

Vienna White – a peculiar albinism in rabbits (*Oryctolagus cuniculus*)

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Abstract. By this work we aim to present in detail the gene *v* (Vienna, BEW) found in rabbits (at *V* locus) and describe the most important blue-eyed white (BEW) breeds according to European Standard for Show Rabbits (UGCPPAMR 2010), and to gather information from the literature on the effect of this gene (*v*) on the health of individuals. The Vienna gene encodes the character that underlies the formation of several breeds and varieties of rabbits. Some of these breeds and varieties are important for meat production, others for experimental medicine, and there are still others important for comparative genetics. There are also breeds and varieties of exhibition that express the BEW (Blue Eyed White) trait, which have become increasingly popular among rabbit breeders. Of these, we mention: Vienna White, BEW Rex, BEW Netherland Dwarf and BEW Hermelin Dwarf (known also as Polish Dwarf).

Key Words: albinism, BEW, blue-eyed white, rabbit genetics, *V* locus, Vienna gene.

The Complex Architecture of Coat Color in Rabbits. Coat color expression in rabbit, *Oryctolagus cuniculus*, depends on genes situated at several loci of the rabbit chromosomes (Covrig et al 2013). These genes act together to produce a large variety of different colors and patterns (Sawin 1955). It is a known fact that the most important loci involved in coat color expression in the rabbit are *A*, *B*, *C*, *D*, *E*, *En*, *Du*, *Si*, *V*, and *W* (Covrig et al 2013; Tobă 2011). There are also other genes acting as color modifiers, controlling the intensity of certain colors or patterns (e.g. the rufus modifier). These modifiers are not single genes, but polygenes that pool their effects (Cieslak et al 2011; Covrig et al 2013).

By this paper we aim to present in detail the gene *v* (Vienna, BEW) found in rabbits (at *V* locus) and describe the most important blue-eyed white (BEW) breeds according to European Standard for Show Rabbits (UGCPPAMR 2010): Vienna White, BEW Rex, BEW Netherland Dwarf Lop and BEW Hermelin Dwarf (also known as Polish Dwarf) and to gather information from the literature on the effect of this gene (*v*) on the health of individuals.

How Vienna Gene Works. The allele responsible for generating the BEW rabbits is called the Vienna gene (*v*), it is located at *V* locus, and is expressed in homozygote form, noted *vv* (Pang & Xu 2013). This gene is recessive, as it lies hidden in certain cases. In general, when no other albino gene, except Vienna, is involved, the *vv* genotype causes no color expression and produces a completely white individual with blue eyes (Pang & Xu 2013), similar to the rabbits of Vienna Breed. The *Vv* heterozygote develops Dutch type markings on colored coat and colored spots on white coat. In such cases, the *V* allele can work with the plus/minus modifiers and the *Du* and *En* genes (Little 1958). The homozygote of the *VV* type develops a normal coat color.

However, there are some exceptions from the rules presented above, more exactly some cases of interallelic interaction. For instance, when Himalayan gene or ruby eyed white (REW) lies hidden (any of these genes are placed at a different locus from *V* - see Petrescu-Mag et al 2012; Petrescu-Mag & Botha 2018; Petrescu-Mag & Gavriloaie 2019), an REW phenotype is obtained (Berlena's Rabbitry 2009).

If genes for traits like shaded, chocolate, or lilac lie behind the BEW, we can obtain BEW individuals with a ruby cast pupil, and these offspring are not accepted in rabbit

exhibitions (Berlena's Rabbitry 2009). Therefore, the suggestion is to cross almost any color with the BEW individuals to improve type, with the exception of shaded colors, chocolate, and lilac. Rabbits having these colors in the background should be avoided, to prevent the ruby cast pupil (Berlena's Rabbitry 2009).

Ruby Eyed White vs Blue Eyed White. In rabbits, there are two distinct and separate types of albinism. The first is the effect of the REW gene in homozygote form, situated at the C locus (Covrig et al 2013), which produces complete melanin restriction in fur, nails, eyes, and every other part of its body (Fontanesi et al 2006; Jeffery et al 1997). This type of albinism can also restrict color to a greater or lesser extent across the body when it is found in a single allele at the C locus (Covrig et al 2013). The other form of albinism is the BEW type (Pang & Xu 2013). BEW is a form of incomplete albinism explained by the restriction of melanin across the majority of the body (Keeler 1948). The eye of BEW rabbits is an example of incomplete restriction of melanin production (Poeschl 2006).

Melanin, the dark pigment of the body, is formed in the melanosome organelle of the melanocyte (Hu et al 2019, 2020). Melanocytes can be found in all the pigmented tissues, such as skin, hair follicles, and parts of the eye (Hu et al 2019, 2020; Poeschl 2006). The melanin pathway consists of a cascade of reactions that converts tyrosine into two types of melanin, more exactly, the black-brown neomelanin and red-blond pheomelanin (Prota 2012; Poeschl 2006). Important to note that both yellow-red pigmentation and the darker tones are caused by melanin pigments (Prota 2012). Genetic mutations affecting enzymes involved along this pathway inevitably result in reduced melanin production and consequently different type of color expression (Poeschl 2006).

Embryologically, the melanocytes have different origins (Prota 2012; Poeschl 2006). For instance, the neuroectoderm of the primitive forebrain is the origin of melanocytes in the retinal pigment epithelium, ciliary epithelium, and iris epithelium (Prota 2012). The neural crest is the origin of melanocytes in the ciliary stroma, iris stroma, and choroid. Melanoblasts from the neural crest migrate to other parts of the body, such as skin, inner ear, and to uveal tract (Poeschl 2006).

The epithelial tissue does have melanocytes present (Poeschl 2006). In the case of BEW, the origin of these melanocytes is different from the origin of the melanocytes of the stroma. In this case, the blue pigment derives from the melanin formed by the melanocytes in the epithelium. In the case of the other type of albino, the REW eye contains no pigment at all, which causes the ruby eye (Poeschl 2006; Prota 2012).

The blue of the BEWs eyes is due to the restriction of pigment in the stoma, remaining only the pigment in the epithelium. In the case of the Vienna rabbits (vv), the pigment across the entire body is not restricted, except for certain parts (Pang & Xu 2013). The melanin in the eye is less probably to be restricted in the partial marked rabbits. Therefore, obtaining the marbling trait or the blue eyes one is possible only when sufficient restriction across the rest of the body occurs (Pang & Xu 2013). Deafness is a common side effect in BEW rabbits (Searle 1990). The genes that restrict the melanin production seem to be closely linked to the genes that affect hearing (Poeschl 2006).

The Vienna allele (situated at V locus), when it is present in one copy ($_v$), restricts a certain amount of melanin distribution in the body and, in peculiar cases, the eyes (Poeschl 2006; Keeler 1948; Pang & Xu 2013). This gene does not restrict all melanin production, or the melanin factors. In two copies (vv), the Vienna allele restricts all melanin distribution from some melanocytes, more exactly of those that originate in the neural crest. Melanin production from melanocytes that have other origins than neural crest is not restricted, and this amount of melanin allows the blue eyes trait to express (Poeschl 2006).

The REW allele (situated to a different locus than V, more exactly to C locus), when it is found in homozygote form (cc), restricts melanin distribution when coupled with most of the alleles on the C series (Putting et al 1994). Unlike the Vienna gene, REW gene in heterozygote form ($_c$) does not totally restrict melanin production in certain regions of the body, but works as a kind of blanket that leaches a certain dose of the melanin across the whole body in general (Poeschl 2006; Putting et al 1994). This fact explains how we get correctly colored Siamese Sables phenotype, for instance, and why Himalaya rabbits

(chc) and Chinchilla rabbits (chc) that carry the REW allele (c) tend to be washed out (Poeschl 2006; Petrescu-Mag & Botha 2018).

There is a misconception among the rabbit breeders that BEW individuals are "whiter" than REW individuals (Poeschl 2006; Berlena's Rabbitry 2009). The melanin restriction is complete in the REW rabbit due to the fact that every source of melanin is restricted (Andrews et al 2012). However, REW rabbits are not "whiter" than BEW rabbits, because the single source of melanin production in BEW individuals is in the primitive forebrain, in the neuroectoderm, with an effect only on the epithelium layer of the eye. Evidences on this can be clearly observed in a REW rabbit with only one Vienna allele (cc_v). This rabbit does not present a "marbled" pattern of white on white, despite the fact that the Vienna gene would create white patches on the coat if it had been pigmented (Poeschl 2006; Berlena's Rabbitry 2009).

Seizures, Epilepsy in BEW Rabbits. There are rabbit breeders who pretend that seizures/epilepsy no longer exists in BEW populations (e.g. BEW Vienna Breed, BEW Netherland Dwarfs), having been bred out over time. However, Berlena's Rabbitry (2009) brings some contrary arguments. The scientist says that every single bloodline acquired when starting with BEW Netherland Dwarfs presented seizures/epilepsy. However, epilepsy seems to be reported also from other rabbit strains, not just the BEW ones (Botha et al 2014) and seizures can be artificially induced (Antonitis et al 1954).

What Are the Most Important BEW Breeds? According to European Standard, the most important BEW breeds are Vienna White, BEW Rex, BEW Netherland Dwarf and BEW Hermelin Dwarf (known also as Polish Dwarf).

Vienna White Breed Description. The body is cylindrical, equally wide at the front and back, with a symmetrical and well-rounded back line at the posterior side. The chest is well developed, the neck short, with a strong nape. The limbs are strong and of medium length. Females should be as goiterless as possible. In older ones, a small, properly formed goiter is allowed. The minimum weight is 3 kg, the normal weight 3.8 kg, the maximum weight 5 kg. The hair is of medium length (3 cm), uniform and with a very dense down. The ears are well covered with hair. The head is short, with a broad forehead and mandible and well-defined cheeks. The ears are fleshy, well rounded at the top. They stand upright and are proportional to the length of the body. The color is clean white and spreads evenly over the whole body, including the head and ears, without any deviation from the white color. The basic color is the same as the coating. The eye color is light blue and the claws are white (UGCPPAMR 2010) (Figure 1).



Figure 1. Vienna White Breed (source: Dorel Danciu, personal archive).

BEW Rex (White Rex). Regarding the shape and body type of the breed, they are identical to those valid for all Rex breeds. The type corresponds to the Castor Rex type. The body is slightly elongated, the front and back are equally wide. The back line is symmetrical and has a well-rounded back. The limbs are straight, of medium length and strong. The neck is hardly visible at all. The head is straighter than in normal-haired breeds, but the forehead and snout are wide and the cheeks are well developed. The ears are upright, strong and fleshy. The length and width must be in harmony with the rest of the body, but due to the short hair, the animals appear longer than in the corresponding breeds with normal hair. The tail is worn straight. The constitution of the female is slightly finer than that of the male and is preferably without goiter. As with all Rex breeds, the White Rex allows females to have a small, properly formed goiter (UGCPPAMR 2010).

The minimum weight is 2.5 kg, the normal 3.4 kg and the maximum 4.75 kg (UGCPPAMR 2010). The hair is very thick, and the hair is in an almost vertical position. The hair in the middle of the back should be 17-20 mm long. The hairs must have sufficient elasticity, and must return to their original shape after disturbance. The ears are well covered with hair (UGCPPAMR 2010). Body hair should not be wavy or curly. The ends of the hairs can exceed the fluff by a maximum of 1 mm (UGCPPAMR 2010). The head must be representative of the rex type. The nose and forehead are wide, the cheeks well developed. The ears must fit the stuffed head, so they can be neither too long, nor too short (UGCPPAMR 2010). The exterior and base color must be pure white, without any deviation, uniform throughout the body, including the head and ears. The White Rex with blue eyes has light blue eyes and the claws are colorless (UGCPPAMR 2010) (see Figure 2).



Figure 2. BEW Rex Breed (source: <https://www.danddsbunnyhutch.com/minirex.htm>).

BEW Netherland Dwarf Lop. The body is short, stocky, with a harmonious back line, broad shoulders, strong neck, but not visible, and a rounded pelvis. The chest is completely rounded. The limbs are short. The constitution of the female is slightly finer than that of the male and without goiter. The minimum weight is 1 kg, the normal weight is 1.4 kg, and the maximum weight is 2 kg.

The fur has uniform hair with dense down, the length of the hair being 2.5 cm. The ears are well covered with hair. The head is specific to the lop breed and must be equally well highlighted in both males and females. The head should be short, with a broad forehead, a wide snout, a curved (aquiline) nose. The cheeks are well developed. The eyes are blue and not deep in the head. The ears have beads at the base, and present a tubular shape. The ears are broad, fleshy, well rounded at the ends. The horizontal length of the ears is 24-28 cm. The body color is white to the white variety with blue eyes (UGCPPAMR 2010) (Figure 3).



Figure 3. BEW Netherland Dwarf Lop Breed (source: Entente Européenne d'Aviculture et de Cuniculture 2003).

BEW Hermelin Dwarf Breed (or Polish Breed). The body is thick and cylindrical, and the front and back are equally wide. The back line is symmetrical, well rounded at the back. The limbs are short. The tail is small and tightly tied to the body. The female does not differ from the male, except for the forehead width. The female is without a goiter. The minimum weight is 0.8 kg, the normal weight is 1.1 kg, and the maximum weight 1.5 kg. The hair is short (18-20 mm), thick, soft, without tips that grow over the fur. The size of the head is proportional to the size of the animal and stands out strongly. The head is short and thick, with a broad forehead and snout. The width of the forehead in the male is 5.5 cm, and in the female 5 cm. The head is tightly positioned on the body and the neck is not visible. The eyes are large and stand out strongly, but they are not exophthalmic. The ears are suitable for the dwarf shape, small, beautifully rounded, well covered with hair, so that the pink skin is not visible. Optimal is an ear length of up to 5.5 cm. The cover and base color is clean white with no yellowish or gray hues. The eyes of the white variety with blue eyes are light blue. The claws are colorless (UGCPPAMR 2010) (Figure 4).



Figure 4. BEW Hermelin Dwarf Breed (Entente Européenne d'Aviculture et de Cuniculture, 2003).

Conclusions. The Vienna gene encodes the character that underlies the formation of several breeds and varieties of rabbits. Some of these breeds and varieties are important for meat production, others for experimental medicine, and some for comparative genetics. There are also breeds and varieties of show that express the BEW (Blue Eyed White) trait, which have become increasingly popular among rabbit breeders. Of these, we mention the Vienna White, BEW Rex, BEW Netherland Dwarf and BEW Hermelin Dwarf (known also as Polish Dwarf).

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