Heart Fatty Acid Binding Protein Gene for Improving Meat Quality

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Intramuscular fat and meat quality

Intramuscular fat (IMF) content is attracting increasingly more attention in swine breeding especially because it is also positively correlated with eating attributes of pork, such as juiciness, tenderness and flavour (Bejerholm and Barton-Gode 1986; Eikelenboom et al. 1996). Pork consumers have clearly demonstrated a preference for intramuscular fat when rating pork in blind taste panel tests (NPPC 1996). Research has shown that average IMF measured through chemical analysis lines up very well with marbling scores. Marbling is also negatively related to the incidence of pale, soft, exudative (PSE) pork (Jones et al., 1994).

Pork loins must have at least 2% fat in lean meat, else, the cooked meat will be too dry and tasteless (Meadus, 2000). In earlier studies, Bejerholm and Barton-Gode (1986) identified a threshold value of 2% intramuscular fat for optimal tenderness. According to a US study (De Vol et al., 1988), the threshold level was 2.5-3%. European scientists also believe at least 2% IMF is needed to produce consumer acceptable pork loins (See et al. 1995). In Canada, retailers would prefer to have loins with more marbling, according to the input provided by retail and export specialists (CCSI, 2000). In general, north American markets, including US and Canada, demand medium-high marbling in fresh pork, while the Japanese market asks for high marbling.

The IMF also has a significant economic value. Blind taste panel surveys (NGEP 1998, NPPC 1998) estimated that a 1% of IMF increase in extreme lean fresh loins (<2% IMF) is worth about US $0.66-$1.32 per kg. According to Meadus (2000), economic value per 1% IMF increase is worth of $0.84 each kg (limited up to 5%).

Current levels of IMF and Trends

The current levels of IMF are usually on the lower side of the desired levels. A survey by Lacombe Research Centre found that about 15% of retail pork loin chops had less than 2% IMF (Meadus, 2000). In a survey of Western Canadian pigs average IMF was estimated to be 3% (Murray,1999) while 25% of longissimus muscles contained less that 2% fat in the studied commercial population. Similar levels have been observed among several breeds in large industries in the US (Swine News 2002) except for Durocs. The average IMF content ranges from 2.15% in NGT Large White to 3.03% in Duroc (Table 1). The results of this survey support the use of the Duroc breed for better pork quality.

Table 1. Intramuscular fat (IMF) content in different breeds

Breed	IMF (%)
Berkshire	2.41
Danbred HD	2.33
Duroc	3.03
Hampshire	2.57
NGT Large White	2.15
NE SPF Duroc	2.71
Newsham hybrid	2.25
Spot	2.35
Yorkshire	2.33

Source: Swine News 2002

Selection for leanness of swine carcasses in the past has resulted in some reductions in IMF content mainly because of a mild but positive correlation with backfat thickness. Current selection for low backfat thickness and increase in lean yield is expected to reduce the IMF content even further. There is a need to explore possibilities to increase the IMF content in lean meat while continuing selection for leaner carcass.

<u>HFABP gene and IMF</u>

The fatty acid–binding protein (FABP) is a family of binding proteins with distinct tissue distributions and diverse roles in fatty acid metabolisms. They are small cytosolic proteins involved in fatty acid binding and transport from the plasma membrane of the cell to the site of fatty acid utilisation (Veekamp and Maatman, 1995). Heart fatty acid binding protein (HFABP) is a member of this family and is mainly expressed in cardiac and skeletal muscle cells.

The HFABP gene has been mapped to swine chromosome 6 (Gerbens et al., 1997a). HFABP gene was sequenced and three restriction fragment length polymorphism (PCR-RFLP) were detected with restriction enzymes *HaeIII*, *HinfI* and *MspI* (Gerbens et al. 1997a). Polymorphism at *HaeIII* was found in Berkshire, Duroc, Landrace and Hampshire populations (Emnett et al. 2000). The gene frequency of allele 1 is 0.63. Gerbens et al. (1998) tested the polymorphism at the three RFLP sites in different breeds including Dutch Landrace (DL), Duroc (DU), Great Yorkshire (GY), Hampshire (HS), Meishan (ME), Pietrain (PI) and Wild pig (WP). All three RFLP sites within HFABP gene were found to be polymorphic in all breeds tested, except for the *HaeIII* and *MspI*

RFLP in Hampshire and Meishan (Table 1). This generally existing polymorphism is very useful for the genetic improvement of traits associated with the HFABP gene.

Table 2. Frequency of one of the alleles at all three RFLP sites within HFABP gene in different breeds

RFLP	Allele	Allele frequency						
		DL	DU	GY	HS	ME	PI	WP
MspI	A	0.98	0.40	0.81	1.0	1.0	0.90	0.70
HaeIII	D	0.32	0.40	0.31	1.0	1.0	0.50	0.10
HinfI	H	0.70	0.70	0.97	0.33	0.45	0.70	0.90
N		20	10	34	6	11	5	5

N is the number of unrelated animals tested in each breed.
DL=Dutch Landrace, DU = Duroc, GY =Yorkshire, HS = Hampshire, ME = Meishan, PI = Pietrain and WP = Wild pig.
Source: Gerbens et al., 1998

The HFABP gene has been considered to be a candidate gene for IMF as well as backfat thickness in pigs. Gerbens et al. (1999) detected the associations of HFABP genotypes with IMF and backfat. The phenotypic difference between homozygous genotypes at HFABP locus can reach 0.4% IMF content in two Duroc populations ($p<0.05$). This genotypic difference is equal to about 15% of mean value of IMF content (Vries et al. 2000).

In the experiment with Duroc populations, the difference between the homozygote with high IMF alleles (*a* at *HaeIII*, *d* at *HinfI* and *H* at *MspI* RFLP) and the homozygote with low IMF allele (*A* at *HaeIII*, *D* at *HinfI* and *h* at *MspI* RFLP) is 0.37%, 0.38% and 0.4%, respectively. In a QTL mapping experiment based on F2 crossbreds of Meishan and Western pigs, Gerbens et al. (2000) assessed that the contrast between homozygotes with high IMF allele and low IMF allele explains 0.36% IMF content. Consistent results were also reported by Gerbens (1997b) in the backcross data of (Large White ? Dutch Landrace) ? Large White.

Candidate gene HFABP was patented in the Netherlands and was said to explain 0.4% IMF content. The effect of HFABP is much smaller according to the experiment of Meadus (2000): HFABP gene and AFABP (adipose fatty acid binding protein) gene together explain 0.3% marbling fat content. Several QTL mapping studies (Paszek et al. 1999; De Koning et al. 1999; and Ovilo et al. 2000, 2002; Grindflek et al. 2001) also detected the QTL effect on IMF content in the region of HFABP.

Use of HFABP gene to improve IMF

Because of the positive correlation of IMF content with backfat thickness, it seems difficult to satisfy the lean carcass preference and the marbling desire at the same time. Fortunately, the difference of IMF content is only partially explained by backfat thickness according to the research of Gerbens et al (1999). In the study by Gerbens et al. (2000) no difference in backfat thickness was found between HFABP alleles while there were significant differences in IMF. Their results support the implementation of HFABP polymorphisms in marker-assisted selection to improve IMF content independently from backfat thickness. HFABP gene seems to be a useful gene to solve the dilemma of lean desire and IMF preference by increasing IMF content independently from backfat thickness. The effect of HFABP gene, estimated as difference between homozygotes, is very large, considering the lower levels of IMF content in swine populations (Table 1).

Assuming that 0.2% IMF (about half of the estimated genotype difference) can be increased on average by selecting HFABP and marginal economic value is $0.84 each kg per 1% IMF change, the economic value each kilogram will be about $ 0.18 from the IMF improvement. Considering that there is a quite high proportion of pork loin that has lower than 2% IMF, extra economic gain will come from reducing the proportion of pork loin whose IMF content is lower than 2%. Supposing that IMF content is normally distributed, mean IMF is 3% on average, and 25% of pork loin has less than 2% IMF, an average 0.2% increase of IMF will reduce the proportion of less-than-two-percent-IMF loin from 25% to less than 21%. If average IMF is 2.15% (corresponding the estimation for NGT Large White), 0.2% increase of IMF will reduce the proportion of less-than-two-percent-IMF loin by at least 7%.

Summary

North American markets as well as the Japanese market are increasingly demanding a proper IMF content in the marketed fresh pork. Improvement of IMF content is not only important for consumers' acceptance of marbling level, but it has also important effect on eating quality such favor, tenderness and juiciness.

The survey results have indicated that there is a large proportion of pork loin which is under consumers' acceptance threshold. Trends of low IMF are expected to continue further because of the intensive selection for lower backfat and higher lean yield, because of the positive correlation between IMF content and backfat thickness. HFABP gene offers the opportunity to increase IMF content without affecting backfat thickness, therefore having fast growing leaner market hogs with desirable level of IMF content.

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