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Genetic insights into PSE meat

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Abstract:

Pale, soft, and exudative (PSE) meat compromises the meat quality, which leads to consumer dissatisfaction and economic losses. This article examines the genetic architecture of PSE (Pale, soft and exudative) meat in pigs and evaluates traditional and genomic-based selection strategies for reducing its incidence.

Keywords: Pork, Hal gene, *RYS1*, *RN*, Stress.

Introduction:

An important quality defect in pig meat is known as Pale, Soft, Exudative (PSE) pork. The PSE condition is characterized by pork that is paler in color, softer in texture and exudes fluid. When the meat's pH is less than 6, in 45 minutes after slaughter, PSE is considered to have happened. Over 10% of pork from contemporary intensive farming is affected by this problem posing a major threat to pork industry. PSE pork is less edible and has a lower commercial value than Red, firm, and non-exudative (RFN) pork. White muscle fibers have a comparatively high glycogen content and are susceptible to PSE. The muscles in the loin area are an example. PSE typically develops in pigs that are genetically prone to stress when exposed to intense pre-slaughter stressors shortly before slaughter, although it can also occur in otherwise normal pigs if they experience stressful conditions prior to slaughter. When these genetically prone pigs are slaughtered, the meats are characterized by a rapid decline in pH during the first hour post-slaughter. The risk of developing PSE meat is influenced by several factors, including the *RYS-1* genotype, slaughterhouse conditions, season, sex of the animal, the type of flooring in transport vehicles, the loading method, and the stocking density during transportation. Additionally, factors such as on-farm fasting duration, loading time, transport time, and lairage duration also play a role (Guàrdia *et al.*, 2004; Shen *et*

al., 2025).

Genetic Basis of PSE Meat:

In pigs, two major genes related to PSE have mainly been studied, i.e. the so called “hal” or *RYR1* gene (particularly *R615C* substitution or the “n” allele) and *RN* gene (*R200Q* substitution in *PRKAG3* gene) (Škrlep *et al.*, 2010). The effect of polymorphisms at *PRKAG3* (*R200Q* and *I199V*) and *RYR1* (*R615C*) genes exhibited a significant effect on meat quality.

- **Heritability:**

Genetic research on PSE muscle shows that many post-mortem meat quality traits have moderate heritability. Heritability of most traits referring to the technological quality of meat is low to moderate (0.15 to 0.30), whereas heritability of intramuscular fat content is high (0.40 to 0.50). A genetic antagonism exists between technological quality of pork and growth or body composition traits. The halothane sensitivity gene is the major factor responsible for the “meat quantity-meat quality” genetic antagonism.

- ***RYR1* gene:**

Many studies have been undergone on the ryanodine receptor (*RYR1*) gene, also variously called the stress gene, halothane or hal gene. The pigs having homozygous recessive (nn) for a mutation of the ryanodine receptor gene are halothane positive. The pig free of the mutation in this gene (NN genotype) i.e., the homozygous dominant has been characterized with higher fat and bone proportions and low carcass weight distributions but less prone to production of pale, soft and exudative (PSE) meat. While the pigs with mutated form of this gene (nn genotype) i.e., homozygous recessive have been characterized by better feed conversion efficiency, faster growth, superior lean content and conformation. The pigs having mutated ryanodine receptor (*RYR1*) gene (n), the major gene giving positive effects on meat quantity has been found to show higher pre slaughter mortality rate, more stress susceptible (porcine stress syndrome) and more prone to produce pale, soft and exudative (PSE) meat. In a study involving a subsample of 1,331 pigs, Guàrdia *et al.* (2004) found that the *RYR-1* gene had a significant effect in pigs carrying the ‘nn’ genotype, which is associated with stress susceptibility. These pigs were shown to have a fourfold increase in the risk of developing PSE meat (PQM > 6µs). The present knowledge of the porcine stress syndrome, pale, soft and exudative (PSE) meat and genetic background of the mutation of the *RYR-1* leads to the imperative conclusion to eliminate this mutated *RYR-1* by selection of healthy pigs, which has been done successfully in other countries with important pig production strategies. In another study, it was found that Swine with the recessive *HAL* gene had a lower pH at 24 hours; this was the only difference. Additionally, swine with the recessive halothane gene allele had paler meat and animals with the n allele had higher drip loss. The homozygous pigs are more stress susceptible (porcine

stress syndrome) and produce meat of poor quality (PSE), which is also the case to some extent in heterozygous animals. (Silveira *et al.*, 2011; Wendt *et al.*, 2000).

The sarcoplasmic reticulum of recessive Hal pigs (*Halⁿⁿ*) contains faulty Ca^{2+} release channels (CRC) or Ryanodine Receptors (RYR1), which permit uncontrollably high Ca^{2+} release in response to stress. The abrupt reduction in postmortem muscle pH that results in PSE pork is induced by abnormal lactic acid metabolism brought on animal stress before slaughter (Salas and Mingala, 2016).

- **RN gene:**

The Rendement Napole (*RN*) gene has been identified as the gene responsible for the higher muscle glycolytic potential, also water holding capacity and cooking yield was lower. The *RN* gene or *PRKAG3* gene encodes the $\gamma 3$ subunit of AMPK (adenosine monophosphate-activated protein kinase), which is an enzyme crucial for regulating energy metabolism in skeletal muscle. The Rendement Napolé (*RN*) gene has two alleles: the dominant mutant allele *RN⁻* and the recessive normal allele *RN⁺*. The condition known as acid pork (AP) is also caused by the presence of the dominant *RN⁻* allele of the Rendement Napolé gene. As these pigs have elevated glycogen stores which break down after slaughter, their meat ends up with a lower ultimate pH, a condition often called “acid meat.”. Salas and Mingala (2016) found that pigs carrying *RN⁻* exhibit an elevated glycolytic potential, which leads to higher production of lactic acid after death and, consequently, a lower final (ultimate) pH (pH_u). Because of the reduced water-holding capacity in muscle tissue seen in both PSE and AP, these meats suffer from excessive drip loss, resulting in diminished cooking and processing yields. Pigs (high frequency in Hampshire) that carry the *RN⁻* mutation produce leaner carcasses but have reduced Napolé yield. It can be inferred that, unless the meat is appropriately chilled, carriers of the *RN⁻* allele are more prone to acquire PSE than non-carriers since they exhibit a faster pH decline during rigor than non-carriers (Josell *et al.*, 2003). For the commercial manufacture of cured and cooked pork products, meat from pigs with the *RN⁻* allele is a serious problem.

- **Other genes:**

Transcriptome analysis helps to improve the quality of pork by offering useful information for research on the molecular mechanisms of meat quality formation. Transcriptome profiling of pork revealed that DEGs between PSE and normal pork include genes related to immunological, inflammatory and wound responses. In particular, PSE pork development may be caused by important genes such as *ADIPOQ*, *LEP*, *PLVAB*, *MYH4*, *MYL6B*, *FOS*, *ATF3*, and *HSPA6*. Furthermore, it was found that *PPP1R3G* and *MSS51* might be significant genes related to the SM's (semimembranosus) meat quality (Zequan *et al.*, 2022).

Genetic Markers and Genomic tools:

Selection may be useful to enhance meat characteristics. There was no genetic competition between meat quality and quantity, and the main factors influencing meat quality were heritable. To determine the best breeding approach for raising meat quality, more study is currently required. This approach may be based on genetic markers or traditional polygenic selection (Le Bihan-Duval *et al.*, 2008). First and foremost, it is necessary to develop stress-resistant breeds. This is due to the fact that incidence of PSE meat has been highly associated with stress. Animals' responses to stress are influenced by a complicated interplay between their genetic makeup and past experiences. Also, it has been found that some genotypes with stress susceptibility and lean meat are linked to the prevalence of PSE meat. Despite having a slow growth rate, tropical breeds in particular are resistant to stress. Conversely, temperate breeds have a high growth rate but are more vulnerable to stress. The incidence of PSE meats may be decreased by combining genotypes from both tropical and temperate locations (Adzitey and Nurul, 2011).

Pig populations from the North-West of Argentina analyzed in a work showed a high genetic variability at the level of the meat quality markers *RYR1*^{1843C>T}, *PRKAG3*^{199I>V/200R>Q}, *CAST*^{76872G>}, *SOX6A* and *SOX6B*. Despite numerous efforts to eradicate the harmful *RYR1* and *PRKAG3* alleles, the current study identified a high frequency of T and *RN*⁻ alleles in two populations examined. Programs for genetic selection may make use of the meat quality markers examined (Rodriguez *et al.*, 2022). The more accurate gene marker tests outperform the traditional methods for assessing *Hal*ⁿ and *RN*⁻ genotypes. Genomic selection against the *Hal*ⁿ and *RN*⁻ alleles may be able to quickly and accurately lower the frequency of the defective genes. As more quantitative trait loci (QTL) are discovered, pig breeders may choose traits more skilfully to improve pork quality and boost pig production efficiency.

For food security and genetic conservation, nucleus herds of Native Pigs are now being established at several R&D stations in the Philippines. Marker-assisted selection (MAS) is being used widely, in order to screen out genetic disorders for breeding reasons and find individuals with advantageous alleles of genes linked to production attributes. A study revealed that 543 (94.11%) of the 577 pigs which were screened for Halothane (HAL) gene were normal (*NN*), 0 (0%) were homozygous mutants (*nn*), and 34 (5.89%) were heterozygous carriers (*Nn*) (Matias *et al.*, 2023).

Conclusion:

Understanding how pork quality traits are genetically controlled, and how they interrelate with growth and carcass traits, is essential to producing high-quality pork. Studies have revealed that *RYR1* gene and *RN* gene has a significant effect on developing PSE meat. Further studies should be done on other genes or genetic mechanisms to explore their effects on meat quality traits or PSE meat. Proper strategies should be developed for selection and breeding of animals free from genes or genotypes which contribute to PSE meat condition.

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