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Review Article

Importance of major genes to compensate for the harmful summer climatic effects in fowl

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Abstract

When environmental temperature is more than 27°C, the fowl upsurges panting and decreases metabolic rate to ease body's heat increment. There are many measures that can be applied to improve the opposing effects of tropical climatic stress. There are many options like nutritional adjustment, day-to-day poultry management, or feed additives, and probiotics are regularly used to alleviate the lethal effects of climatic stress in poultry. There are several major genes, viz. naked neck (Na), frizzle (F), slow feathering (K), and dwarf (dw), that could be implemented as a considerable elucidation to progress productive and reproductive outcomes for fowls grown in tropical climatic conditions. The birds carrying naked necks (Na) and frizzle (F) genes increase fame due to their decorative appearance and enhanced productive and reproductive activity in hot weather. The dwarf (dw) breeders dam line has better survivability, adaptability, disease resistance and hatchability in summer climates compared to normal fowls. The sex-linked slow feathering introgression in fowl is used for wing sexing in some layer breeds. The practical application of major genes as a breeding strategy has been discussed for countries that have tropical climates or challenging hot summers.

Keywords: Dwarf gene, Frizzle gene, Major genes, Naked neck gene, Slow feathering gene

Highlights

- There are few major genes that reduce heat stress. Incomplete dominant gene, naked neck (Na), affects the trait directly, lowering plumage and thereby reducing metabolic heat output.
- The frizzle (F) gene (also incomplete dominant) causes the contour feathers to curve outward away from the body, reducing the featherweight of broilers in addition to the reduction caused by the Na gene.
- The sex-linked dominant slow feathering (K) gene is used as an 'auto-sex' strain, and breed crosses have an effect on reducing plumage coverage, all of which may assist the bird in resisting heat stress.
- A sex-linked recessive gene that produces dwarf fowl has improved heat tolerance and disease resistance.

INTRODUCTION

Poultry farming nowadays occupies an important position for the livelihood or socio-economic development of the farmers in terms of profit from meat and egg. It serves as the cheapest animal protein source, from backyard farming to industries. However, their production performances are decreased during tropical thermal stress.

Thermal sensitivity of poultry flocks is caused due to multiple factors like exposure to sunlight, environmental temperature, humidity of geographical locations, air flow, stocking density and type of fowl (species/breeds/strains/genotypes), and variation in metabolic rate or thermoregulation.

Tropical climates or hot summers are very stressful for commercial poultry breeds not only in India but also in other Asian, African, and a few American countries, which is highly challenging for poultry farmers.

Reduced heat tolerance is the outcome of numerous generations of selection for meat and egg output. In poultry, metabolic heat output has increased as growth rates have increased, while the ability to tolerate high temperatures has decreased. In commercial strains, selection for production traits has increased the line's susceptibility to stress conditions. Because of the

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decline in immunity due to thermal sensitivity, birds' disease resistance is also frequently compromised (Pawar *et al.*, 2016).

When poultry fowls are exposed to thermal tension, the biosynthesis of utmost proteins is slowed down, but a group of highly well-preserved proteins recognized as heat shock proteins (HSPs) is speedily produced. In a heat-shocked cell, the HSP may bind to heat-sensitive proteins and defend them from breakdown, or may stop damaged proteins from instantly precipitating and permanently affecting cell life. Polymorphism of HSPs genes based on SNP markers has been reported to be associated with heat tolerance of poultry birds and can aid in marker assisted selective breeding of poultry birds for heat resilience (Chen *et al.*, 2013; Galal *et al.*, 2019; Kumar *et al.*, 2021).

For the maintenance of the growing trend of poultry farming, enhanced heat-tolerance along with disease resistance is always anticipated. Earlier research has discovered that genetic variations or forms are much of the foundation for fowl's response to heat anxiety; however, information in this area is inadequate and requires more research to discover its full potential (Lara and Rostagno, 2013). Genetic marker assisted selective breeding using the marker genes linked to heat-tolerance and disease resistance in commercial poultry is the essential requirement for more advancement in the poultry industry. The important role of major genes to improve thermal stress response capacity vis-à-vis production and reproduction performances in poultry has been reviewed at this juncture.

Plumage mass and thermal sensitivity

By introgression of major genes in poultry breeds or lines, we can enhance thermos tolerance, and increase meat and egg productions using scaleless gene(sc/sc), naked neck (Na), frizzle (F), dwarf (dw) and slow feathering (K) (Fathi *et al.*, 2013, 2022).

Scaleless gene (sc/sc): Scaleless is totally devoid of plumage cover, foot scales and spurs due to a single recessive mutation, which disrupts skin development during embryogenesis. These genes are located on chromosome 4, and it displayed a nonsense mutation in FGF20 gene, which is expressed in developing feathers. It is found that this autosomal recessive mutation (sc/sc) improves heat tolerance in rapidly growing poultry lines (Fig. 1). These ugly-looking fowls are less favoured by modern consumers (Desta, 2021). These bared-skinned fowls are vulnerable to sunburn and cold weather, as well as parasites, with higher mortality rates. On the other hand, chickens with little plumage mass, like naked necks and frizzles, are becoming popular.

Fig. 1. Scaleless (sc/sc) chickens carry a single recessive mutation that causes a lack of almost all body feathers, as well as foot scales and spurs, due to a failure of skin patterning during embryogenesis.

Naked neck gene (Na): The autosomal incompletely dominant naked neck gene (Na) is positioned near the middle of the third chromosome in chicken. This gene lowers plumage mass by about 40% in homozygous chickens (Fig. 2A) and 20 to 30% in heterozygous birds (Fig. 2B) than normal ones (Fathi *et al.*, 2013, 2022). Naked neck broiler also showed better immune competence traits compared to normal broilers in heat stress condition.

The Naked Neck is a breed of chicken that is naturally devoid of feathers on its neck and vent. They looked like turkeys, also called Transylvanian Naked Neck, as well as the Turken. The incomplete dominant naked neck can be easily introgression into normal breeds as hybrid lines. The French naked neck is commonly confused with the Transylvanian and with the naked-necked gamefowl.

The naked neck gene (Na) causes bare skin on the neck which becomes reddish toward sexual maturity. The heterozygote state (Na/na) can also be recognized easily by a small tuft of feathers on the ventral side of the neck and which is above the crop (Fig. 2B).

Use: Naked neck gene introgression has been done in several broiler and layer lines in ICAR- Central Avian Research Institute, Izatnagar. The naked neck broilers displayed significantly more body weight and better feed conversion ratio comparing normal broilers

Fig. 2A

Fig. 2B

Fig. 2C

Fig. 2. Naked neck homozygous (Na/Na) (Fig. 2A); Heterozygous (Na/na) fowls (Fig. 2B) with different degrees of feather loss; Naked neck homozygous (na/na) normally feathered broiler (Fig. 2C)

Fig. 3A

Fig. 3B

Fig. 3A & B. Frizzle chicks have oval bodies with shafts of contour curved feathers, well-developed comb and wattles.

(na/na) in Fig. 2C. The latest experiments demonstrated that naked neck had improved heat dissipation with lower body temperature, higher body weight gain, improved feed conversion ratio, blood biochemical components and carcass characters related to normal broilers (Fathi *et al*., 2022). The outcome of these research findings recommended that naked neck birds had better humoral and cell-mediated immune responses as related to normal broilers (Fathi *et al*., 2022; Fernandes *et al*., 2023). Performance characteristics of naked neck fowl as its body weight at 20 weeks of age is 1005 g, age at sexual maturity is 201 days, annual egg production is 99, egg weight at 40 weeks is 54 g, fertility is 66%, and hatchability is 71%.

Frizzle gene (F): The frizzle gene (F) is an autosomal, incomplete dominant gene localized within the type II α-keratin cluster on chromosome 33. Frizzling appearance can be identified in chicks three to four days after hatching (Fathi *et al*., 2013, 2014, 2022). The shafts of the contour feathers are curved instead of straight (Fig. 3). The feathers are more delicate, and the barbs eventually wear off the outer primaries, leaving the birds unable to fly.

In the homozygous (FF) fowls, plumage breaks very easily, and the birds very soon lose most of their feathers and easily dissipate body heat in summer. The heterozygous (Ff) fowls have less pronounced curling in plumages and are sturdier. The activity of the F gene is positioned in the plumage follicle. This gene causes a structure anomaly in the feather and anomalies of internal organs (like, distended spleen, heart, gizzard and alimentary system, etc.) (Dong *et al*., 2018).

Frizzle fowls are available all over the hot and humid coastal areas of our country including Andaman and Nicobar Islands. These fowls also exist on high elevations in hilly regions of Northeastern states like Sikkim. These fowls are famous for better adaptability to hot and humid climatic stress. Frizzle birds showed oval bodies and well-developed comb and wattles. The beak and shanks of these fowls have no relationship with plumage, and skin of the fowl is thin and pale pink in color (Fathi *et al.*, 2014).

The frizzle fowl has a single comb, and the ear lobes are well developed and have white spots. The eyes of these fowls are bright and very well established. Feather color varies among birds, and the most common colors are white, brown, black or mixed color.

The production and performance features of frizzle fowl as body weight at 20 weeks of age is 1.0 kg, age at sexual maturity is 185 days, annual egg production is 110 numbers, egg weight at 40 weeks is 53 g, fertility is 61%, and hatchability is 71%.

The dwarf gene (dw): It is a sex-linked recessive gene, which is located on the Z chromosome. Dwarfism is related with reduced body weight by about 40% and 30% in homozygous male and female fowls, respectively compared to the normal fowl (dw/dw is dwarf phenotype, DwDw, Dwdw, are normal phenotype) (Fathi *et al.*, 2013, 2014, 2022) (Fig. 4). There has been a controversy concerning the benefit of the dwarf gene in thermal-stressed layers. The dwarfism give is more advantages in heavy breed related to a lighter breed.

In tropical humid climate, introgression of dwarf gene growing more exciting for broiler breeding plans, by reducing energy requirements and feed consumption. An improved adaptability of dwarf hens to summer stress was detected in the experiment. It has been observed that dwarf laying poultry have improved

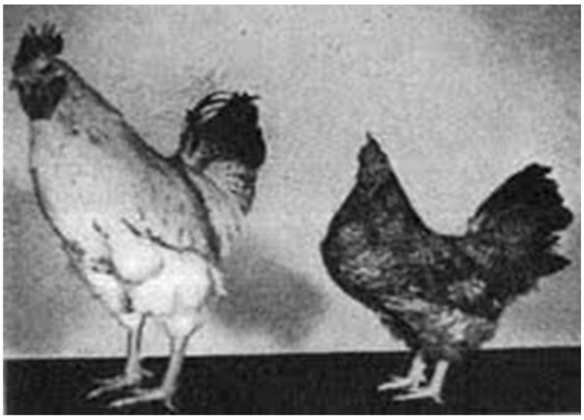

Fig. 4. Dwarf poultry breed, a sex-linked recessive gene associated with reduced body weight by about 40% and 30% in homozygous males and females, respectively compared to the normal status

resistance to Marek's disease, and displayed lower mortality in fowls injected with Marek's disease virus in thermal stress conditions (Wasti *et al.*, 2020). The production characteristics of dwarf fowl as body weight at 22 weeks of age is 750-1000 g, age at sexual maturity is 162.3 days, 40-week egg production is 57 numbers, egg weight at 40 weeks is 55.8 g, fertility is 62-92%, and hatchability are 35-65%.

The slow feathering gene (K): The slow feathering condition in fowl is a wonderful dominant sex-linked mutation on chromosome Z and is commercially used for sex differentiation of day-old chicks in layer strains after hatching (Fig. 5). This condition is also documented as a multiple allelic trait, which has 4 diverse alleles (are extremely slow, Kn, slow feathering, Ks, delayed feathering, K, and rapid feathering, k+) occupying on the same locus (Khosravinia and Manafi, 2016).

Fig. 5. The slow feathering chick, dominant sex-linked gene used for sex identification of day-old chicks in some egg-type strains at hatch

The direct gene action is related to the growth of feathers according to a combination of alleles it possesses. Slow feathering fowls innately have improved heat tolerance due to less heat generation. The sex-linked slow and fast feathering gene has been extensively exploited in commercial poultry breeding for auto-sexing after hatching. The growth pattern of plumage is characteristically dissimilar between the rapid and slow feathering fowls during hatch with a correctness of 98%. In the poultry industry, hybrids obtained from both fast and slow-feathering genotypes, sex documentation of day-old chicks can be carried out very easily without training, with an average of 96% correctness (Goger *et al.*, 2017). Performance characteristics of slow feathering fowl as body weight at sexual maturity is 1645.3 g, age at sexual maturity is 153.3 days, hen day egg production is 133 numbers, egg weight is 55.85g, fertility is 97.9%, and hatchability is 79.5%.

Conclusion

Several institutes and researchers in India and abroad have documented that the Na and F genes are extremely tolerant to high thermal stress conditions and can improve both growth performance, egg laying and disease tolerance. Introgression of a sex-linked dwarf gene in heavy broiler maternal lines expands the success of the commercial project under tropical climate with persistent thermal stress and humidity. For dwarf fowls, lesser space is required for housing and lesser amount of feed and water, with better survivability and fertility, better hatchability, better FCR, and more resistance to viral disease could be accomplished. Using sex-linked slow feathering genes for auto-sexing in day-old chicks of layer strains offers an accurate and low-cost operative methodology.

Conflict of interest: Authors declare that they have no conflict of interest in the study.

Author's contribution: BP: Planned and written manuscript; HP, SC, PG, DKY, AM, RW: Revised the manuscript.

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