observed a large positive correlated response in LML* when selecting for IMF in pigs. Redness traits Ca* and LMa* were higher in the H line, particularly LMa*. Yellowness was higher in the carcass of the L line, but showed no response in LM. Differences in color distance ΔE higher than 1 are considered the minimum that the human eye can detect (6). Differences higher than 1 in ΔE were found in carcass and meat, but highest posterior density intervals at 95% of probability were large. To our knowledge, no studies comparing differences in color with ΔE have been performed.

Although LMpH was greater in H line (P=0.99) with a difference between lines of 0.05, in practice this difference is not relevant. Schwab *et al.* (2) found no effect of selection for IMF on this trait, in porcine.

Tables 5 and 6 show correlated responses on FA composition of the LM. Saturated fatty acids (SFA) percentage did not present differences between lines. In contrast, selection for IMF modified percentages of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), showing H line higher values for MUFA percentage and lower values for PUFA percentage. The differences between H and L lines in PUFA/SFA and n-6/n-3 ratios were relevant, being negative for PUFA/SFA ratio (P=1.00) and positive for n-6/n-3 ratio (P=1.00). In a review, De Smet *et al.* (9) display that an increment in IMF leads to modifications in FA composition, explained by the different FA composition of the two major lipid fractions, phospholipids and triacylglycerols, and by the relative contribution of these fractions to total lipids when IMF increases.

Table 5. Correlated responses to selection for SFA, MUFA, PUFA (expressed as a percentage of total fatty acids) and fatty acid ratios of the *Longissimus* muscle estimated as the differences between high and low lines in the fifth generation.

Trait	D[1]	P[2]	$HPD_{95\%}$[3]
SFA[4]	0.03	0.53	[-0.86, 0.97]
MUFA[5]	4.56	1.00	[3.56, 5.54]
PUFA[6]	-4.77	1.00	[-6.42, -3.16]
n-6/n-3[7]	0.35	1.00	[0.15, 0.52]
PUFA/SFA	-0.13	1.00	[-0.18, -0.08]

[1]D, median of the marginal posterior distribution of the difference between high and low lines; [2]P, probability of D being greater than zero when D>0 and probability of D being lower than zero when D<0; [3]$HPD_{95\%}$ highest posterior density region at 95% of probability; [4]SFA=C14:0+C15:0+C16:0+C17:0+C18:0; [5]MUFA=C16:1+C18:1n-7+ C18:1n-9; [6]PUFA=C18:2n-6+C18:3n-3+C20:2n-6+C20:3n-6+C20:4n-6 +C20:5n-3+C22:4n-6+C22:5n-3+C22:6n-3;[7]n-6=C18:2n-6+C20:2n-6 +C20:3n-6+C20:4n-6+C20:5n-6+C22:4n-6n-3=C18:3n-3+ C20:5n-3 +C22:5n-3+C22:6n-3.

Table 6. Correlated responses to selection for individual fatty acid composition (expressed as a percentage of total fatty acids) of the *Longissimus* muscle estimated as the differences between high and low lines in the fifth generation.

Trait	D[1]	P[2]	$HPD_{95\%}$[3]
C14:0	0.52	1.00	[0.30, 0.72]
C15:0	0.01	1.00	[0.00, 0.02]
C16:0	0.15	0.65	[-0.58, 0.92]
C16:1	0.89	1.00	[0.60, 1.19]
C17:0	-0.07	1.00	[-0.10, -0.05]
C18:0	-0.74	1.00	[-1.01, -0.47]
C18:1 n-7	-0.08	0.99	[-0.13, -0.02]
C18:1 n-9	3.51	1.00	[2.75, 4.29]
C18:2 n-6	-2.58	1.00	[-3.49. -1.65]
C18:3 n-3	0.08	0.92	[-0.03, 0.19]
C20:2 n-6	-0.06	1.00	[-0.08, -0.04]
C20:3 n-6	-0.21	1.00	[-0.27, -0.16]
C20:4 n-6	-1.61	1.00	[-2.06, -1.17]
C20:5 n-3	-0.43	1.00	[-0.58, -0.27]
C22:4 n-6	-0.67	1.00	[-0.84, -0.51]
C22:5 n-3	-0.04	0.99	[-0.17, -0.02]
C22:6 n-3	-0.41	1.00	[-0.70, -0.14]

[1]D, median of the marginal posterior distribution of the difference between high and low lines; [2]P, probability of D being greater than zero when D>0 and probability of D being lower than zero when D<0; [3]$HPD_{95\%}$ highest posterior density region at 95% of probability.

Individual FA showed a similar pattern as for the FA groups. Difference between H and L lines for individual SFA, C14:0, C15:0 and C16:0 were positive and for C17:0 and C18:0 were negative. Due to their different behaviors, the total percentage of SFA did not show differences between lines. Individual MUFA C16:1 and C18:1n-9 were higher in the H line. In pigs, a moderate high genetic correlation between IMF and C18:1n-9 was reported (10). Individual PUFA C18:2n-6 was higher in the L line, as well as the remaining n-6 fatty acids. All n-3 fatty acids were also higher in the L line, except C18:3n-3, which was lower.

IV. CONCLUSION

A successful experiment of divergent selection for IMF was carried out. In the fifth generation, the difference between H and L lines represented 27.7% of the mean. Carcass quality was affected by selection for IMF, producing an increase in dissectible fat content, a slight decrease in meat to bone ratio and modifications in color parameters. Meat quality was also affected showing modifications in color and FA composition of the LM.

ACKNOWLEDGMENTS

This work was supported by project AGL2011-29831-C03-01 from the Spanish National Research Plan. Dr. S. Agha was financed by a scholarship from EMMAG program. M. Martinez-Alvaro was financed by a FPI grant (BES-2012-052655) by the Ministry of Economy and Competitiveness of Spain.

REFERENCES

1. Saap, R.L., Bertrand, J.K., Pringle, T.D. & Wilson, D.E. (2002). Effect of selection for ultrasound intramuscular fat percentage in Angus bulls on carcass traits of progeny. Journal of Animal Science 80:2017-2022.
2. Schwab, C.R., Baas, T.J., Stalder K.J., & Nettleton, D. (2009). Results from six generations of selection for intramuscular fat in Duroc swine using real-time ultrasound. I. Direct and correlated phenotypic responses to selection. Journal of Animal Science 87:2774-2780.
3. Suzuki, K.M., Irie, H., Kadowaki, H., Shibata, T., Kumagai, M. & Nishida, A. (2005b). Genetic parameter estimates of meat quality traits in Duroc pigs selected for average daily gain, *Longissimus* muscle area, backfat thickness and intramuscular fat content. Journal of Animal Science 83:2058-2065.
4. Hernández, P. & Gondret, F. (2006) Rabbit meat quality and safety. In L. Maertens & P. Coudert (Eds.), Recent advances in Rabbit Sciences (pp. 267-290). Melle: ILVO.
5. Blasco, A. & Ouhayoun, J. (1996).Harmonization of criteria and terminology in rabbit meat research. Revised proposal. World Rabbit Science 4: 93-99.
6. Fairchild, M.D. (2013). Color appearance models. Wiley, United Kingdom.
7. Zomeño, C., Juste, V. & Hernández, P. (2012). Application of NIRS for predicting fatty acids in intramuscular fat of rabbit. Meat Science 91:155-159.
8. Pla, M., Hernández, P. & Blasco, A. (1996). Carcass composition and meat characteristics of two rabbits breeds of different degrees of maturity. Meat Science 44:85-92.
9. De Smet, S., Raes, K. & Demeyer, D. (2004) Meat fatty acid composition as affected by fatness and genetic factors: a review. Animal Research 53: 81-98.
10. Ros-Freixedes, R., Reixach, J., Tor, M. & Estany, J. (2012). Expected genetic response for oleic and acids content in pork. Journal of Animal Science 90:4230-4238.