CLARIFIDE®

HOLSTEIN COAT COLOR GENETICS

Most dairy producers working with Holstein cattle know that the breed comes in two color patterns—black and white or red and white. While it is simple to visually determine the phenotype of the cow, the genetics behind Holstein coat color are complex with many possible genotypes determining the animal's appearance.

There are two different locations within the Holstein genome that influence coat color.[1] One location affects Recessive Red coat color and the black/red color form, while the other location affects a Dominant Red color. Recessive Red is the most common form of red coat color in Holstein cattle. It is important to note that Recessive Red is located in a different part of the genome than Dominant Red—there are different conditions for both that affect the coat color trait. Genetic tests are available for both locations, and research is ongoing to refine the understanding of the genetics determining coat color.

RECESSIVE RED AND BLACK/RED

There are four known forms of the gene at the Recessive Red location. There are two copies of the gene (one from the sire and one from the dam) that interact with each other, depending upon the form(s) present, to produce color patterns. This interaction is a simple dominance hierarchy described in Figure 1.

Figure 1. Order of Dominance for Forms of Recessive Red

Allele	Description	Function
E^D	Dominant form	Codes for black and white coat color
E^{BR}	Black/Red form	Codes for black/red condition
E^+	"Wild-type" form	Codes for red and white coat color
e	Recessive form	Codes for red and white coat color

Animals with at least one copy of the E^D form of the gene will be black and white, regardless of the other copy (unless altered by the Dominant Red, as described below). E^D dominates the other copy at the Recessive Red location.

Animals with the black/red condition are typically born red and turn black over time, sometimes retaining some red coloring around the nose, ears and down their topline. Black/red is sometimes referred to as "Telstar Red" after the original animal identified as a carrier of this condition, Roybrook Telstar. These animals have at least one copy of the E^{BR} form of the gene, and do not have the dominant form E^D.

The wild-type form has been identified recently and is similar in effect to the recessive form of the gene (e). Animals with two copies of wild-type or two copies of recessive or one wild-type and one recessive will have the most common type of red and white appearance.

1. Lawlor TJ, VanRaden PM, Null D, Levisee J, Dorhorst B. Using haplotypes to unravel the inheritance of Holstein coat color for a larger audience, in *Proceedings*. 10th World Congress of Genetics Applied to Livestock Production 2014.

Figure 2 explains potential genotypes related to Recessive Red, with their corresponding haplotype results and phenotypes.

Figure 2. Example Genotypes and Associated Phenotypes

Genotype	HHR Haplotype Code	HBR Haplotype Code	Phenotype	Designation or Genetic Code(s)
E^D E^D	HHRT	HBRT	Black	TR
E^D E^{BR}	HHRT	HBRC	Black	B/R
E^D E^+	HHRC	HBRT	Black	RC
E^D e	HHRC	HBRT	Black	RC
E^{BR} E^{BR}	HHRT	HBRH	Black/Red	B/R
E^{BR} E^+	HHRC	HBRC	Black/Red	B/R RC
E^{BR} e	HHRC	HBRC	Black/Red	B/R RC
E^+ E^+	HHRH	HBRT	Red	-RED
E^+ e	HHRH	HBRT	Red	-RED
e e	HHRH	HBRT	Red	-RED

Though there are a variety of potential genotypes, Recessive Red follows a traditional inheritance pattern for recessive traits. Following in Figure 3 are examples using E^D and e alleles, but the example could be applied to any of the genotype combinations.

Figure 3. Example Mating Outcomes for Recessive Red

Parent Genotypes	Progeny Appearance	Progeny Genotype
E^D E^D x E^D E^D	All black and white	All E^D E^D
E^D E^D x E^D e	All black and white	50% E^D E^D and 50% E^D e
E^D E^D x e e	All black and white	All E^D e
E^D e x E^D e	75% black and white, 25% red and white	50% E^D e, 25% E^D E^D, 25% e e
E^D e x e e	50% black and white, 50% red and white	50% E^D e and 50% e e
e e x e e	All red and white	All e e

Figure 4. Possible Dominant Red Genotypes and Associated Phenotypes

Genotype	HDR Haplotype Code	Phenotype	Designation or Genetic Code(s)
d d	HDRT	Black	DR0
D d	HDRC	Red	DR1
D D	HDRH	Red	DR2

Figure 5. Example Mating Outcomes for Dominant Red

Parent Genotypes	Progeny Appearance	Progeny Genotype
DD x DD	All red and white	All DD
DD x Dd	All red and white	50% DD and 50% Dd
DD x dd	All red and white	All Dd
Dd x Dd	75% red and white, 25% black and white	50% Dd, 25% DD, 25% dd
Dd x dd	50% red and white, 50% black and white	50% Dd and 50% dd
dd x dd	All black and white	All dd

Figure 6. Description of Official Genetic Codes and Designations Associated with the Expression of Red Coat Color

Designation or Genetic Code	Interpretation
TR	Tested free of any alleles for red coat color
RC	Red carrier (either e or E+)
B/R	Carrier of the allele causing the black/red phenotype
-RED	Not an official genetic code—animals observed with red coat color are labeled with the "–RED" suffix on their names.
DR0	Tested free of Dominant Red
DR1	Carrier of Dominant Red
DR2	Homozygous for Dominant Red

DOMINANT RED

Dominant Red is a more recently reported trait that is completely independent of Recessive Red.[2] Tracing back to a Canadian cow named Suriname Sheik Rosabel-Red, Dominant Red has been previously referred to as "Variant Red." There is a very low incidence of animals expressing Dominant Red in the North American Holstein population. Dominant Red follows an inheritance pattern typical of other dominant traits, such as polled.

It is important to note that the Dominant (D) form of this gene also will dominate over the Recessive Red, so an animal who is expected to be black and white due to the Recessive Red part of the genome will be red and white if it has at least one copy of the D form of the Dominant Red gene. See Figures 4 and 5.

There are a variety of genetic codes that are printed on animals' pedigrees and other official documents related to each genotype. See Figure 6.

CLARIFIDE REPORT INTERPRETATION

CLARIFIDE® results will include genotype information for Recessive Red and Dominant Red information, and utilize haplotype information for black/red. Shown in Figure 7 is a Holstein color chart to understand the reporting and interpretation.

2. Dorshorst B, Henegar C, Liao X, Sällman Almén M, Rubin C-J, Ito S, et al. (2015) Dominant Red Color in Holstein Cattle Is Associated with a Missense Mutation in the Coatomer Protein Complex, Subunit Alpha (*COPA*) Gene. PLoS ONE 10(6): e0128969. doi: 10.1371/journal.pone.0128969.

Figure 7. Holstein Association USA (HAUSA) Reporting Color Chart

	Actual Genotype	Genotype from CLARIFIDE	Haplotypes from CDCB	CLARIFIDE Reporting	Interpretation	Phenotype	Approx. Frequency in Holstein	HAUSA Report with No Direct Gene Test	HAUSA Reporting with Direct Gene Test
Dominant Red (from direct test or HDR)		**Genotype from ZBN**							
	d d	DR0	HDRT	DR0	Black, see Recessive Red	Black	>99%	HDR0	
	D d	DR1	ADRC	DR1	Heterozygous, Dominant Red	Red		HDR1	DR1
	D D	DR2	HDRH	DR2	Homozygous, Dominant Red	Red		HDR2	DR2

		Genotype from CLARIFIDE	Haplotypes from CDCB						
Recessive Red (from direct test HHR and HBR)	E^{D} E^{D}	E^{D} E^{D}	HHR=0/HBR=0	E^{D}/E^{D}	Black	Black	91.0%	HHRT, HBRT	TR
	E^{D} E^{BR}	E^{D} E^{+}	HHR=0/HBR=1	E^{D}/E^{BR}	Black, carrier of black/red	Black	0.9%	HHRT, HBRC	B/R*
	E^{D} E^{+}	E^{D} E^{+}	HHR=1/HBR=0	E^{D}/E^{+}	Black, wild-type red carrier	Black	0.4%	HHRC, HBRT	RC*
	E^{D} e	E^{D} e	HHR=1/HBR=0	E^{D}/e	Black, carrier of Recessive Red	Black	5.6%	HHRC HBRT	RC
	E^{BR} E^{BR}	E^{+} E^{+}	HHR=0/HBR=2	E^{BR}/E^{BR}	Homozygous black/red	Red, then Black	0.1%	HHRT, HBRH	B/R*
	E^{BR} E^{+}	E^{+} E^{+}	HHR=1/HBR=1	E^{BR}/-	Black/red, red carrier (recessive or wild-type)	Red, then Black	0.1%	HHRC, HBRC	RC B/R*
	E^{BR} e	E^{+} e	HHR=1/HBR=1	E^{BR}/-	Black/red, red carrier (recessive or wild-type)	Red, then Black	0.1%	HHRC, HBRC	RC B/R*
	E^{+} E^{+}	E^{+} E^{+}	HHR=2/HBR=0	E^{+}/E^{+}	Homozygous, wild-type red	Red	0.1%	HHRH, HBRT	
	E^{+} e	E^{+} e	HHR=2/HBR=0	E^{+}/e	Wild-type red, carrier of Recessive Red	Red	0.3%	HHRH, HBRT	
	e e	e e	HHR=2/HBR=0	e/e	Homozygous, Recessive Red	Red	1.8%	HHRH, HBRT	

*Because the direct gene test is not available with the CLARIFIDE portfolio to differentiate between E+ and B/R, for a genotype containing E+, the RC or B/R code would not be labeled on pedigrees or official performance products; pedigree analysis will be done upon request and the appropriate code will be added if it can be determined.

SUMMARY

Producers who desire to increase the number of red animals in their herd should first identify those animals that may be carriers. Once identified, those animals can be part of mating programs to proliferate the appropriate genes for red coat color.

For more information, visit www.clarifide.com.

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