Association of Liver X Receptor Alpha and Beta Genes with Carcass Lean and Fat Content in Pigs

A.S. Leaflet R2150

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Summary and Implications

A three-generation resource family of a cross between the Berkshire and Yorkshire (BY) pig breeds and four pig commercial populations were used to investigate whether the Liver X Receptor Alpha (LXRA) and Beta (LXRB) genes play a role in influencing lean and fat growth in pigs. Our current findings from this study have suggested that *LXRA* and *LXRB* might have potential effects, especially for loin lean and fat content.

Introduction

Molecular genetic markers or genes identified are becoming of more and more importance in assisting the pig breeding and production industries in improving both the quantity and quality of pig meat production. Liver X receptor alpha (LXRA) and beta (LXRB) are genes reported to have important physiological roles in lipogenesis and myogenesis as determined in humans and mice. Therefore both *LXRA* and *LXRB* are attractive candidate genes for carcass composition and meat quality in pigs. The objectives of this study were identification of different genetics forms (polymorphisms) in the *LXRA* and *LXRB* genes, linkage mapping of these two genes and investigation of their associations with variation in fat and lean growth in pigs.

Materials and Methods

DNA samples and phenotypic data used in the study were from the BY resource family and four pig commercial lines (line A, B, C and D). Lines A and B were based on Duroc and Hampshire populations respectively. Line C is a synthetic line derived from several breeds including Pietrain, Duroc, Large White and Landrace. Line D is a synthetic between Duroc and Large White. All of these lines have been maintained as closed populations for at least 10 years. Traits presented in this paper are shown in Table 2 and 3.

Three gene fragments, two for *LXRA* and one for *LXRB*, were isolated using a comparative genomic approach and the sequence available in porcine database. Three pig specific primer sets were redesigned in order to genotype the single nucleotide polymorphisms (SNPs) discovered in these three gene fragments. Linkage mapping of the *LXRA* and *LXRB* genes was performed in the BY resource family. Associations between the individual gene markers and carcass composition traits in the BY F_2 family were detected using a mixed statistical model that included litter as a random effect, sex, year season and marker genotype as fixed effects, in addition, live weight was included as a covariate. The model for analysis within the commercial lines included sire of the pig as a random effect and slaughter date and genotype as fixed effects. Only females were used so sex was not included as an effect. Hot carcass weight was added as a covariate for carcass composition traits. The combined line analyses were not performed due to the significant effects of line by genotype interaction.

Results and Discussion

The *LXRA* gene was mapped on SSC2. Association analyses in the BY family revealed that the *LXRA HpyCH4* III polymorphism had a significant association with loin eye area ($P < 0.01$) and total lipid ($P < 0.05$) (Table 1). We also found that the *LXRA HpyCH4* III polymorphism approached a significant association with marbling score. The animals homozygous for allele *T* of the *LXRA HpyCH4* III polymorphism had higher marbling score, and more total lipid than those of homozygous CC genotype animals. Therefore this makes the TT genotype the favorable one because a certain level of carcass lipid content is generally considered more desirable. Statistical analyses indicated that the *LXRA Bsl* I polymorphism was associated with marbling score ($P<0.01$) and all the lean meat traits measured including loin depth at 10th rib ($P<0.1$), loin eye area ($P<0.1$) and boneless loin percentage ($P<0.01$) in commercial line C (Table 2).The less frequent genotype (heterozygous CG) has an unfavorable effect on carcass lean content but a favorable effect on marbling score. In the initial allele frequency test, we found that *G* allele of the *Bsl* I polymorphism was shown to occur predominately in the other three lines investigated. It can be assumed that strong selection pressure to increase lean muscle mass over the past 30 years may have contributed to the high frequency of the favorable allele in commercial pig populations. These findings may explain the associations between the polymorphisms in *LXRA* with lean muscle mass as well as fat content.

The *LXRB* gene was mapped on SSC6. Association analyses of the *LXRB Aci* I polymorphism showed significant associations with loin eye area ($P < 0.01$), marbling score ($P < 0.05$) and total lipid ($P<0.05$) (Table 1). The CC genotype was associated with bigger loin eye area, but also lower marbling score and less total lipid when compared with animals with the TC genotype. Significant effects or trends were observed on lean meat traits including

lean percentage ($P < 0.05$), loin depth ($P < 0.05$) and loin eye area ($P < 0.1$) in lines A, B and D (Table 2). In addition, the *LXRB Aci* I polymorphism also associated with 10th rib backfat ($P < 0.05$) (line A).It should be noted that the *Aci* I polymorphism appeared to have different effects among the BY family and the three (A, B, D) pig commercial lines investigated. The less frequent genotype TC had favorable effects on lean (%), loin eye area and loin depth but less favorable effects on back fat in commercial lines. This opposite effect of the *LXRB Aci* I polymorphism across populations may indicate different linkage disequilibrium or epistasis among these pig populations.

In conclusion, our results provide evidence that the *LXRA* and *LXRB* genes might have potential effects for lean muscle growth and fat content.

Acknowledgments

This work was funded in part by Sygen International, PIC USA and the Iowa Agriculture and Home Economics Experiment Station and State of Iowa and Hatch funds. Technical assistance from Ms. Kimberly Glenn and Dr. Laura Grapes is appreciated.

Table 1. Association results of the *LXRA HpyCH4*III and *LXRB Aci* I polymorphisms with phenotypes in the BY family.

Traits	Genotypic least squares means (SE)[a]			*P*- value
***LXRA HpyCH4*III**	TT	TC	CC	
Number of animals	161	239	95	
Loin eye area (cm^2)	36.46 (0.65)i	36.15 (0.61)e	34.61 (0.72)fj	P < .01
Total lipid (%)	3.29 (0.16) ac	3.00 (0.15)d	3.00 (0.18)b	P < .05
Marbling (score 1-5)	3.78 (0.07)c	3.63 (0.07)d	3.70(0.09)	P < .10
***LXRB Aci* I**		TC	CC	
Number of animals		271	231	
Loin eye area(cm^2)		35.42 (0.61)	36.44(0.61)	P < .01
Total lipid (%)		3.23 (0.16)	2.97 (0.16)	P < .05
Marbling (score 1-5)		3.74 (0.07)	3.61 (0.07)	P < .05

[a] Significant levels: a and b, $P<0.1$; c and d , $P<0.05$; e and f, $P<0.01$; i and f, $P<0.005$

Table 2. Association results of the *LXRA Bsl* I and *LXRB Aci* I polymorphisms with phenotypes in the four different pig commercial lines.

Trait	Line	No of animals	Genotypic least squares means (SE /No of animals)[a,b]		*P*- value
***LXRA Bsl* I**			CG	GG	
Marbling score	C	229	1.48 (0.08/35)	1.13 (0.04/194)	P < .01
Loin depth at 10th rib(mm)	C	443	69.7 (0.62/102)	70.9 (0.38/341)	P < .1
Loin eye area (cm^2)	C	443	48.0 (0.52/102)	48.9 (0.32/341)	P < .1
Boneless loin (%)	C	443	8.01 (0.08/102)	8.24 (0.05/341)	P < .01
***LXRB Aci* I**			TC	CC	
10 th rib backfat (mm)	A	439	20.8 (0.39/120)	21.7 (0.30/319)	P < .05
Lean percentage	A	439	57.5 (0.21/120)	57.0 (0.17/ 319)	P < .05
Loin eye area (cm^2)	B	439	43.9 (0.42/142)	43.1 (0.32/297)	P < .1
Loin depth (mm)	D	482	54.0 (1.24/40)	51.1 (0.46/442)	P < .05

[a b] Number of animals ranged from 229 to 482 for each trait recorded in those four lines.

[c] Least squares means for two genotypes of the two polymorphisms were shown in the table due to the very low number of the other homozygous genotype in those lines.