Genetic Control of Cancer Eye in Cattle

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Cancer eye has been reported in cats, cattle, dogs, horses, sheep, swine and human beings. Since it occurs so much more frequently in cattle, however, it is considered primarily a bovine problem.

The cattle industry suffers significant economic losses from cancer eye each year. These losses result from a reduction in the average productive life and salvage value of affected animals.

Cancer eye may occur in any part of the eye. Its development is a continuous process beginning with the first cellular change and ending with the formation of the cancerous lesion. For convenience, this process has been arbitrarily divided into three stages as shown and explained in Figure 1.

A number of factors play a role in determining whether or not an animal will develop this disease. Of primary importance is the amount of pigment the animal has in the eye area. Pigment is apparently quite effective in inhibiting the development of a lesion within the pigmented area. This inhibitory effect does not extend to areas outside the pigment.

Cancer eye has been reported in a number of breeds of cattle, including Ayrshire, Brahman, Brown Swiss, Durham, Guernsey, Hereford, Hollandensa, Holstein, Javanese Mongolian, Jersey, Normandy and Shorthorn. All these breeds have variable amounts and patterns of pigmentation in the area of the eye. Differences in the frequency of lesion development among breeds are closely related to the average amount of pigment within each breed—the more extensively pigmented breeds having the lower incidence of the disease. Breed difference in frequency of lesion development, then, is believed to result from breed
differences in average amounts of pigment in the area of the eye. This was clearly indicated in a study of the eyes of 1,591 animals representing 23 breed groups (breeds and breed crosses) in 15 herds located in various areas of the United States and Canada (6). Lesion (benign precursor and carcinoma) frequencies differed significantly among breed groups, ranging from 0 to 52.8 percent. Lesions were observed only in breed groups having no pigment or pigment in varying amounts in the eye. No lesions were observed in breed groups having completely pigmented eyes. A similar study involving Herefords only (a breed with wide variation in amounts and patterns of pigment) also revealed high lesion frequency to be significantly associated with low average amounts of pigment, indicating that individual differences in susceptibility are likewise influenced by individual differences in pigment. Figure 2 shows examples of the animal-to-animal variability in amount of pigmented area on the skin surrounding the eyes (circumocular skin) of Hereford cattle.

It should be noted that lesions have been observed in pigmented areas of the eyeball (corneoscleral area)(2,7,10). This was interpreted by French (7) as evidence against the inhibitory effect of pigment. However, observation at regular 6-month intervals of a large number of animals clearly showed that lesion development began in the corneoscleral area before the pigment was present (10). The preexisting lesion on the eyeball appears to initiate or provoke the development of pigment at the same site as the lesion or adjacent to it. When this occurs, the lesion-pigment relationship will thereafter take one of a number of alternative paths. The lesion and pigment may show no apparent change, or the lesion may regress with a continued increase in pigmentation, or the lesion may continue to develop with or without a reduction in amount of pigmentation. These events suggest that pigment does provide protection against lesion development.

Age is another important factor in the development of this disease. Cancer eye rarely develops before 4 years of age and is most frequent in cattle older than 8 years. In a survey of 2,087 Hereford cattle in 31 herds in various areas of the United States, it was found that age-specific lesion frequency increased soon after 40, 69 and 99 months of age (9). Animals in age group 40 to 69 months showed a lesion frequency of 12 percent; those in the 70 to 99 months group showed 25 percent; and those in the 100 months upward group showed 37 percent.

Other factors found to be related to an increased incidence of the disease are high levels of nutrition (1) and exposure to high levels of sunlight or ultraviolet light (5). There is not enough evidence to implicate a virus in the initiation of the disease (8).
A number of studies have shown that the amount of pigmented area on
the skin surrounding the eye is a highly heritable trait (3,4,7,10). Heri-
tability estimates for this trait range from 0.27 to 1.37, and average 0.60.
The amount of pigmented area on the eyeball (corneoscleral pigment)
has also been found to be highly heritable (10). In this study, three sepa-
rate heritability estimates were made, ranging from 0.60 to 1.09 with an
average of 0.79. Direct selection for pigment in either area, then, should
produce a rapid rate of change in the average amount of pigmentation.
Direct selection for eyeball pigment would not always be possible, how-
ever, because this pigment is not totally expressed in most animals until
sometime after 5 years of age. This difficulty would not be encountered
in direct selection for eyelid pigmentation, as it shows little or no change
in amount or pattern after birth.

The genetic relationship between amount of eyeball and eyelid pig-
ments has also been studied and found to be highly genetically correle-
ted (10). Direct selection for either, then, should produce a favorable
correlated response in the other. Since pigmentation patterns of the cir-
cumocular skin are fixed at birth, and those of corneoscleral pigment
are not, direct selection should be based on the amount of pigment in
the eyelid. Such selection would produce, as a direct response, an in-
crease in the amount of eyelid pigment and, as a correlated response,
an increase in the amount of corneoscleral pigment.

In view of the inhibitory effect of pigment on the development of
lesions, and the relative ease of effectively breeding for increased
amounts of pigment in the area of the eye, it appears that lesion develop-
ment on the eye can be completely inhibited, or much reduced in fre-
quency, in breed groups in which it is now a problem. Selection of breed-
ing stock on the basis of presence or absence of lesions is not recom-
mended, in view of the advanced age at which such selection would be
effective. Since lesions are not initiated in pigmented areas, selective
breeding for increased amounts of eyelid pigment, with the consequent
increase in eyelid and eyeball pigments, would be an effective means of
lowering the incidence of the disease.
Figure 1. Benign precursor lesions and carcinoma of the eye: Lesions starting on the eyeball (corneoscleral area), third eyelid, and caruncle progress from plaque (A), perhaps through papilloma (B), to carcinoma (C). Lesions developing on the circumocular skin (eyelid and lacrimal lake) begin with keratoses and/or acanthoses with focal ulceration (D), sometimes through the papilloma stage (photo not available), to carcinoma (E).

Figure 2. Variation in amount of circumocular (eyelid and lacrimal lake) pigment in Hereford cattle. (A) 0%, (B) 18%, (C) 65% and (D) 100%.
SUMMARY

It is suggested that the incidence of cancer eye can be significantly lowered by effectively breeding for increased amounts of pigmentation in the skin surrounding the eye. Factors that lead to this conclusion are:

1. Pigment is effective in inhibiting the development of a lesion within the pigmented area.
2. Eye pigmentation traits are highly heritable.
3. Pigmentation in the skin surrounding the eye and pigmentation on the eyeball are highly genetically correlated.

Selection based upon the extent of pigment on the skin surrounding the eye is recommended, since its pattern and amount are fixed at birth. Selection based on pigment on the eyeball is not suggested because it is usually not fully expressed until late in the reproductive life of the animal. These factors, taken together, indicate that selective breeding for increased amounts of eyelid pigment will result in increased amounts of eyelid and eyeball pigments and, consequently, a reduction in the incidence of cancer eye.

Literature Cited


