NETWORKING SYSTEM FOR MARKER-ASSISTED SELECTION IN PIGS

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ABSTRACT

DNA test of Hal-1843 halothane stress gene on chromosome 6 has been applied with MS-PCR method for PSS-gene free of breeding lines in order to reduce hog mortalities and improve meat quality without PSE in commercial herds in Taiwan since 1996. In 2002, both estrogen receptor gene (ESR) on chromosome 1 for litter size and heart fatty acid binding protein gene (HFABP) on chromosome 6 for meat quality have been applied on boars in the growth performance test stations since 2002. The genotyped percentage of pedigree registration population on PSS, ESR, HFABP, IGF27, IGF23 and PRLR were evaluated their allele effect in marker-assisted selection scheme after 2008. Due to free of PSS gene in Duroc, Landrace and Yorkshire breeding herds, boars born in 2013 had average daily gain of 1.136, 1.152 and 1.169 kg per day from 40 to 110 kg of body weight, respectively. Feed efficiency in the ratio of feed uptake to weight gain from 40 to 110 kg was 2.059, 2.062 and 2.065 in Duroc, Landrace and Yorkshire boars, respectively. To date, auction breeding pigs of Duroc, Landrace and Yorkshire should be PSS-gene free from growth performance test station and body conformation contest. Duroc breed served as terminal sire in crossbred LYD hog production let an increase of breeding stocks having HHaadd haplotype (HH6) of H-FABP gene from 53.7% to 86.4% in order to improve the marbling pork. In conclusion, selection of elite breeding stocks of D, L and Y pig raised in Taiwan with exotic blood origin would be the excellent genetic resources for hog production in tropical region.

Keywords: Genetic Marker, Hog Production, DNA Test

INTRODUCTION

Livestock and poultry in Taiwan include pig, dairy cow, goat, rabbit, chicken, duck, and goose as major farm animals for meat, milk and egg production. Other minor species are horse, sheep, turkey, quail and ostrich. Due to high land prices and rising environmental awareness, most local farmers operate on a small scale in rural areas of Central and Southern Taiwan. Coupled with import-dependent feeds and expensive laborers, the local livestock industry operates at a rather high production cost. Fortunately, local livestock farmers are highly diligent, and have advanced feeding and breeding skills. The main island of Taiwan is mountainous and afforested, with fertile, cultivated, well-watered and heavily populated lowlands to the west of the central mountain range with a total land area of 36,179 km^2. The human population is 23.1 million. The climate is subtropical, with hot humid summers, mild winters and heavy rainfall. There is a continuous growing season for crops and agriculture prospers, in spite of typhoons, violent summer thunderstorms, and flooding, as well as prolonged winter droughts. About a quarter of the land is arable. Five percent of the land is meadow and pasture.

There are 12 breeds of pig for genomic resources of hog production in Taiwan (Fig. 1). In November of 2013, the number of pig farms totaled 8,557, raising a total of 5,806,237 pigs including of 21,446 boars, 533,844 sows and 71,000 gilts. About 85% of pigs are LYD hogs in which they are progeny from hybrid sows of Landrace and Yorkshire with Duroc terminal sire. The other 15% of pigs (885,737 head) was black coat color with maternal blood origin of local breed Taoyuan or imported breed Berkshire, Meishing and Hampshire.

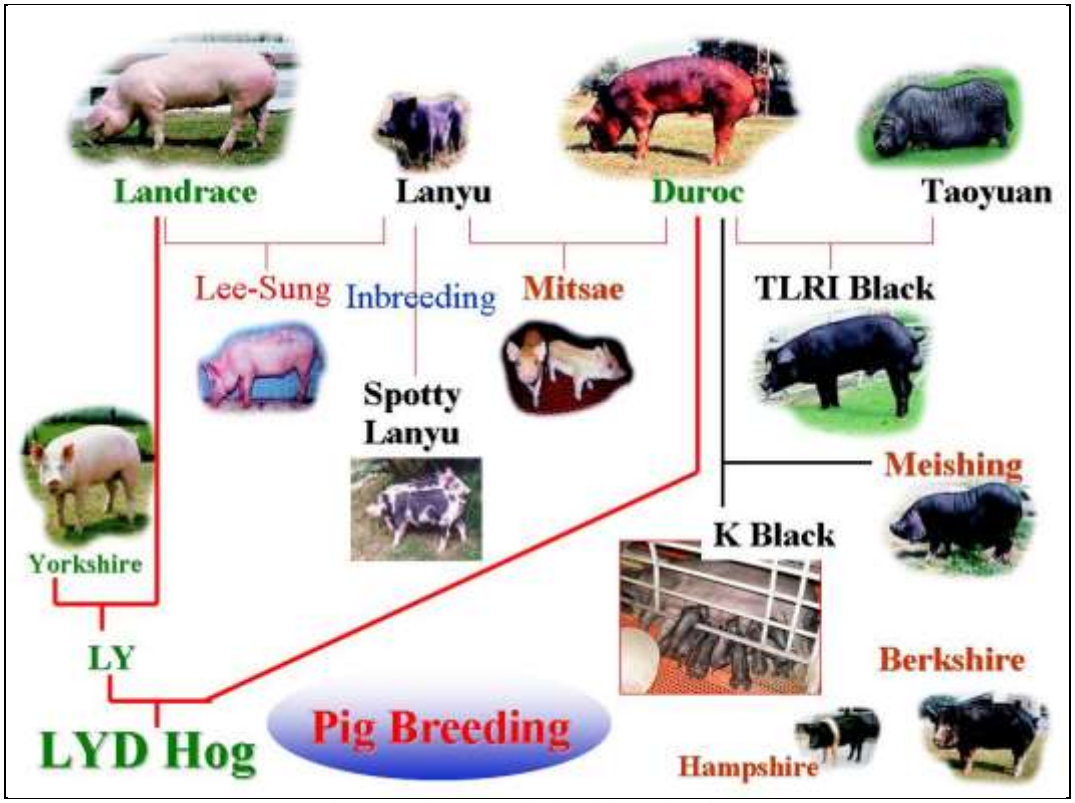


Fig. 1. Breed resources for hog industry in Taiwan.

Molecular genomic analysis has revolutionized how geneticists and breeders evaluate the production differences that exist within the domesticated animals (Mantaldo and Meza-Herrera, 1998). In this case the DNA tested gene is known as a marker, because it marks a section of chromosome affecting performance. The gene whose presence it detects is known as a quantitative trait loci (QTL), with linkage between the marker and the QTL. The pig industry is actively using some of genome information to improve swine production by marker-assisted selection (MAS). Over the past decade tremendous progress has been made mapping and characterizing the swine genome. Currently, moderate to high-resolution genetic linkage maps containing highly polymorphic loci have been produced using independent mapping populations. To date, >5,000 mapped loci are cataloged for the pig genome (http://www.thearkdb.org/arkdb/). Large scale sequencing of expressed sequences (ESTs) in conjunction with genomic sequencing has permitted the identification of single nucleotide polymorphisms (SNPs) that can be used to finely map economic traits, such as meat quality, growth rate and feed efficiency. Thus, the tools and information have been developed to permit application of genomics into improving the health and performance of pigs. Clearly, low cost diagnostics based on this information will be the next wave of development for livestock and poultry farming.

PEDIGREE REGISTRATION OF BREEDING PIG STOCKS

Industry technology chain for pig breeding in Taiwan includes four working steps: birth recording, trait performance test, pedigree registration, and stock auction with various items (Fig. 2). Pig performance database are on http://www.angrin.tlri.gov.tw/ web site.

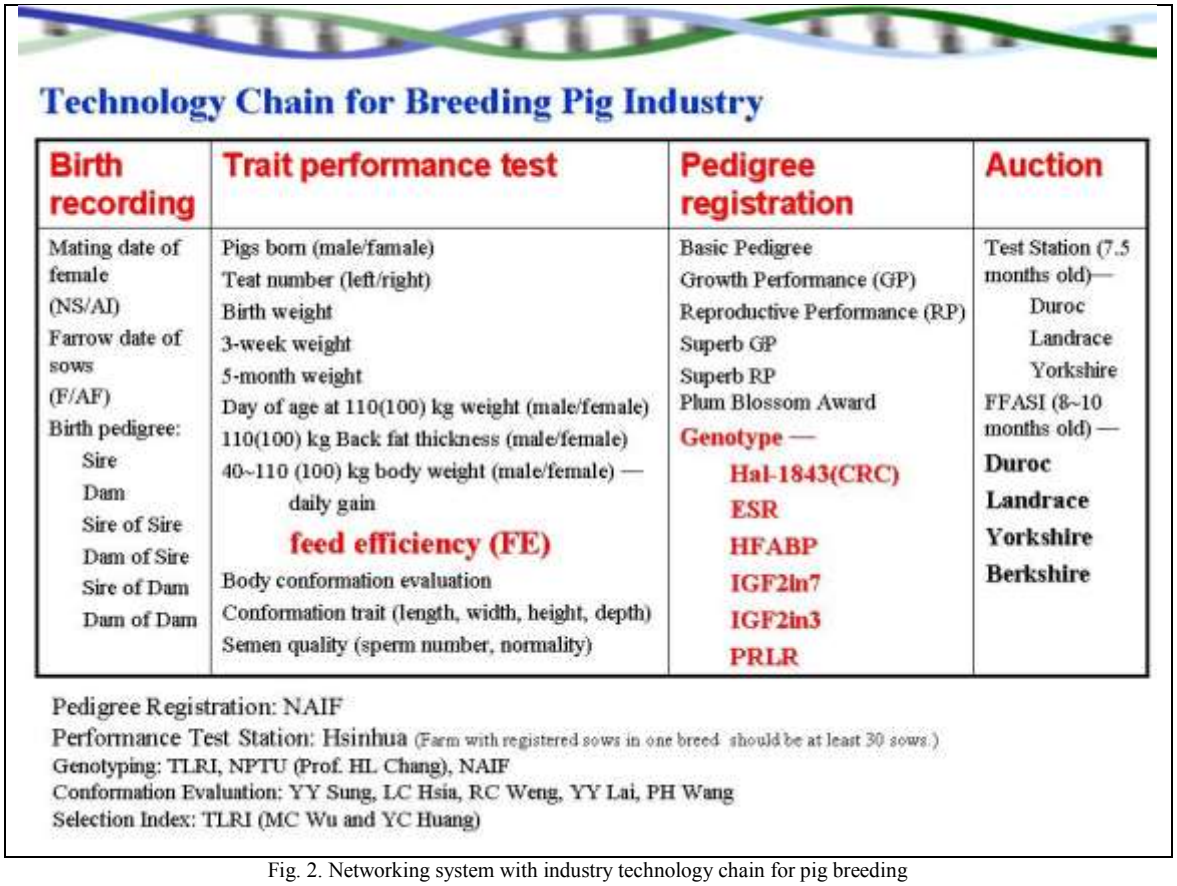


Fig. 2. Networking system with industry technology chain for pig breeding

The pedigree registration networking system is the record of pedigree and performance of pure breed pigs. Taiwan Basic Pedigree Information Registration was amended in 1975 for records of mating and piglets production of purebred pigs in Landrace, Yorkshire, Hampshire, and Duroc breeds. In 2000, Berkshire, TLRI Black (E), Meishing, and Taoyuan breeds were registered for the development of black pig production system. A new black breed named as K Black in 2009 derived from hybrid of Duroc and Meishing breeds with selection on solid black coat color and litter size at KHAPS breeding herd. Recently, miniature pig breeds of Lanyu (A), Spotty Lanyu (O), Binlang (U) and Mitsae (S) were registered for bio-medical research needs. Hence, a total of 12 breed (A, B, D, E, H, K, L, O, S, T, U, Y) of 187,383 pigs with recent year born had been recorded on the pedigree registration (Table 1) since 1975. There were no pedigree registration of Berkshire and Hampshire breed based upon recent year born in 2011 to 2013. Breed of L, Y and D are three major breeds for pedigree registration in Taiwan. L and Y breeds are the maternal breed and so more gilts registered. D breed is served as the terminal sire and part of registered boars were off-tested boars from growth performance test.

A profile on pedigree registration counts by birth year of registered pigs from 1971 to 2013 (pigs born in 2013 were not completed on pedigree registration) was tabulated to show the population size and number of farms involved in pig breeding industry (Table 2). A goal of pedigree registration of breeding stocks in number was set on 5,000 head each year with a ratio of sire to dam should be 1:3 or above. Due to FMD outbreak on March of 1997, the breeding pig industry was affected and counts of pedigree registration decreased more than 50% from the highest 8,344 head born in 1995 to 3,877 head born in 1997. .Number of farms with pedigree registered pigs also decreased from 102 to 53 due to the disease outbreak. Based upon year born from 1997 to 2012, approximately 4,200 head registered from 40 or less farms. Under the condition and stage of FMD vaccination program, breeding farms would keep a minimum number of breeding stocks to continue on the improvement of growth and reproduction traits.

Table 1. Cumulative counts on pedigree registration of purebred pigs in Taiwan

台灣種豬登錄統計 Pedigree Registrations of Pig Breeds in Taiwan

品種 Breed	性別 Gender	登錄頭數 Head	登錄號(最初) Reg. No. (Early)	登錄號(最近) Reg. No. (Last)	出生年(最初) Birth Year (Early)	出生年(最近) Birth Year (Last)	近年出生 Recent year born			
							2011	2012	2013	2014
Y	公 M	9050	000024	214241	1971	2013	207	172	73	-
Y	母 F	25319	000004	214369	1971	2013	622	421	96	-
U	公 M	15	206035	214404	2007	2013	1	6	2	-
U	母 F	15	206036	214407	2008	2013	-	5	3	-
T	公 M	4	207053	207530	1999	2004	-	-	-	-
T	母 F	7	206984	207532	1999	2005	-	-	-	-
S	公 M	3	206041	214401	2010	2013	-	-	2	-
S	母 F	7	206040	214402	2008	2013	1	2	1	-
O	公 M	3	206057	214398	2008	2011	1	-	-	-
O	母 F	13	206042	214399	2006	2012	3	1	-	-
L	公 M	15484	000043	214373	1971	2013	456	393	172	-
L	母 F	70299	000062	214376	1971	2013	1405	1306	429	-
K	公 M	29	200135	210299	2005	2011	9	-	-	-
K	母 F	125	200136	210320	2005	2012	25	19	-	-
H	公 M	774	000039	199787	1972	2006	-	-	-	-
H	母 F	857	000005	159585	1971	2001	-	-	-	-
E	公 M	25	206410	214197	1999	2011	2	-	-	-
E	母 F	42	211265	214199	2000	2012	2	1	-	-
D	公 M	24264	000016	214380	1971	2013	1227	1226	579	-
D	母 F	40745	000011	214365	1971	2013	885	691	245	-
B	公 M	34	206246	209861	1995	2010	-	-	-	-
B	母 F	163	206240	206547	1995	2004	-	-	-	-
A	公 M	15	206160	214383	2007	2011	3	-	-	-
A	母 F	91	206152	214397	2006	2012	14	24	-	-
Y		34369	000004	214369	1971	2013	829	593	169	-
U		30	206035	214407	2007	2013	1	11	5	-
T		11	206984	207532	1999	2005	-	-	-	-
S		10	206040	214402	2008	2013	1	2	3	-
O		16	206042	214399	2006	2012	4	1	-	-
L		85783	000043	214376	1971	2013	1861	1699	601	-
K		154	200135	210320	2005	2012	34	19	-	-
H		1631	000005	199787	1971	2006	-	-	-	-
E		67	206410	214199	1999	2012	4	1	-	-
D		65009	000011	214380	1971	2013	2112	1917	824	-
B		197	206240	209861	1995	2010	-	-	-	-
A		106	206152	214397	2006	2012	17	24	-	-
合計 Total		187383	000004	214407	1971	2013	4863	4267	1602	-

http://pigbase.angrin.tlri.gov.tw/pigfarm/pigregbreed2.asp

Table 2. Pedigree registration profiles and percentage to year goal of 5,000 head.

Pedigree Registrations of Pig Breeds (D, L, Y and other breeds in total)

出生年 Birth Year	頭數 Head	年登錄 5,000 頭達成率(%) Year goal of 5,000 head(%)	登錄號 (最初) Reg. No. (Early)	登錄號 (最近) Reg. No. (Last)	品種數 Breed	場數 Farm	雄親數 Sire	雌親數 Dam
2013	1602	32.0	212128	214407	5	20	305	831
2012	4267	85.3	206772	214399	9	33	592	1850
2011	4863	97.3	201227	214398	9	37	572	2093
2010	4376	87.5	196598	214381	10	39	602	1982
2009	4417	88.3	192934	213959	8	39	572	1894
2008	3642	72.8	189457	214196	9	41	553	1719
2007	4140	82.8	184927	214194	7	49	501	1768
2006	4395	87.9	180286	213731	8	47	560	2030
2005	4557	91.1	175859	213067	6	50	598	2187
2004	4268	85.4	171435	214185	6	56	554	2072
2003	4243	84.9	167486	214192	6	44	552	2077
2002	3695	73.9	164025	214183	5	43	583	1961
2001	5019	100.4	158471	214191	7	46	708	2496
2000	5613	112.3	152951	213064	6	51	696	2621
1999	5795	115.9	146021	212235	7	60	706	2683
1998	5192	103.8	140910	206406	5	59	712	2402
1997	3877	77.5	136345	206403	5	53	723	2129
1996	6694	133.9	129437	206405	5	81	1013	3364
1995	8344	166.9	121872	206509	5	97	940	3736
1994	8273	165.5	112677	192033	4	102	1006	3922
1993	7675	153.5	105874	183973	4	97	942	3737
1992	6084	121.7	099773	175666	4	98	907	3260
1991	6148	123.0	092434	146264	4	97	937	3242
1990	5788	115.8	086641	151797	4	82	940	3192
1989	6880	137.6	079695	183966	4	86	952	3340
1988	7392	147.8	072666	183980	4	88	990	3349
1987	6885	137.7	065797	177729	4	80	1018	3251
1986	6459	129.2	059678	106351	4	77	986	3243
1985	7159	143.2	038375	183965	4	86	1109	3511
1984	7932	158.6	043394	102140	4	103	1087	3495
1983	4305	86.1	033935	175530	4	102	831	2080
1982	4202	84.0	023939	098178	4	101	741	2007
1981	2924	58.5	015457	131919	4	91	572	1283
1980	2932	58.6	012503	183979	4	78	538	1263
1979	2061	41.2	008763	127638	4	69	460	932
1978	2082	41.6	002511	090377	4	61	308	588
1977	1090	21.8	001707	090259	4	46	223	371
1976	717	14.3	000959	090257	4	32	136	242
1975	786	15.7	000431	090256	4	29	82	135
1974	349	7.0	000004	037893	4	14	13	27
1973	160	3.2	000011	010094	4	8	1	3
1972	85	1.7	000016	090411	4	10	1	1
1971	16	0.3	000005	029725	4	6	-	-

http://pigbase.angrin.tlri.gov.tw/pigfarm/pigregbreed1A.asp

GROWTH PERFORMANCE TEST

The exotic Duroc, Landrace, and Yorkshire are the most popular breeds for three-way cross LYD hog production in Taiwan. Young Duroc, Yorkshire and Landrace boars with registered parent(s) were performance tested at Hsinhua Station. Hsinhua Station located at Taiwan Livestock Research Institute started the first test group on September 1989. The starting weight set around 30 kg during 1989 to 1995 was increased to 40 kg in accordance with the national hog cholera free project requirements. The end weight was set at 110 kg during all test periods. The average daily gain, feed efficiency and back fat thickness of boars in 1989 were ranged 0.837~0.873 kg, 2.47~2.57 and 1.65~1.97 cm, respectively. The above three traits were recorded and evaluated as a contemporary group deviation form for selection index calculation purposes. Selection index of boars at growth performance test station was set to SI=100 + 60 (ADG-MADG) – 40 (FE-MFE) – 45 (BF-MBF) in 1981 for improvement of lean production and had been used in Duroc breed from 1981 to 2004 and for Landrace and Yorkshire from 1981 to 1990. Consideration of reproductive performance after growth, therefore, selection index for Landrace and Yorkshire boars was reset to SI=100 + 130 (ADG-MADG) – 40 (FE-MFE) – 40 (BF-MBF) and was used from 1990 to 2004. Feed efficiency is the key factor for production cost, hence, selection index of 2005 version for Duroc is reset to SI=100 + 120 (ADG-MADG) – 55 (FE-MFE) – 50 (BF-MBF), and for Landrace and Yorkshire is SI=100 + 140 (ADG-MADG) – 60 (FE-MFE) – 30 (BF-MBF).

All original data and evaluated results were stored in an internet-based database. The performance tested data and related information can be easily accessed from the web site (http://www.angrin.tlri.gov.tw). The maximum body weight at 150 days of age can reach to 154 Kg for those of growth performance test pigs at Hsinhua Station during the test year from 2001 to 2013 (Table 3). Growth performance test boars should be the halothane stress gene free in order to make the class comparison at 180 days of age. Boars with selection index 100 or above were then giving both pedigree registration and growth performance registration. The best measurement on age to 110Kg, average daily gain, feed efficiency, backfat thickness at 110Kg, and selection index were shown in Table 4.

Table 3. Body weight at 150 days of age at Hsinhua Station for growth performance test

Year	Hd	Max. (Kg)	Month for measuring Body weight at 150 days of age (Kg) Query date: 2014/5/12																							
			1		2		3		4		5		6		7		8		9		10		11		12	
			Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.	Head	Max.
2001	640	148	88	143	19	131	86	148	24	147	107	139	-	-	79	127	24	131	93	133	21	120	79	137	20	138
2002	637	145	97	139	-	-	88	140	13	127	110	136	-	-	98	128	8	143	90	145	27	125	98	134	8	138
2003	717	154	103	138	13	122	92	154	16	133	90	128	19	144	91	145	74	130	126	137	9	122	67	131	17	134
2004	893	150	117	139	94	147	73	150	43	128	65	136	37	126	81	126	97	137	119	129	4	121	79	125	84	143
2005	725	149	14	117	71	138	110	149	-	-	97	146	-	-	111	139	103	136	114	132	-	-	105	128	-	-
2006	872	146	118	141	109	146	112	138	-	-	99	127	-	-	110	131	112	130	106	129	-	-	106	135	-	-
2007	852	147	116	137	112	134	97	129	-	-	102	147	-	-	112	129	96	132	107	136	-	-	110	132	-	-
2008	868	150	115	150	105	136	108	147	-	-	103	133	-	-	115	129	106	131	114	125	-	-	102	131	-	-
2009	861	143	116	132	114	142	111	143	-	-	101	131	-	-	117	134	102	135	107	132	-	-	93	139	-	-
2010	812	139	106	130	105	139	102	131	-	-	99	128	-	-	111	131	99	136	99	133	-	-	91	137	-	-
2011	839	151	97	125	97	151	102	132	-	-	106	131	28	117	77	127	115	140	108	134	-	-	109	129	-	-
2012	872	149	115	138	112	139	101	132	-	-	103	144	-	-	108	133	114	149	109	136	-	-	110	138	-	-
2013	893	154	118	139	112	151	114	148	-	-	109	147	-	-	108	134	112	140	111	154	-	-	109	141	-	-
2014	322	144	105	144	112	131	105	141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

http://pigbase.angrin.tlri.gov.tw/pigfarm/bsdclrpt_2eDEN.asp

Table 4. Growth performance of halothane stress gene free boars in Taiwan

Year of birth	Breed	No. of boar	Age to 110kg, day		Average daily gain, kg		Feed efficiency (Feed/Gain)		Back fat thickness at 110Kg, cm		Selection index	
			Earliest	Mean	Greatest	Mean	Best	Mean	Thinnest	Mean	Highest	Mean
2000	D	208	123	156.2	1.382	1.020	1.95	2.117	1.04	1.370	128	105.9
2001	D	228	126	150.2	1.208	1.017	1.93	2.123	1.08	1.304	128	106.9
2002	D	179	128	148.9	1.300	1.046	1.93	2.090	1.10	1.276	134	108.4
2003	D	208	125	148.7	1.250	1.040	1.90	2.061	1.02	1.224	125	106.7
2004	D	224	121	149.2	1.390	1.056	1.90	2.038	1.03	1.216	130	107.7
2005	D	278	127	148.6	1.390	1.063	1.92	2.031	1.00	1.224	141	112.7
2006	D	295	125	147.6	1.310	1.075	1.90	2.031	0.90	1.222	136	111.2
2007	D	278	128	146.5	1.330	1.094	1.95	2.041	1.07	1.232	138	110.4
2008	D	308	124	148.7	1.420	1.097	1.93	2.056	1.07	1.244	140	111.1
2009	D	282	126	147.7	1.330	1.109	1.93	2.057	1.10	1.252	143	111.5
2010	D	287	128	149.4	1.320	1.100	1.96	2.070	1.12	1.293	139	110.9
2011	D	309	128	148.5	1.390	1.109	1.98	2.078	1.12	1.311	135	109.0
2012	D	310	121	143.8	1.410	1.121	1.98	2.073	1.16	1.296	144	110.5
2013	**D**	**222**	**125**	**144.5**	**1.460**	**1.136**	**1.95**	**2.059**	**1.15**	**1.294**	**139**	**110.7**
2000	L	125	120	149.0	1.357	1.082	1.94	2.091	1.08	1.349	150	113.8
2001	L	82	126	142.6	1.471	1.105	1.94	2.116	1.10	1.288	158	117.7
2002	L	109	120	144.4	1.461	1.104	1.88	2.086	1.05	1.296	162	117.3
2003	L	155	120	141.7	1.492	1.134	1.73	2.061	1.01	1.224	167	115.6
2004	L	118	121	143.7	1.357	1.128	1.91	2.037	1.04	1.227	147	113.9
2005	L	127	126	142.1	1.360	1.113	1.92	2.045	1.01	1.210	145	115.0
2006	L	140	120	143.1	1.330	1.102	1.91	2.030	1.09	1.234	141	114.2
2007	L	144	120	142.6	1.360	1.124	1.86	2.046	1.05	1.234	145	113.3
2008	L	121	124	144.9	1.410	1.100	1.97	2.054	1.09	1.237	158	113.5
2009	L	128	128	145.0	1.340	1.133	1.98	2.063	1.10	1.258	151	115.6
2010	L	113	128	146.7	1.310	1.114	1.98	2.082	1.17	1.309	143	114.2
2011	L	128	123	145.7	1.370	1.109	1.99	2.088	1.17	1.322	150	112.6
2012	L	109	121	143.2	1.390	1.142	1.93	2.086	1.17	1.316	150	112.8
2013	**L**	**83**	**117**	**143.2**	**1.450**	**1.152**	**1.97**	**2.062**	**1.15**	**1.318**	**152**	**114.4**
2000	Y	36	126	152.3	1.357	1.063	1.95	2.095	1.17	1.372	152	115.3
2001	Y	29	140	152.2	1.286	1.066	1.98	2.103	1.21	1.359	138	112.6
2002	Y	19	137	149.4	1.167	1.065	1.98	2.113	1.17	1.349	125	114.5
2003	Y	34	141	154.7	1.190	1.053	1.96	2.079	1.14	1.293	129	109.9
2004	Y	33	132	150.4	1.260	1.065	1.93	2.055	1.15	1.271	142	113.3
2005	Y	42	133	146.4	1.210	1.071	1.95	2.035	1.10	1.249	138	111.8
2006	Y	31	133	146.0	1.310	1.124	1.94	2.043	1.14	1.262	138	115.8
2007	Y	37	127	142.4	1.300	1.117	1.96	2.058	1.10	1.242	132	114.6
2008	Y	49	133	145.4	1.320	1.131	1.96	2.067	1.10	1.251	140	113.7
2009	Y	44	132	146.6	1.350	1.127	1.98	2.047	1.15	1.288	133	115.5
2010	Y	43	119	145.1	1.370	1.145	1.96	2.083	1.19	1.325	135	112.7
2011	Y	52	129	145.8	1.330	1.138	2.00	2.097	1.19	1.322	139	113.0
2012	Y	50	122	143.4	1.390	1.160	1.99	2.081	1.25	1.312	138	112.1
2013	**Y**	**35**	**132**	**147.3**	**1.390**	**1.169**	**1.96**	**2.065**	**1.26**	**1.351**	**132**	**110.3**

Note: See the text for selection index of L, Y and D.

Source: http://pigbase.angrin.tlri.gov.tw/pigfarm/bsdmphotogene4L.asp

PIG GENOMICS AND INDUSTRY APPLICATIONS

Methods for pig breeding in Taiwan are the combination of methods between index selection and genetic marker-assisted selection. Economic traits associated genes, e.g., PSS, ESR, and H-FABP genetic markers have been applied at the growth performance test station for boars since 2003. Present genetic improvements for the economically important traits in pigs resulted from the more detailed genetic maps and our growing understanding of the function and structure of the individual genes. Pale soft and exudative (PSE) pork and PSS (Porcine Stress Syndrome) pigs are associated with variation in the Halothane gene (RYR1 or CRC1) on chromosome 6. The halothane RYR1 appears to be functional gene or QTL responsible for all the effects on lean growth and stress susceptibility. The estrogen receptor ESR on chromosome 1 is associated with litter size (Rothschild *et al.* 1996). H-FABP (Heart fatty acid binding protein) gene on chromosome 6 was discovered to affect intramuscular fat in Duroc pig (Gerbens *et al.* 1998).

Removal of the Halothane stress gene from breeding lines using the halothane test in 1988 and then MS-PCR DNA marker test (Hal-1843) in 1996, which reduced mortalities of hogs and improved meat quality in fresh pork. In 1996, halothane gene free (normal gene was named to AA) boars reached 74.2%, 90.0%, and 60.2% in Landrace, Yorkshire, and Duroc breed, respectively. A farm-level gene screening program on halothane stress gene (AB and BB genotype) was conducted in breeding farms in 2004, genotyping results indicated that pigs born in 2003 to 2013 had an increase of Duroc pigs with normal gene AA from 65.5% to 95.2%; and Landrace and Yorkshire pigs in nucleus herds had near 100% of stress gene free (Table 5).

Table 5. Percentage of Hal-1843 stress gene free of D, L and Y pigs in breeding farms

	Duroc			Landrace			Yorkshire		
Birth year	Farms	Head	Normal (%)	Farms	Head	Normal (%)	Farms	Head	Normal (%)
2003	24	508	65.4	23	437	99.1	14	52	98.1
2004	24	902	72.9	21	577	96.9	15	117	98.3
2005	23	2184	70.7	21	853	98.0	16	208	99.5
2006	23	2020	76.7	21	774	98.1	14	204	95.6
2007	25	1713	81.4	23	987	97.9	13	256	99.6
2008	28	1437	83.6	20	880	92.7	16	334	99.4
2009	27	1796	88.6	21	1106	96.6	19	379	99.5
2010	29	2015	89.5	24	1264	98.2	15	418	99.3
2011	25	1859	90.8	22	1090	98.9	18	450	98.9
2012	25	1741	92.5	22	1077	99.4	14	330	99.1
2013	21	993	95.2	17	645	99.8	9	177	98.9

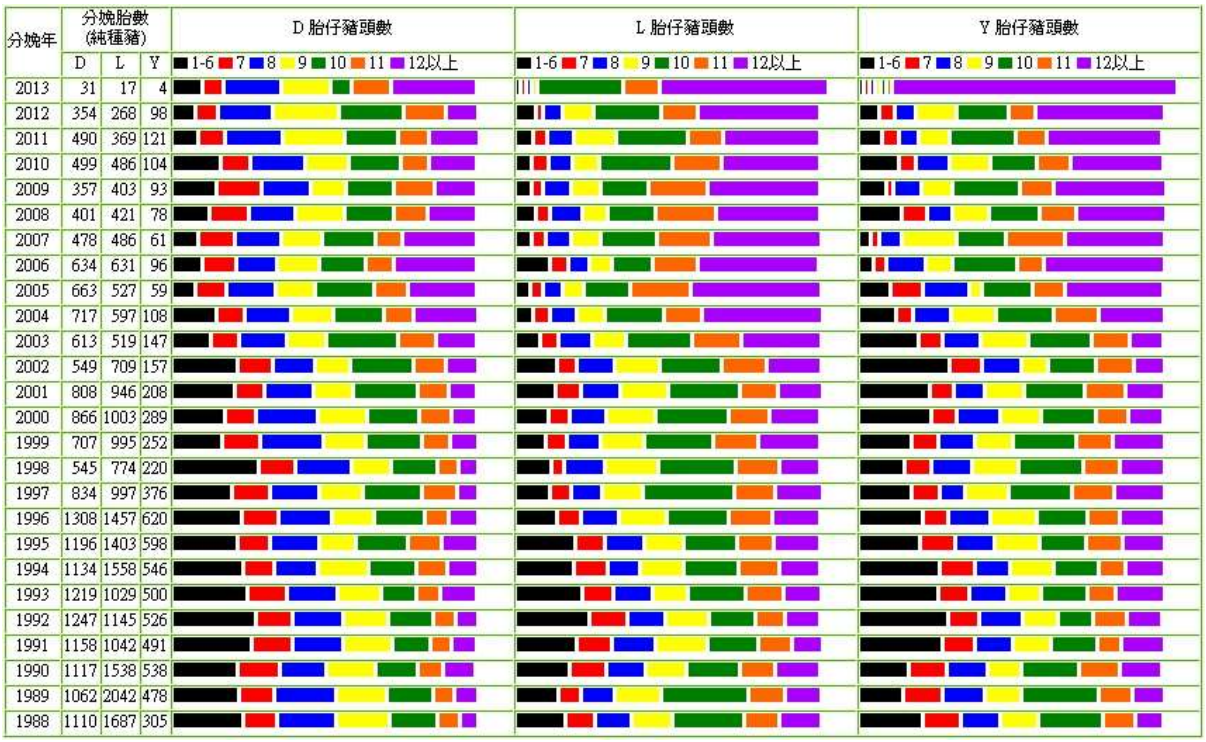
Sold price between AA and AB genotype of stress gene in Duroc boars were from less difference to larger amount as the birth year from 2003 to 2010 at Hsinhua Station, Zhunan Station and FFASI Auction (Table 6).

Table 6. Auction Price on AA and AB genotypes of stress gene in Duroc boars.

Birth year	Stress gene	Hsinhua Station			Zhunan Station			FFASI Auction			Total	
		Head	Price (NT$)	Highest Price (NT$)	Head	Price (NT$)	Highest Price (NT$)	Head	Price (NT$)	Highest Price (NT$)	Head	Price (NT$)
2003	**AA**	142	41411	151000	175	50751	423500	99	36377	200000	416	44142
2003	AB	53	39292	113000	57	45710	221000	86	35151	152000	196	39341
2004	**AA**	156	47185	661500	238	47151	701500	153	35973	258000	547	44034
2004	AB	52	38086	130000	46	35739	193000	69	32608	176000	167	35176
2005	**AA**	189	48283	283000	252	43317	386500	141	37929	281000	582	43624
2005	AB	34	30147	74000	43	51465	292500	49	46204	700000	126	43666
2006	**AA**	222	37157	160000	275	33101	215500	141	33226	201000	638	34539
2006	AB	34	26911	81000	28	24446	55000	35	30457	202000	97	27478
2007	**AA**	218	36740	148000	253	38891	250000	197	33208	173000	668	36513
2007	AB	27	33592	88000	34	34544	93000	30	32000	70000	91	33422
2008	**AA**	233	46965	159000				223	38748	188000	456	42946
2008	AB	28	36285	119000				30	28533	71000	58	32275
2009	**AA**	237	51438	311000	221	41226	160500	235	44587	305000	693	45858
2009	AB	12	34166	89000	13	28769	51000	18	29166	100000	43	30441
2010	**AA**	241	43547	251000	294	36680	200000	220	47945	361000	755	42154
2010	AB	22	29818	100000	15	25233	85000	10	31100	52000	47	28627
2011	**AA**	272	39522	190000	298	34503	154000	216	35944	311000	786	36635
2012	**AA**	273	42333	206000	310	34493	191000	205	37214	236000	788	37917
2013	**AA**	191	36471	120000	174	35028	191000	117	35094	100000	482	35615

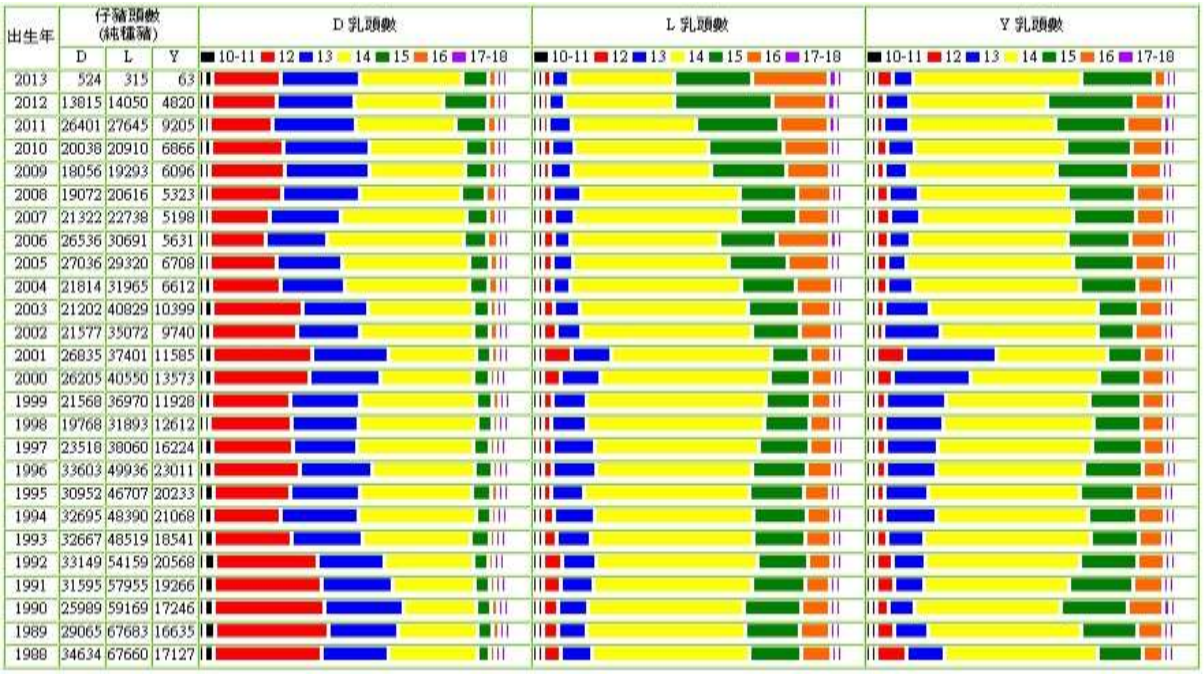
http://pigbase.angrin.tlri.gov.tw/pigbase/Price_Duroc_PSS.asp

Rothschild *et al.* (1996) estimated that the B allelic effect of ESR gene varied from 1.15 piglets per litter in Meishing pig to 0.42 piglets per litter in Yorkshire. Therefore, the relevance of results found in LY crosses involving the L and Y breeds in commercial lines. There has been an increase in the rate of genetic response by incorporating the ESR genotype in selection indices for sow lines in nucleus herds. Furthermore, the increase in average litter size is observed in crossbred products derived from these lines. Litter performances of D, L and Y primiparous sows with registration certificate were presented in Fig. 3. Number of piglets born alive in L, Y and D had a significantly increase in 2005 along with an increase profile of total counts on teat nipples in newborn piglets of L and Y breeds (Fig. 4). Such results might due to the application of Hal-1843 nucleotide mutation test to free PSS of registered D and L sows because there were a little increase on percentage of BB (also named as MM for maternal prolific effect) genotype of ESR-B allele form 2003 to 2012 (Table 7).



分娩年	分娩胎數 (純種豬)			D 胎仔豬頭數	L 胎仔豬頭數	Y 胎仔豬頭數
	D	L	Y	1-6 7 8 9 10 11 12以上	1-6 7 8 9 10 11 12以上	1-6 7 8 9 10 11 12以上
2013	31	17	4			
2012	354	268	98			
2011	490	369	121			
2010	499	486	104			
2009	357	403	93			
2008	401	421	78			
2007	478	486	61			
2006	634	631	96			
2005	663	527	59			
2004	717	597	108			
2003	613	519	147			
2002	549	709	157			
2001	808	946	208			
2000	866	1003	289			
1999	707	995	252			
1998	545	774	220			
1997	834	997	376			
1996	1308	1457	620			
1995	1196	1403	598			
1994	1134	1558	546			
1993	1219	1029	500			
1992	1247	1145	526			
1991	1158	1042	491			
1990	1117	1538	538			
1989	1062	2042	478			
1988	1110	1687	305			

Fig. 3. Litter size profile of D, L and Y primiparous sows in percentage of litters.
(http://pigbase.angrin.tlri.gov.tw/pigfarm/LittersizeLYD.asp)



出生年	仔豬頭數 (純種豬)			D 乳頭數	L 乳頭數	Y 乳頭數
	D	L	Y	10-11 12 13 14 15 16 17-18	10-11 12 13 14 15 16 17-18	10-11 12 13 14 15 16 17-18
2013	524	315	63			
2012	13815	14050	4820			
2011	26401	27645	9205			
2010	20038	20910	6866			
2009	18056	19293	6096			
2008	19072	20616	5323			
2007	21322	22738	5198			
2006	26536	30691	5631			
2005	27036	29320	6708			
2004	21814	31965	6612			
2003	21202	40829	10399			
2002	21577	35072	9740			
2001	26835	37401	11585			
2000	26205	40550	13573			
1999	21568	36970	11928			
1998	19768	31893	12612			
1997	23518	38060	16224			
1996	33603	49936	23011			
1995	30952	46707	20233			
1994	32695	48390	21068			
1993	32667	48519	18541			
1992	33149	54159	20568			
1991	31595	57955	19266			
1990	25989	59169	17246			
1989	29065	67683	16635			
1988	34634	67660	17127			

Fig. 4. Total counts on teat nipples of newborn piglets in D, L and Y breeds
(http://pigbase.angrin.tlri.gov.tw/pigfarm/TeatnumberLYD.asp)

Table 7. Percentage of prolific MM genotype of ESR gene of D, L and Y pigs.

	Duroc			Landrace			Yorkshire		
Birth year	Farms	Head	ESR MM (%)	Farms	Head	ESR MM (%)	Farms	Head	ESR MM (%)
2003	21	955	0.0	17	645	2.9	9	175	41.7
2004	25	1637	0.0	22	1070	1.0	14	328	35.4
2005	25	1745	0.0	22	1078	0.2	18	446	31.6
2006	28	2005	0.0	24	1242	1.0	15	416	32.5
2007	26	1701	0.1	21	1036	0.6	19	362	30.9
2008	28	1428	0.0	20	816	0.0	16	332	28.3
2009	23	1329	0.0	20	716	0.1	12	213	29.6
2010	23	1578	0.1	17	543	0.4	12	134	22.4
2011	22	1757	0.0	20	605	0.5	13	149	24.8
2012	24	532	0.0	21	237	0.4	13	63	11.1
2013	22	199	0.0	19	118	0.8	6	15	6.7

http://pigbase.angrin.tlri.gov.tw/pigbase/bsdquery8TAEHIP2.asp

MEAT QUALITY

Genetic makeup of pigs can have a significant influence on meat quality. Two of the main genes that can affect ultimate meat quality, are the halothane (stress) gene and the Napole (RN^-) gene. Fresh meat color has a subtle but important impact on consumer purchase decisions. Most consumers prefer a bright reddish-pink color in fresh pork. Intramuscular fat or marbling has been related to meat eating quality which is defined as flavor, juiciness and/or tenderness of meat. Pork with a higher amount of intramuscular fat would be expected to produce meat with more desirable and less variable eating quality than the meat with less intramuscular fat. However, some consumers prefer pork containing little or no marbling, in order to avoid the associated calories.

H-FABP gene with three nucleotide mutations (defined as H, a, and d alleles) maps to chromosome 6 and found them to be associated with variation in intramuscular fat in the Duroc breed (Gerbens *et al.* 1998) and not to the QTL regions on chromosomes 4 and 7 identified by De Koning *et al.* (1998). Three desirable alleles of H, a, and d in H-FABP gene were detected by genotyping and produced possible 27 combinations of their genotypes in Table 8. According to the amount of desirable alleles, we redefined various combinations into seven groups HH6 (Hhaadd, with 6 desirable alleles in total), HL5, HL4, HL3, LL2, LL1 and LL0 (hhAADD, with zero desirable allele).

Frequency of HH6 in the Duroc registered boars born after 2003 in the performance test station was 61.7% (174/282), but zero percentage in Landrace and Yorkshire breeds. More than half of Duroc boars (57.36%) or gilts (54.56%) sampled at five month of age had HH6 from pig breeding farms in 2004, but less than 2% of Landrace pigs had and zero in Yorkshire pig. The percentage of HH6 genotype of Duroc pigs born in 2003 to 2013 increased from 53.7% to 86.4% with H allele frequency of 98.9% (Table 9). Although H allele frequency in L and Y pigs were 80% and 37%, respectively, H-FABP genotype codes were more with HL4 in Landrace and HL3 in Yorkshire pigs. The pig industry will continue to compete on the low cost per kilo of lean meat with marbling quality. In general, the pig industry arguably some 20-30% of genetic potential is not realized on the small scale farms due to poor herd health, poor husbandry, and incomplete application of the nutritional needs of the modern improved genotype. The breeding companies will be integrators of a range of advanced technologies, providing a package of genetic services to the pig producer. With crossbred LYD or LD hog production system in Taiwan, focusing on H-FABP gene of terminal sire Duroc breed by using haplotype of H-a-d loci (shown in Fig. 5) would be beneficial to breeding farms and hog producers with better meat quality.

Table 8. Seven codes defined for 27 combinations of three allelic mutation genotypes of heart fatty acid binding protein gene in pigs

	aa	**Aa**	**AA**	
HH	HH6	HL5	HL4	**dd**
	HL5	HL4	HL3	**Dd**
	HL4	HL3	LL2	**DD**
Hh	HL5	HL4	HL3	**dd**
	HL4	HL3	LL2	**Dd**
	HL3	LL2	LL1	**DD**
hh	HL4	HL3	LL2	**dd**
	HL3	LL2	LL1	**Dd**
	LL2	LL1	LL0	**DD**

Table 9. Genotype frequency of HFABP in D, L and Y pigs

Birth year	Breed	Farms	HFABP genotype and H allele frequency										
			Head	LL0	LL1	LL2	HL3	HL4	HL5	HH6	HH6(%)	H--	H--(%)
2003	D	22	244	7	6	1	37	41	5	131	53.7	230	94.3
2004	D	24	528	10	6	12	116	63	12	308	58.3	499	94.5
2005	D	22	1766	38	17	21	291	231	96	1065	60.3	1683	95.3
2006	D	23	1582	20	13	8	238	162	43	1098	69.4	1541	97.4
2007	D	22	1332	12	11	11	151	145	25	977	73.3	1298	97.4
2008	D	27	1437	8	22	13	182	127	31	1054	73.3	1394	97.0
2009	D	25	1674	10	16	5	220	121	31	1271	75.9	1643	98.1
2010	D	27	1993	22	19	7	230	130	30	1555	78.0	1945	97.6
2011	D	25	1839	5	19	5	189	134	46	1441	78.4	1810	98.4
2012	D	25	1498	1	1	2	92	54	13	1335	89.1	1494	99.7
2013	**D**	**21**	**938**	**2**	**8**	**0**	**49**	**65**	**4**	**810**	**86.4**	**928**	**98.9**
2012	L	21	981	6	7	153	53	724	37	1	0.1	815	83.1
2013	**L**	**16**	**550**	**5**	**6**	**111**	**18**	**391**	**16**	**3**	**0.5**	**428**	**77.8**
2012	Y	14	285	33	62	86	66	38	0	0	0.0	104	36.5
2013	**Y**	**8**	**154**	**12**	**32**	**49**	**39**	**22**	**0**	**0**	**0.0**	**61**	**39.6**

Note: Genotype code is defined in Table 8.
Source: http://pigbase.angrin.tlri.gov.tw/pigbase/bsdquery8TAEHIP3.asp

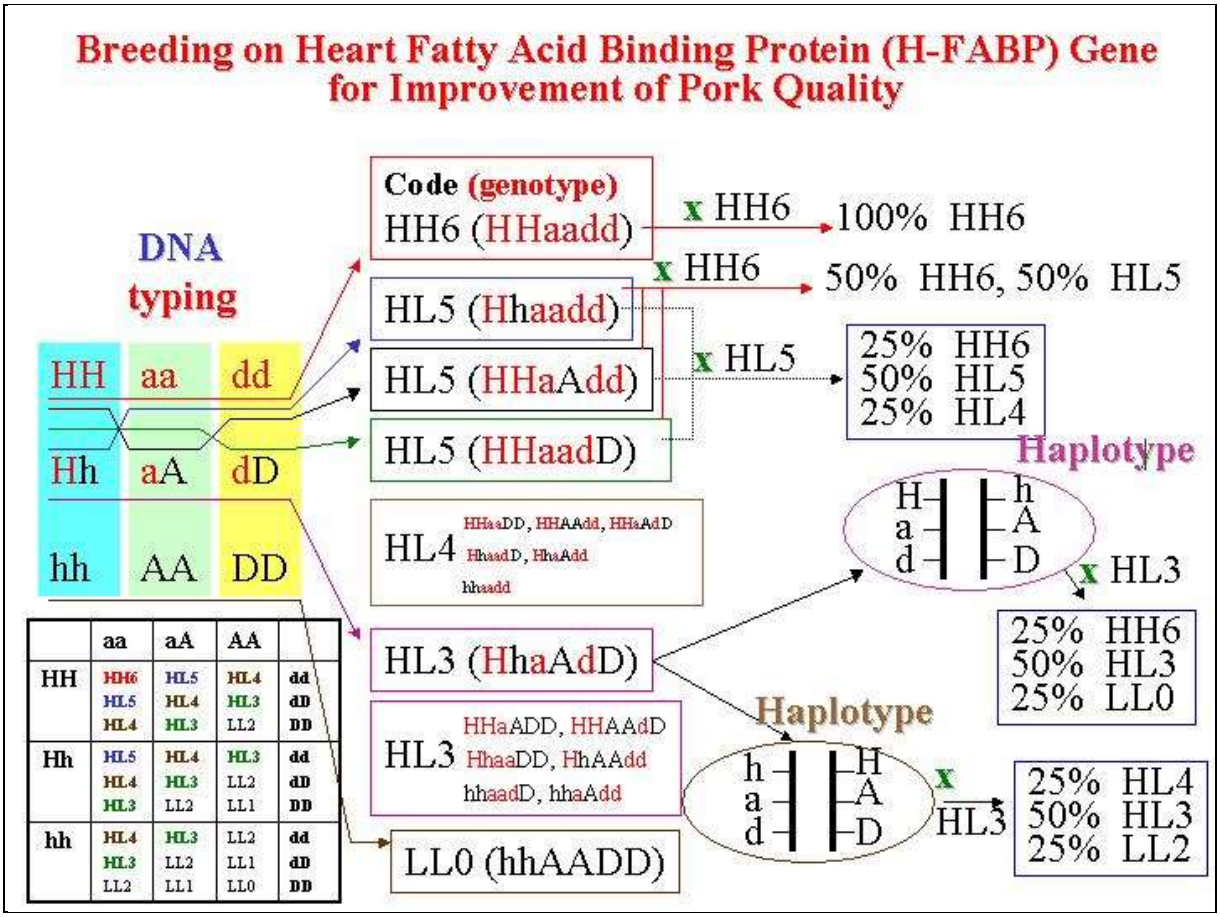


Fig. 5. Breeding on heart fatty acid binding protein gene for improvement of pork quality

EXPORTATION OF PIG STOCKS

Taiwan pigs preserved a high percentage of exotic blood through a long-term agriculture trade relationship. New stocks of pigs have been importing to Taiwan from USA and Canada since 1980. However, animals in Taiwan with the imported blood had survived after decades' tropical hot weather culling, which might have special genes for hot and high humidity weather adjustment. Lines of these excellent farm animals owned high economic value for the production performance. Taiwan was No. 18 country in pig production in the 2013 world listings based on number of sows on farm. Taiwan boars of D, L and Y breeds have a better feed efficiency (Feed/Gain ratio) from 40 to 110 Kg of body weight (Fig. 6). Pig breeding stocks not only had pedigree registration also had genotype registration for exportation certificate. Profile of genotyped breeding stocks with PSS, ESR, HFABP, IGF27, IGF23 and PRLR genes was presented in Fig. 7. Furthermore, breeding farms will focus on developing an excellent pig breed and/or line which is able to export to other hot weather region, e.g., China, Brazil, Mexico, Spain, Vietnam, India and Philippines. Therefore, selection of elite breeding stocks of Duroc, Landrace and Yorkshire pig raised in Taiwan with exotic blood origin would be the excellent genetic resources for hog production in tropical region.

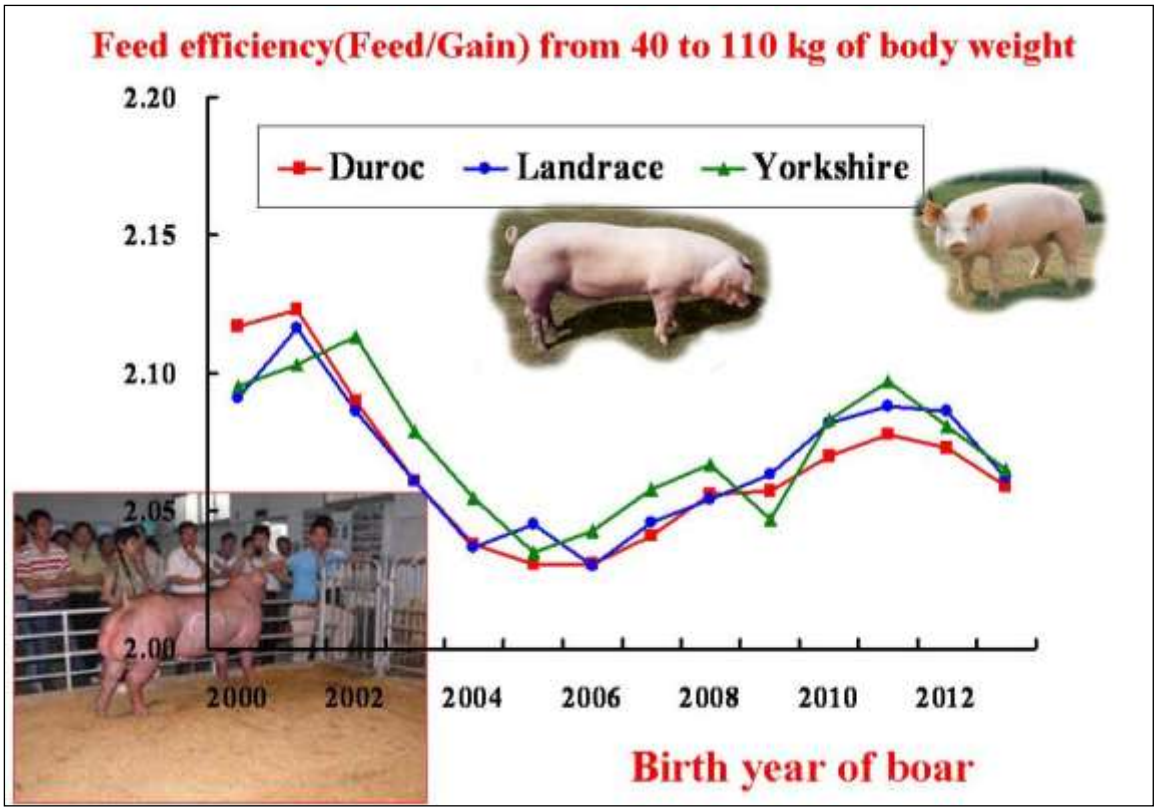


Fig. 6. Profile of feed efficiency (Feed/Gain) of growing D, L and Y boars

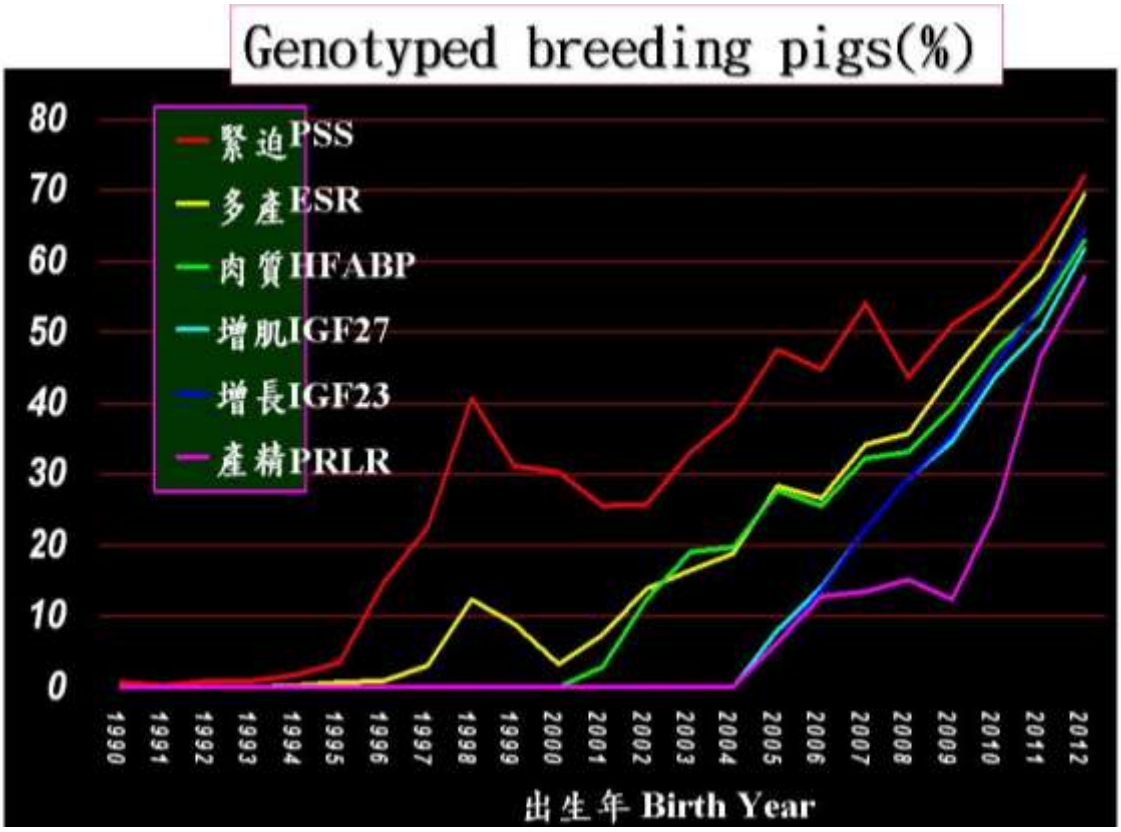


Fig. 7. Genotyped profile from pedigree registration population by birth year
(http://pigbase.angrin.tlri.gov.tw/pigfarm/pigregnew2.asp)

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