A historical review of pig testing programs in Denmark

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Abstract: The first swine testing station and program in the world was started in Denmark. Denmark has tested breeding and genetics traits of pigs for more than 100 years and have developed an efficient structure and system to select pigs which produce quality pork for the consumer. The Danish pork is exported to many countries around the world. The testing programs described in the article have proven to be very successful over the last 100 years. The history of swine testing for superior pigs is not finished yet. The selection criteria for quality swine breeding animals will also need to be updated on a regular time table because the production systems are changing yearly and new environmental codes and animal welfare regulations are added each year so the testing programs on pig farms also need to change to meet the new production standards. It is not uncommon to obtain some unusual traits when selecting for extreme traits in pigs when they are on testing programs. When these traits are obtained, it requires additional testing to remove these traits. An example would be the Porcine Stress Syndrome. Osteochondrosis is another example. The gene mapping research will also open up new directions for swine testing programs. Therefore, as long as we produce pigs for quality pork and efficient production we will need outstanding swine testing programs.

Key words: swine; testing program; history; Denmark
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Until 1887 pig breeding in Denmark was based upon the export to Germany of heavy pigs weighing from 120 to 150 kg. To satisfy this market the old native Danish Landrace breed was crossed with Middle White and Berkshire boars imported from England in order to produce still fatter pigs. In 1887 the importation of Danish pigs became prohibited by Germany and our farmers had to change over to the production of bacon for the English market.

This change over was not an easy one. For the production of bacon, a completely different type of pig was required. It had to be longer, more meaty and with a thin layer of back fat. Prior to 1895 there was no organized pure breeding of Landrace pigs, but fortunately previous experience had shown that sows of the old native Landrace breed crossed with Large White boars resulted in animals giving a better bacon quality. A considerable number of Large White boars were therefore imported from England and crossed with the native breed.

It was however impossible to prevent the animals obtained from this crossbreeding to be utilized for further breeding and crossing without any organized plan, which also resulted in a great variation in type and quality of the bacon produced.

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1 The early development

It thus became necessary to organize pig breeding. After recommendation from the State Advisor efforts was made to establish a "pure breed" and the system of State Recognized Breeding Centres (Pedigree breeds) was initiated in 1895 – 1896. The centres were privately owned farms but were subjected to supervision by district committees. The objectives of these breeding centres were to: (1) Provide the ordinary pig producers with purebred boars and sows. It was considered producers to go on crossing Landrace sows with Large White boars and purchase the first crosses to the bacon factories. (2) Improve the Danish Landrace by breeding and selection to such an extent that the breed itself was good enough to fulfil all the requirements of a perfect bacon pig and therefore make the crossing of the Landrace sows with Large White boars unnecessary.

The establishment of breeding centres increased rapidly. In 1898 there were about 70 Landrace centres and in 1950 about 270 spread around the country. Large White centres increased to 33 in 1930, but decreased in number as to the plan to 4 in 1950. The last centre of Large White was closed in 1967. But after the new era of cross breeding was initiated in the early nineteen seventies Large White centres have been established again (se later). In 1937 the carcase quality of pigs delivered from the Landrace centres exceeded the quality of pigs from the Large White centres.

The quality of the breeding work done in the centres was strongly controlled by advisors and the district committees. The owners received each year a minor amount of money from the government. The main thing was that all animals in the centre were approved in relation to their conformation. All animals born had to be ear clipped with the number of their mother. All activities of mating and farrowing had to be registered. A herd book was established by the start of the breeding system. The criteria for entering the herd book were moderated and strengthen during the years in relation to more and more information available from the test stations. The hereditary background should be documented in tree generations. The first Herd Book was edited in 1906. In fig. 1, Herd Book No. 2 "Rasmus" is shown.

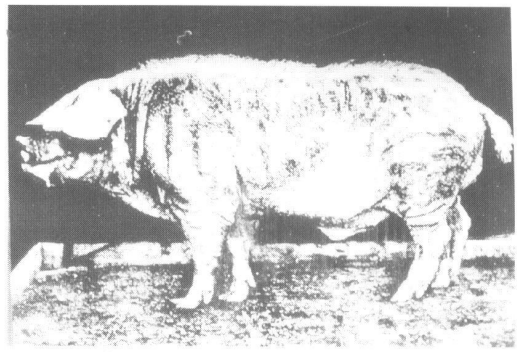

Fig. 1 Herd Book No. 2 "Rasmus" born in 1902 (Notice the heavy head and deep shoulders in relation to the light hindquarter)

When the first pig breeding centres were set up, efforts were made to select stock containing as little Large White blood as possible. However, it is possible that some of the first selected animals could contain some Large White genes. On the other hand it is important to emphasize that since 1895 no Large White animals have been used in the Landrace centres.

It became very soon apparent when district committees visited the breeding centres to approve and score the boars and sows that the selection of breeding animal possessing good hereditary factors could not be carried out exclusively by means of an external examination, because many of the pigs qualities could not be determined in the living animal, such as growth rate, thickness, firmness and distribution of back fat, thickness and fleshiness of the belly and the amount and quality of meat. Whether or

not pigs carried good or bad hereditary factors for these and other characteristics could only be determined by a test of their progeny.

2 Progeny testing

In such tests the environmental conditions for all groups of progeny has to be kept completely identical in order to be able to register any possible difference between the parents.

Such investigations were commenced in 1899, only four years after the first breeding centres were established. From 1899 to 1906 the tests were carried out at various farms, but without any uniformity, and therefore also difficult to compare the results. Based on these preliminary experiences and with the view to standardising the environmental conditions of all the groups, the first Pig Progeny Testing Station was built in 1907, the first establishment of its kind in the world.

At the end of the nineteen twenties five Testing Stations were in operation for testing of progeny from the animals approved at the breeding centres. The work was partly financed by the State (National Institute of Animal Science, NIAS) and partly by the Co-operative Bacon Factories. The NIAS was responsible for the technical aspects and the calculating and publishing of the test results.

The selection of pigs based on progeny testing increased steadily. As many of the pigs from pedigree sources could not be recognized as State breeding centres because the animals were not sufficient good, the agricultural associations in collaboration with the Co-operative Bacon Factories made a set up of fifteen smaller local testing stations. They were controlled by a committee to ensure that they worked on the same line as the state establishments (Fig. 2).

That the farmers had a great interest in the breeding work with pigs came from the fact that the pigs they delivered for slaughter were classified and paid in relation to the thickness of back fat of the single carcases. The first Co-operative Bacon Factory had been established in 1887. Carcase quality has always been the big driver for Danish pig production, and therefore also have had a big impact on all activities within research on pigs.

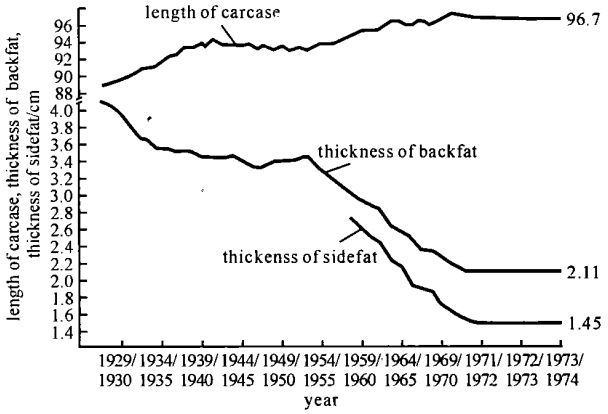

Fig. 2 The development in the length of carcase thickness of backfat and thickness of sidefat in the years 1926 – 1972

At the test stations the pigs were fed with skimmed milk and barley in groups of 2 female and 2 castrated males. The test period was from 20 to 90 kg live weight. After slaughter the fat thickness in the back and belly, and the body length was measured. Other registered characteristics were visual scores for hams, shoulder, bacon type etc. (Fig. 3).

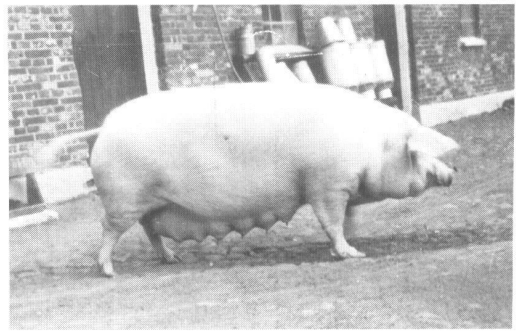

Fig. 3 Danish Landrace sow 1940 (Head and ears still big enough, but more of the weight is moved backwards)

In 1931 an agreement between the agricultural associations and the Co-operative Bacon

Factories resulted in the foundation of The National Committee for Pig Production (NCPP). Beside the elected members from the organisations mentioned the professor in Pig Breeding and Pig Production at The Royal Veterinary and Agricultural University and the Chief Advisor in Pig Breeding have ever since been advisory members of the committee.

3 Developments 1945 to 1973

After the slow down in pig production during World War II the breeding centres had only 5 – 6 approved sows per herd. As the production of pigs increased there was also an increasing demand for better and better breeding animals. In 1960 the average of approved sows in the centres were 10, and 21 in 1971. In 1973 the Ministry of Agriculture allowed the NCPP to take over the recognition of the breeding centres in cooperation with the NIAS.

When, during the recent years, the uniformity of the Danish Landrace increased, it became necessary to pay closer attention to the environment of the progeny test in order to be able to test the differences between the groups. Three new testing stations was planned to replace the five old ones. The stations (Fig. 4) were identical in their construction and contained 400 pens for individual feeding. In 1960 an extra station was built, and thereafter the capacity of tests were 1 200 – 1 300 groups per year.

The groups consisted still of 2 male castrates and 2 female and the test period was from 20 to 90 kg. From 1970 the test period was changed to 25 – 90 kg due to some health problems at the beginning of the test. The feed was until 1965 skimmed milk and ground barley, when there was changed to a pelleted full-feed mixture, produced on the same factory, and given after the same feeding standard at all the stations.

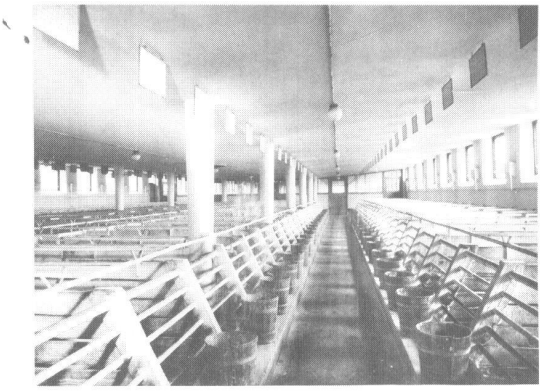

Fig. 4 Interior from one of the new test stations with individual pens

The daily gain of the tested pigs were in average 674 g in 1948 – 1949 and 686 g in 1969 – 1970, the feed conversion rate decreased in the same period from 3.15 to 2.88 Scandinavian Feed Unit (SFU) per kg of gain.

Until the late fifties the carcase evaluation was still based on fat thickness in the back, thickness of belly and the length of body as objective measurements. Some visual judgements of hams, firmness of fat, shoulder and bacon type were still done. But the market demands for more and more meaty carcases resulted in a need for more objective measurements. From 1954 all carcases were cut at the last rib. The meatiness was judged by score, the side fat was measured, the area of fat and muscle was measured by planimeter and the meat quality scored by points from 0 – 5 (pale-dark). The various figures for each pig were passed to the breeders when they received results from the tested groups. Meat / fat relationship at the cut side as the first, but from 1959 also the area of m. longissimus dorsi.

At the end of the nineteen sixties the demand for even more meaty carcases was still obvious. The evaluation of the carcase quality was still done at the local slaughterhouses under rather bad conditions. In order to make the carcase measurements more uniform and correct, it

was decided to establish two carcase evaluation centres (Fig 5) where the carcases from all the tested pigs could be thoroughly examined They were ready for use from 1967. All carcases about 10 000 – 12 000 per year were transported to the Evaluation Centres in cooled lorries

Fig 5 Interior from the Carcase Evaluating Centre

Besides the fat measurements and the body length one side of each pig was dissected and the weight of the different cuts and tissues registered For loin and ham the weight of muscle plus bone and fat was weighted separately. Based on the figures from the dissection a special formula calculated the percentages of meat in the carcase which was done on an electronic basis

During the very intensive selection for more meat it unfortunately was seen that the colour and the water binding capacity of the meat became worse In cooperation with the Meat Research Institute an objective muscle quality score was developed It was based on colour and pH_{24} in three different muscles (loin ham and neck), and computerised to a KK-number ranging from 0 1 – 10 0

Meat percentage and KK-number as new characteristics were very quickly accepted by the breeders and the effects on the breeding stock was recognized within a few years

At the end of this period the local breeding work was included in the work of the recognized breeding centres They had during the time given good support to the local pig production

4 Developments 1973 to 1983

In the years up to this period the conventional production of pigs had seen increasing problems with too low daily gain health problems and reproduction On this background the possibility for cross breeding artificial insemination and SPF production was discussed very intensively in the last part of the sixties and resulted in new strategies for the breeding work

The number of conventional breeding centres were reduced to 278 in 1975 and at the same time 3 new SPF breeding centres were recognized Hereto came the establishment of 2 new Large White breeding centres In 1978 became 2 Duroc and 1 Hampshire SPF propagation herds approved In 1983 the situation was 131 Landrace 72 Large White 28 Duroc and 5 Hampshire centres A new structure was introduced in 1981 where the breeding centres were allowed to have more breeds in their herd but at least 30 approved sows per herd They were also allowed to have multiplying of crossbred boars and sows from tested parents

The success of the Danish breeding system as far had been the combination of progeny- and sib testing The breeding stock was selected on the basis of the best test results from full and half sibs

As an result of the cooperation between the researchers at the NIAS and the NCPP there was introduced an economical index for both Landrace and Yorkshire in 1980 The characteristics were Daily gain feed efficiency Pct Meat in carcase and the KK number for quality of the meat

In 1973 the first multiplier herds became started up. They should on the bases of purebred Landrace and Large White bought from the breeding centres produce crossbred young females for the producers. In 1983 the number were 81 conventional multiplier herds and 55 SPF multiplier herds.

Due to the health situation the testing stations introduced "all in-all out" from 1976. The system worked on a section basis where all sections at all stations took part.

Until 1972 the selection on daily gain and feed conversion had been based upon a uniform feeding scale on all test stations (semi ad libitum). It was now changed to ad libitum feeding from self feeders. The goal was to breed pigs which could stand ad libitum feeding and at the same time keep the good production characteristics.

The old test stations were no longer up to standard. Therefore a new station with a capacity of 2 800 pigs per year was planned and built in 1981. The composition of the test groups was at the same time changed to three pigs: 1 female, 1 castrated male and 1 male. The female and the castrated male were at the end of the test slaughtered and evaluated at the Carcase Evaluation Centre. And the live male was scanned at the last rib to measure the muscle area and the fat thickness. If good enough it could pass back to the breeder or to one of the centres for artificial insemination.

The ultra sonic scanning equipments became soon more handy and safe in use, and from 1971 it was used for a coarse selection of breeding animals at the breeding centre. During the following years the use of scanning became widespread. The geneticist at NIAS had in 1977 developed an index for scanning based on daily gain, side fat thickness and muscle area. In 1980 it was further developed to a breeding value index.

From 1975 young boars from well tested parents were performance tested at some of the old local test stations. After test an index for breeding value was calculated for each animal. This index was based also upon results from parents, sib and half sibs and own performance.

The number of data from breeding centres, test stations, evaluating centres and performance testing were increasing rapidly. At the same time the use of EDB to handle big amounts of data became more and more common. This resulted in a proposal from NIAS to establish a Pig Breeding Data Base. It started with inputs whish already were available and all new data were from here stored in the base. Ever since the Database has been the most valuable tool for the geneticist for examine the genetic value of the different breeds and for developing new strategies for the future breeding work.

From the early seventies the selection for pct. meat in carcase was very strong, and we noticed an increasing tendency to sudden death and pale, soft and exudative meat (PSE) in the animals. The reason for this stress susceptibility was intensively studied at research institutes in many pig producing countries. One of the methods to detect this defect on the pig was the halothane sensitivity test. From 1979 all the boars entering the performance testing stations were subjected to this test. If not positive and with high index the boars could pass to an A.I. centres.

It should be mentioned here, that young boars with the very best index and with a negative halothane test on the first hand only could be used by the breeder who had delivered the boar for testing at the stations.

5 Development 1983 to 1995

From 1983 all breeders who wanted to be elite breeders had to be evaluated once a year by

a group consisting of one geneticist, one pig producer, one pig production advisor and one representative from each of the four breeds. The primary selection criteria are the level of index and the progress in the breeding herd. The centres are recognized for one year at the time.

From 1990 the index calculation was based on BLUP calculations where also all information from tested relatives were included. From 1988 a sub index for reproduction characteristics was introduced. In 1992 the number piglets born in litters of Landrace and Large White litters became a part of the breeding goal.

From 1986 the number of tested pigs per group were reduced to two, one castrated male and one female, and the period of testing extended to 30 – 100 kg liveweight. From 1989 it became possible to select entire males for boar taint (Scatole test), therefore the test groups were changed to two males. As mentioned before all potential boars were performance tested at stations.

The evaluation of meat content and meat quality was changed in 1985, and the Carcase Evaluating Centres closed. The Meat content and meat quality was then measured and registered at the slaughterhouse. The meat content based on muscle and fat thickness measurements with an optical Meat-Fat meter, and the meat colour with an optical probe.

Due to low heritability the KK number had been taken out of use in 1980 and replaced by halothane test and in some cases by blood typing primarily in Large Whites. From 1987 no Landrace animals could be approved if they were halothane positive.

To prevent health problems at the test station and all pigs were delivered to the station 3 – 4 weeks old. After a welcome treatment they were raised in a separate weaner-house until entering the test at 30 kg.

6 New structure from 1993 (Dan-Breed)

The idea of the new structure was to protect the genetic material and create a steady genetic progress. It should prevent the possibility for a breeder participating in the breeding work to sell his stock to competing interests.

The Landrace and Large White breeds, containing app. 2 000 sows each, should still function as female lines. Duroc with 1 500 and Hampshire with 500 sows should be kept as sire lines. The single herds within Landrace and Large White should count from 100 – 250 sows and Duroc and Hampshire herds at least 75 sows.

The testing (performance testing) will be carried out on one station with a capacity of 5 000 boars yearly. The boars are tested in big pens where also are installed feed machines to register the individual feed consumption.

Performance testing is also carried out in all breeding herds (daily gain and scanning for meat content). This increases the number of tested animals with a factor 10, or up to about 75 000 individuals.

The selected boars from the test station are passed to an AI centre. Only breeders are allowed to purchase semen from the young boars. Semen from the youngest and best boars can only be used in the elite herds. The intention is also that the young selected boars as soon as possible shall produce 40 – 50 litters. It increases the selection rapidly.

Data from the breeding and testing are stored in the Pig Breeding Data Base. Today all breeders have computers on the farm and have free access to all the data concerning their own herd and also the data from the performance testing of boars. They are also offered helpful programs to facilitating the management of their nu-

cleus herd.

7 Developments 1995 to 2005

In this period the Dan Breed programme has shown its strength and effectiveness in changing the genetic value of the breeding animals within the nucleus herds. The flow of genes from the nucleus to the production is today very fast. Not least because of an steady increasing use of AI at all levels of the production. Also the multiplying herds producing crossbred young females is very effective in the spread out of genes prom the nucleus herds.

The traditional and well known pyramid of an effective pig production based on nucleus herds, multiplying herds and production herds is still functioning, but today much more effective than before.

The breeding objective of the four breeds is under constant revision. Meat quality characteristics such as pH_{24} in all breeds and intramuscular fat in Duroc has been into the breeding goal for some time and then excluded again, when problems solved. It was decided, and almost finished, to eliminate the *RN* gene from the Hampshire breed in which it is connected to low pH after slaughter.

Litter size has increased significantly over the past ten years. At the same time, mortality is increasing among the newborn piglets. To stop a continued increase in mortality it was decided to include survival in the breeding objectives for Landrace and Large White. The latest figures can be seen in tab. 1.

Tab. 1 Nucleus herds litter size of purebred litters 2003 – 2004

breed	litter size (purebred litters in nucleus herds)	LP5[1], number	percentage of gilts /%
Duroc	10.1	–	68.7
Hampshire	8.5	–	69.2
Landrace	14.6	10.0	67.0
Large White	13.7	9.5	55.4

1) LP5= piglets alive after five days

The killing out percentage in Landrace and Large White has increased significantly since 1992. As there is found no negative influence on other traits, the killing out percentage has been included in the breeding objective for all four breeds. The latest figures can be seen from tab. 2.

Tab. 2 Average production results of boars at performance test station Bøgildgård 2003 – 2004

breed	number	daily gain (30 – 100 kg) /(g·d^{-1})	feed conversion[1] /(FUp·kg^{-1})	lean meat /%	killing-out /%
Duroc	1 409	957	2.33	60.3	74.6
Hampshire	657	842	2.44	62.6	75.4
Landrace	1 018	916	2.41	61.6	73.9
Large White	1 063	915	2.33	61.8	74.8
total	4 147	–	–	–	–

1) FUp= Feed units pig, Danish energy system

In tab. 2 is also shown some figures from the performance testing station for boars. For Duroc and Hampshire, the breeding objective consists of (economic weights in brackets): daily gain 0 – 30 kg (DKr 0.12), daily gain 30 – 100 kg (DKr 0.11), lean meat percentage (DKr 8.5), conformation (DKr 12.5) feed conversion (DKr – 81) and killing out percentage (DKr – 5). For Landrace and Large White the same traits are used, supplemented with the

number of live pigs per litter five days after farrowing with an economic weight of DKr 41. The weight of conformation is set to DKr 25.

Tab. 3 and 4 contains figures from the performance testing on the nucleus herds.

Tab. 3 Nucleus herds average production results for boars 2003 – 2004

breed	number	daily gain /(g·d^{-1})		lean meat /%	conformation points
		0 – 30 kg	30 – 100 kg		
Duroc	9 684	370	1 012	59.7	2.92
Hampshire	2 773	358	848	61.9	2.91
Landrace	17 889	375	968	62.1	2.92
Large White	13 354	357	952	61.4	3.04
total	43 700	–	–	–	–

Tab. 4 Nucleus herds average production results for young sows 2003 – 2004

breed	number	daily gain /(g·d^{-1})		lean meat /%	conformation points
		0 – 30 kg	30 – 100 kg		
Duroc	11 118	368	963	59.8	3.04
Hampshire	3 708	362	812	61.8	3.06
Landrace	22 485	378	935	62.1	3.09
Large White	15 322	357	920	61.4	3.14
total	52 633	–	–	–	–

8 Final remarks

From the historic review above you can see that it has taken the Danish pig breeding research more than 100 years to develop a system and a structure which fulfil the tasks for breeding and production of pigs up to the wishes of the consumers.

The history has not finished yet. The pig breeding will also in the future still face new challenges, because the production systems are changing in relation to the code of welfare and environmental regulations. What we have seen is also, that selection for one or more traits can result in weakness in other important traits. In Denmark is more research dealing with longevity and leg weakness in progress. Osteochondrosis is one of the diseases which is under investigation in relation to the selection.

General and specific resistance to disease is another field, which will need more research.

The gene mapping projects going on in many research institutes will undoubtedly give valuable information about the pig genome and open up for new possibilities for the selection on more specific important traits.

In this situation it will be very important, as always, to keep the pig in a state of physiological homeostasis.

Appendix: Materical from

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(**Edited by CHA I Yan**)

译文

丹麦种猪测定方案的历史回顾

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摘要: 全球第一个种猪性能测定站和测定方案在丹麦出现, 丹麦经过 100多年在猪遗传育种中的应用, 目前已经形成能够满足消费者对猪肉生产需要的有效结构和体系. 丹麦猪肉出口到世界许多国家. 本文描述的丹麦测定方案, 经过最近 100年的证明是成功的. 对优秀种猪性能测定的历史目前还在继续. 因为养猪生产体系每年都在发生变化, 新的环境法规和动物福利条例每年都在增加, 因此猪场的测定方案需要经常改变, 以满足这些新的生产标准, 相应地优秀种猪的选择标准也需要经常地更新. 当我们按测定方案选择极端性状的猪时, 经常会有不寻常的性状出现. 如果出现这些性状, 则需要额外的测定以去除这些性状. 比如, 猪的应激敏感综合征及软骨病. 猪基因图谱的研究为我们开启了性能测定的新途径. 因此, 只要我们需要肉质优良和生产效率高的猪, 就必须有杰出的猪性能测定方案.

关键词: 猪; 测定方案; 历史; 丹麦

在丹麦, 至 1887年为止, 主要培育 120 ~150 kg的大型肉猪, 用于出口到德国. 为了满足该脂肪型肉猪市场, 采用老本地丹麦长白与英格兰进口的中白猪和巴克夏猪进行杂交生产. 1887年, 丹麦猪出口德国受禁, 农场主只好转型生产腌肉型肉猪用以出口到英国.

这样的转型并非易事, 因为腌肉型的肉猪生产要求的猪种类型完全不同于脂肪型肉猪的生产. 与脂肪型肉猪相比, 腌肉型肉猪的体型较长、瘦肉率较高、背膘较薄. 在 1895年以前, 尚缺乏有组织的纯种长白猪育种, 不过幸运的是, 已有的生产经验表明本地丹麦长白母猪与大白公猪杂交生产的肉猪, 其腌肉质量较好. 因此, 这一时期丹麦从英国进口了大量的大白公猪用于与本地猪杂交.

然而, 由于缺乏有组织的育种计划, 不可避免地出现长大杂种作为种猪用于进行繁育和杂交, 导致腌肉猪生产中类型与质量的巨大差异.

1 早期发展

为此, 建立有组织的育种体系势在必行. 在国家有关专家的建议下, 各方致力于丹系长白的 "纯种" 选育, 并于 1895 ~1896年间起动了 "丹麦国家认证育种中心(纯系品种)"体系. 这些中心隶属于农场主私人所有, 但接受地区有关委员会监督, 育种中心的主要目标有以下 2个方面: (1)为普通养猪生产者提供纯种公猪和母猪, 相当多的养猪户用长白母猪与大白公猪杂交生产肉猪, 一些养猪户直接购买一代杂种生产肉猪供应腌肉加工. (2)通过选种选育改良丹系长白以达到其纯种也能够满足生产优质腌肉的各种要求, 这样, 就不必要依赖长白母猪与大白公猪杂交的生产模式.

育种中心很快就发展起来, 1898年大概有 70个长白育种中心, 到 1950年, 全国各地约有 270个. 到 1930年大白育种中心也增加到 33个, 但随后按计划精简, 到 1950年剩下 4个, 最后一家大白育种中心于 1967年关闭. 但是随着新杂交育种时代的到来, 在 20世纪 70年代初期, 大白育种中心又重新建立起来(参见后文). 1937年, 长白猪育种中心对改善胴体品质的贡献已经超过了大白猪育种中心.