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Influence of Naked Neck Gene on Laying Performance and Some Hematological Parameters of Dwarfing Hens

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Abstract: Dwarfing gene is of interest among scientist, because of its numerous pleiotropic effects in physiology, nutrition and pathology. Also, the naked neck (Na) gene has received great attention for poultry production, because of their association with heat tolerance. From this view, An experiment was conducted to evaluate the effect of sex-linked dwarf (dw), autosomal naked neck (Na) and double segregation genes on laying performance and some hematological parameters of egg-type chicken under prevailing condition of Egypt. Three hundred brown Dahlem (Germany strain) hens from four genotypes {normal body size-normally feathered (Dw-nana), dwarf size-normally feathered (dw-nana), normal body size-naked neck (Dw-Nana) and dwarf size-naked neck (dw-Nana)} were reared under the same environmental, managerial and hygienic conditions from 20 to 40 weeks of age. The results obtained showed that the sex-linked dwarf (dw) gene significantly reduced body weight, egg mass and egg number compared to normal body size sibs. On the other hand, the dwarf birds had significantly consumed less feed and better feed conversion ratio. With respect to internal and eggshell quality, it could speculate that the presence of dw gene associated with higher yolk percentage, higher haugh units and thicker eggshell thickness than that of normal body size counterparts. Concerning hematological parameters, the presence of dw gene significantly reduced plasma T3, plasma cholesterol and liver enzymes compared to normal body size hens. The opposite trend was noticed for both total lipids and triglycerides. In contrary to dw gene, the Na gene had a better effect on laying performance parameters of egg-type chicken. With respect to double segregation genes, it could be noted that the introducing Na gene could compensate the reducing effect associated with dwarfing (dw) gene on laying performance measurements and some hematological parameters. In conclusion, the loss of revenue due to reduction in egg production associated with sex-linked dwarf gene may be exceeded by revenue saved from lower feed intake and better feed efficiency. Moreover, incorporating the Na gene into dwarfed birds could compensate the reduction effects associated with dwarfing (dw) gene.

Key words: Dwarf gene, naked neck gene, laying performances, egg quality, blood parameters

Introduction

Under different conditions (as climates, seasons, locations), major genes, such as dwarf (dw) and naked neck (Na) should be incorporated more widely in commercial male and female stocks to improve intensive production systems in hot climates (Testik and Celon, 2000). The dwarf gene is of interest among scientists. Because of, its numerous pleiotropic effects in physiology, nutrition, behavior, pathology etc. Introducing dwarf (dw) gene in egg-type birds resulted in decreasing adult body weight; reducing maintenance feed requirements, improving feed efficiency as well as adaptability in a hot-humid tropical environmental (Rashid *et al*., 2005). Heat tolerance and feed efficiency can be improved in layers by the dw gene, which causes a reduction in body size and is an important factor of acclimatization to warm environments through heat loss by radiation and convection on one hand and endogenous heat production on the other (Gowe and Fairfull, 1995). The dwarfing (dw) gene is known to lower daily yolk production, yolk mean weight and the number of fast-growing follicles on the ovary. This occurs without any alteration in the relative proportion of yolk albumen (Merat, 1972; Abplanalp *et al*., 1987). During growth, dwarf chickens are fattier than normal chickens; however, a surprising inversion of this difference is observed in adult laying hen (Guillaume, 1976). Moreover, Demarne *et al*. (1984) have shown that the fatty acid composition of yolk lipids was altered by dwarfism: higher linoleic acid and lower oleic acid levels were found in yolk triglycerides of dwarf hens. All these results might reflect a dysfunction of lipid metabolism in dwarf hens (Burghelle-Mayeur *et al*., 1989). With respect to naked neck (Na) gene, the naked neck birds have received great attention for poultry production, because of their association with heat tolerance (Merat, 1986). It has been reported that the reduction of feather coverage provides relative heat tolerance and therefore, in high ambient temperature, heterozygous naked neck chicken are superior to their normally feathered counterparts (Cahaner *et al*., 1993). The naked neck gene has been associated with increased laying rate, egg size and egg

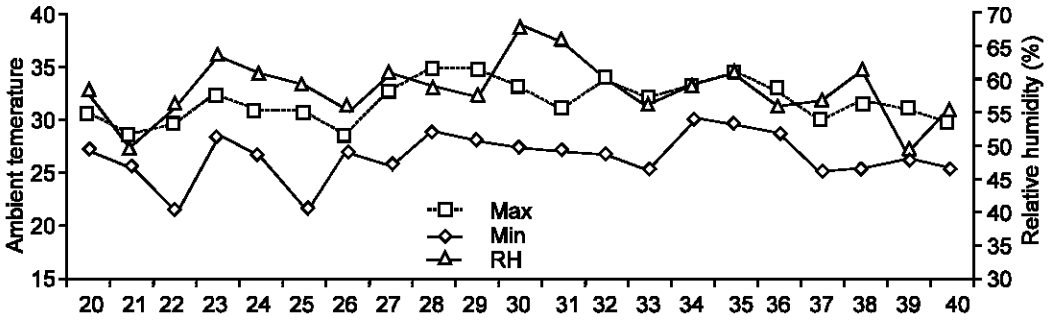

Fig. 1: Maximum and minimum ambient temperature and relative humidity recorded during the experimental period from 20 to 40 weeks of age

mass in hot environments (Galal, 1999; Garces *et al.*, 2001; Younis and Galal, 2006). The association of the Na and dw genes was previously found to have a favorable effect on egg weight and feed efficiency of brown-egg layer (Bordas and Merat, 1984). Also, Horst *et al.* (1990) reported that the interaction between Na and dw genes might be advantageous. The dw gene is known to depress mean egg weight and the Na gene might compensate for this depression (Galal and Younis, 2006). This experiment was designed to evaluate the effect of sex-linked dwarf (dw), autosomal naked neck (Na) and their combination on laying performance and some hematological parameters of chicken under prevailing environmental conditions of Egypt.

Materials and Methods

Genetic flocks and management: At 20 weeks of age, three hundred brown Dahlem females {75 normal body size-normally feather (Dw-nana), 75 dwarf size-normally feather (dw-nana), 75 normal body size-naked neck (Dw-Nana) and 75 dwarf size- naked neck (dw-Nana)} were housed into individual laying cages suitable for the quantitative measurements of egg production and feed intake to the end of experiment period (40 weeks). They were the offspring of Dahlem (Germany strain) commercial male line (Dwdw-nana) and commercial female line (Dw-Nana). The experiment was in accordance with animal welfare and ethics. They were reared under the same environmental, managerial and hygienic conditions. Feed and water were provided *ad libitum*. They were fed a diet containing 18% crude protein and 2800 Kcal ME/kg from 20 weeks to the end of experiment (40 weeks). Average weekly high and low ambient temperatures and relative humidity recorded during the experimental period are presented in Fig. 1.

Measurements and observations

Body weight and body measurements: Body weight, keel length and shank length were individually recorded for each genotype at 20 and 40 weeks of age. Shank length was determined on live birds by measuring the length of the tibiotarsus (from the top of hock joint to the foot pad) with a digital caliper.

Egg production parameters: At 20 weeks of age, egg number and egg weight were recorded individually per week (data not shown) then per period (20 weeks). Egg mass was calculated by multiply the egg number by egg weight.

Feed consumption and feed conversion ratio: Feed consumption was recorded individually from 20 to 40 weeks of age and feed conversion ratio was calculated. Feed wastage was carefully controlled to be very small.

Egg quality measurements: An egg quality experiment was applied for each genotype at 40 weeks of age. Eggs were collected and weighed to the nearest 0.1 g. After measuring of internal egg quality (albumen weight, yolk weight and albumen height), the liquid contents of the egg were a side and shell plus membranes washed to remove adhering albumen. Haugh units were calculated using the HU formula based on the height of albumen by a micrometer and egg weight (Eisen *et al.*, 1962). Then, shells were weighed upon cooling to the nearest 0.01 g. Egg thickness in mm was measured using a digital micrometer by taking the mean value of the thickness measured three location on the egg. The percentage of yolk, albumen and shell was assessed for each genotype.

Blood parameters: At 40 weeks of age, a 2.0 mL blood sample was withdrawn from the jugular vein during slaughtering. Blood samples were taken and centrifuged at 1500 g for 10 min and the resulting plasma was stored at-20°C for later analysis. The frozen plasma was thaw prior to analysis. Total protein, albumen, total lipids, cholesterol, triglycerides, GOT, GPT, uric acid and creatinine levels were determined in plasma by enzymatic methods using available commercial kits SCLAVO INC., 5 Mansard count, Wayne

Table 1: Body weight, shank length and keel length of laying hens as affect by dwarf (dw), naked neck (Na) and double segregation genes

		Genotype				
Trait	Age (wk)	Dw-nana	dw-nana	Dw-Nana	dw-Nana	Prob.
Body weight, g	20	1560.8^{b}±20.56	1289.7^{d}±25.16	1650.7^{a}±24.60	1345.9^{c}±31.17	0.01
	40	1885.3^{b}±42.5	1514.6^{d}±39.8	1987.7^{a}±52.6	1680.5^{c}±48.9	0.01
Shank length, cm	20	9.88^{a}±0.68	7.57^{c}±0.92	10.02^{a}±0.45	8.26^{b}±0.52	0.01
	40	10.26^{b}±0.72	8.61^{c}±0.58	11.15^{a}±0.91	8.92^{c}±0.69	0.01
Keel length, cm	20	10.62^{b}±0.71	9.54^{c}±0.66	11.52^{a}±0.82	9.95^{c}±0.53	0.01
	40	11.05^{b}±0.87	9.86^{d}±0.59	11.83^{a}±0.57	10.12^{c}±0.61	0.01

Table 2: Egg production measurements, feed consumption and feed conversion ratio of laying hens as affect by dwarf (dw), naked neck (Na) and double segregation genes

	Genotype				
Trait	Dw-nana	dw-nana	Dw-Nana	dw-Nana	Prob.
Egg mass, kg	8.03^{a}±0.51	6.97^{c}±0.38	8.25^{a}±0.40	7.22^{b}±0.42	0.001
Egg number, No	132.25^{a}±1.56	118.72^{c}±2.10	132.80^{a}±1.12	122.17^{b}±1.24	0.001
Egg weight, g	60.72^{b}±0.68	58.71^{c}±0.42	62.12^{a}±0.50	59.10^{c}±0.61	0.001
Feed consumption, kg	18.87^{a}±0.67	15.47^{b}±0.61	18.15^{a}±0.44	15.45^{b}±0.58	0.001
Feed conversion ratio	2.35^{a}±0.05	2.22^{b}±0.08	2.20^{b}±0.09	2.14^{b}±0.04	0.001

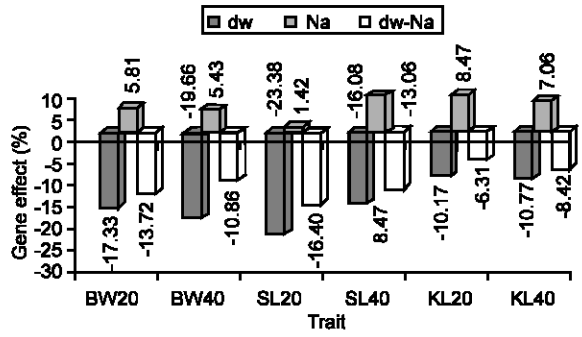

Fig. 2: Gene effect (deviation from Dw-nana genotype) for body weight, shank length and keel length

NJ 07470, USA. The globulin level was calculated as the difference between the plasma total protein and albumen levels. The T3 concentrations were determined in plasma samples by radioimmunoassay as described previously (Darras *et al*., 1992).

Statistical analysis: Data were subjected to a one-way analysis of variance with genotype effect using General Linear Model (GLM) Procedure of SAS User's Guide (2001). When significant differences among means were found, means were separated using Duncan's multiple range tests.

Results and Discussion

Body weight and body measurements: Data presented in Table 1 and Fig. 2 showed that the dwarfing (dw) gene significantly reduced body weight, shank length and keel length compared to normal body size hens. This reduction in body weight caused by the dw gene reported in the present study confirmed with Missohou *et al.* (2003); Chen *et al.* (2004) Younis and Galal (2006). Furthermore, the associated physiological and biochemical effects of the dw gene (Table 4) could explain the reduction in body weight of dwarf hens. The concentration of triiodthyronine (T3) circulating in the plasma of dwarf birds is significantly lowered compared to normal size birds. In contrary to dw gene, the Na gene significantly increased body weight, shank length and keel length of laying hens compared to normally feathered counterparts. This result is in an agreement with Deeb and Cahaner (1996); Singh *et al.* (1998); Galal and Younis (2006). They reported that, under high ambient temperatures, the Na gene had a better effect on body weight of chickens. The naked neck chickens (NaNa or Nana), compared to normally feathered sibs (nana), have heavier body weight (Patra *et al.*, 2002). Furthermore, it could be noticed that incorporating Na gene into dwarfing layer hens compensates the reduction effect of dwarfing (dw) gene on body weight and body measurements.

Egg production parameters: Effect of dwarf (dw), naked neck (Na) and double segregation genes on egg production measurements, feed consumption and feed conversion ratio are summarized in Table 2 and Fig. 3. It could be speculated that the presence of dw gene significantly reduced egg mass, egg number and egg weight by about 1.1kg (-13.2%), 13.5 eggs (-10.23%) and 2.0g (-4.8%), respectively compared to normal body size (Dw-nana) counterparts. The effect of sex-linked dwarf gene on egg production and egg size confirmed results reported by Zulkifli *et al.*, 1992; Garces *et al.*, 2001. Also, in egg-laying strains, the dwarfing (dw) gene had been shown to decrease egg production (Bernier and Arscctt, 1972) and more particularly clutch length (Amin-Bakhche and Mérat, 1975). Missohou *et al.* (2003)

Table 3: Egg quality measurements of laying hens as affect by dwarf (dw), naked neck (Na) and double segregation genes

	Genotype				
Trait	Dw-nana	dw-nana	Dw-Nana	dw-Nana	Prob.
Egg weight (g)	60.51^{ab}±0.45	56.48^{c}±0.39	61.12^{a}±0.62	59.87^{b}±0.57	0.001
Yolk (%)	29.15^{b}±0.17	30.10^{a}±0.22	29.51^{ab}±0.19	30.14^{a}±0.31	0.001
Albumen (%)	60.99^{a}±1.15	59.75^{b}±1.12	60.47^{a}±1.54	59.55^{b}±1.32	0.001
Haugh unit	81.15^{b}±0.82	83.10^{a}±0.85	82.24^{a}±0.91	83.56^{a}±0.88	0.001
Shell (%)	9.86^{c}±0.13	10.15^{b}±0.10	10.02^{a}±0.12	10.31^{a}±0.09	0.001
Shell thickness (mm)	0.335^{b}±0.01	0.354^{a}±0.02	0.373^{ab}±0.01	0.382^{a}±0.01	0.001

Table 4: Blood parameters of laying hens as affect by dwarf (dw), naked neck (Na) and double segregation genes

	Genotype				
Trait	Dw-nana	dw-nana	Dw-Nana	dw-Nana	Prob.
Plasma total protein (g/dl)	9.19^{ab}±0.13	9.58^{a}±0.29	8.85^{b}±0.89	8.38^{b}±0.42	0.001
Plasma albumen (g/dl)	3.71^{a}±0.13	3.77^{a}±0.15	3.68^{a}±0.12	1.67^{b}±0.10	0.001
Plasma globulin (g/dl)	5.48^{b}±0.22	5.81^{b}±0.31	5.97^{b}±0.20	6.71^{a}±0.19	0.001
Total lipids (mg/dl)	1178.0^{b}±16.35	1392.25^{a}±17.52	1359.00^{a}±18.22	1347.00^{a}±10.15	0.001
Cholesterol (mg/dl)	201.5^{a}±5.69	125.50^{b}±6.22	119.50^{c}±6.50	117.50^{c}±7.33	0.001
Triglycerides (mg/dl)	976.50^{b}±20.54	1266.75^{a}±31.58	1239.50^{a}±33.17	1229.50^{a}±38.71	0.001
GOT (U/ml)	46.75^{a}±1.79	45.50^{a}±1.29	42.50^{b}±1.30	40.52^{c}±1.79	0.001
GPT (U/ml)	18.25^{a}±1.57	16.25^{b}±1.34	15.25^{c}±1.86	13.12^{d}±1.01	0.001
Uric acid (mg/dl)	5.55^{c}±0.81	6.17^{b}±0.68	6.87^{a}±0.81	6.45^{ab}±0.31	0.001
Creatinine (mg/dl)	0.51^{b}±0.05	0.50^{b}±0.04	0.72^{a}±0.07	0.58^{b}±0.02	0.001
T3 (ng/dl)	176.29^{a}±2.60	139.58^{c}±4.96	178.40^{a}±3.05	154.68^{b}±2.77	0.001

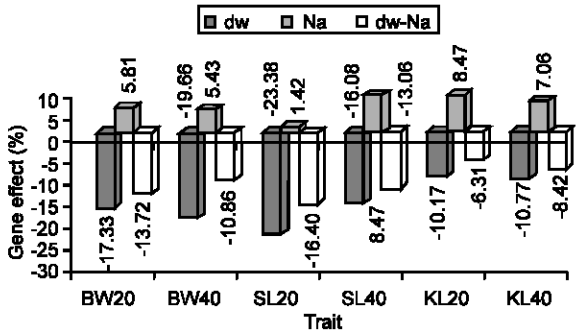

Fig. 3: Gene effect (deviation from Dw-nana genotype) for egg production measurements, feed consumption and feed conversion ratio

reported that the total egg number (-18%) and egg weight (-9%) were significantly reduced by the dw gene. On the other hand, Rashid *et al*. (2005) reported that the existence of dwarf in an autosomal recessive state (adw) led to better feed utilization and higher hen day egg production. Moreover, the small egg size reflects the high and positive correlations between body weight and egg size and may be associated with smaller reproductive tract of dwarf layers (Katongole *et al*., 1990). With respect to naked neck gene, there was no significant difference between Dw-nana and Dw-Nana genotypes for egg mass and egg number. However, the naked neck birds produced significantly heavier egg weight by about 1.4g (2.3%) compared to Dw-nana genotype. Under Egyptian conditions, Galal (1999) concluded that incorporating Na gene into normally feathered birds led to increased egg weight. Recently, Chen *et al*. (2004) reported that egg weight was increased by the Na gene, as usually observed in layers. Concerning double segregation genes, it could be showed that the dw-Nana birds produced significantly lower egg mass, egg number and egg weight by about 0.8kg (-10.1%), 10.1eggs (-7.6%) and 1.6g (-2.7%), respectively compared to Dw-nana genotype. This observation could be attributed to the Na gene compensate the negative effect of the dw gene on egg production parameters. Similar results were obtained by Younis (2001); Galal and Younis (2006).

Feed consumption and feed conversion ratio: Lower feed intake and better feed utilization are economically important characteristics of the dwarf layers (Katongole *et al*., 1990). Data presented in Table (2) showed that the presence of dwarfing (dw) gene in a single manner or interact with Na gene significantly reduced feed intake compared to Dw-nana counterparts. However, the feed intake did not significantly affected by Na gene in the single state. Missohou *et al*. (2003) found that the dw gene resulted in a lower feed intake, which has been described as an important characteristics of dwarf layers, compared to normal body size. Concerning the feed conversion ratio, the presence of dw gene in a single manner or combined with naked neck gene exhibited better effect on feed conversion ratio. Similar trend was observed for naked neck genes. Mathur and Horst (1992); Galal and Younis (2006) reported that the feed efficiency was improved by dwarf gene.

Egg quality measurements: Data presented in Table 3 and Fig. 4 showed that the presence of dw gene in a single state or interact with Na gene significantly

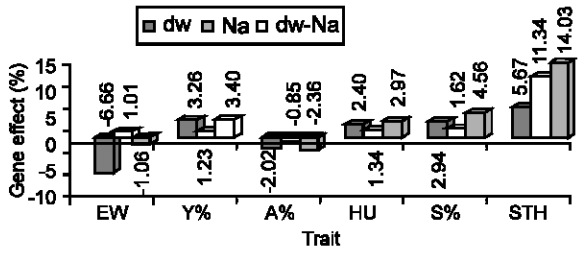

Fig. 4: Gene effect (deviation from Dw-nana genotype) for egg quality measurements

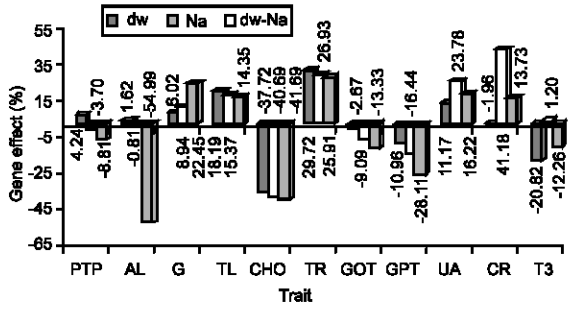

Fig. 5: Gene effect (deviation from Dw-nana genotype) for some blood parameters

increased yolk percentage compared to normal body size-normally feathered (Dw-nana) sibs. However, the Dw-Nana genotype was intermediated. Conversely, the presence of dw gene in a single manner or combined with Na gene significantly reduced albumen percentage compared to Dw-nana and Dw-Nana counterparts. With respect to eggshell quality, it could be noticed that the dw, Na and double segregation genes significantly increased both percentage and thickness of eggshell compared to normal body size normally feathered genotype. The effect of the dw gene on egg characteristics reported in literature is not entirely consistent. In comparison with the normal body sized counterpart, albumen height of dwarfs was either similar (Horst and Peterson, 1981) or increased (Mérat, 1971), breaking strength in hot environments was found to be either similar (Horst and Peterson, 1981). Shell thickness was reported to be higher (Amin-Bakhche and Merat, 1975) or similar (Merat, 1972).

Blood parameters: Effect of dwarf (dw), naked neck (Na) and double segregation genes on some blood parameters of egg-type chicken are presented in Table 4 and Fig. 5. There was no significant difference between Dw-nana and dw-nana genotypes for plasma total protein. Inversely, the dw-nana genotype had significantly higher plasma total protein compared to Dw-Nana and dw-Nana genotypes. Albumen is serves as the major reservoir of protein and involved in colloidal osmotic pressure, acid-base balance and it acts as a transport carrier for small molecules such as vitamins, minerals, hormones and fatty acids (Margaret, 2001). The dwarf-naked neck birds had significantly lower plasma albumen compared to remaining genotypes. The globulins are composed of three fractions, designated alpha, beta and gamma. Alpha-globulins are a group of proteins manufactured almost entirely by the liver. Normally, these proteins increase with acute nephritis, severe active hepatitis, active, usually systemic inflammation, malnutrition and in nephritic syndromes (Margaret, 2001). The double segregation genes significantly increased plasma globulin compared to other genetic groups. Plasma total lipids and triglycerides of Dw-nana genotype were significantly lower than those of remaining genotypes. The dwarf, naked neck and double segregation genes had significantly decreased plasma cholesterol compared to Dw-nana sibs. Conversely, in laying hens, Burghelle-Mayeur *et al.* (1989) reported that the dwarfing gene did not significantly modify plasma concentrations of triglycerides and total cholesterol. With respect to liver function, it could be noticed that the presence of dw, Na and their combination significantly improved the liver function via decreased the liver enzymes (GOT and GPT) compared to Dw-nana counterparts. The uric acid of Dw-Nana genotype was significantly higher than those of Dw-Nana and dw-nana genotypes. However, there was no significant difference between Dw-Nan and dw-Nana genotypes. The presence of Na gene significantly increased plasma creatinine compared to other genetic groups. In considering T3 as anabolic hormone, the present results showed that the presence of dw gene in a single state or interact with Na gene significantly decreased plasma T3 compared to Dw-nana genotypes. Scanes *et al.* (1984) and Decuypere *et al.* (1986) reported that the concentration of triiodthyronine (T3) and insuline-like growth factors I (these are important hormones regulating growth) circulating in the plasma of dwarf birds are lowered compared to normal birds. In contrary to dw gene, there was no significant difference between Dw-nana and Dw-Nana genotypes for plasma T3.

In conclusion, the loss of revenue due to reduction in egg production associated with sex-linked dwarf gene may be exceeded by revenue saved from lower feed intake and better feed efficiency. Moreover, incorporating the Na gene into dwarfed birds could compensate the reduction effects associated with dw gene.

References

Abplanalp, H., D. Napolitano and C. Tai, 1987. The effects of the gene for sex-linked dwarfing (dw) on egg production and body composition of hens in a line selected for high numbers of multiple yolked eggs. J. Anim. Breed. Genet., 104: 304-308.

Amin-Bakhche, M. and P. Mérat, 1975. Study of a sex-linked dwarfing gene in the fowl: Oviposition time and characteristics of the successive eggs in laying sequences. Annales de Genetique et de Selection Animale, 7: 13-22.

Bernier, P.E. and G.H. Arscctt, 1972. Fifteen years of observation on the dwarf gene in the domestic fowl. Ann. Genet. Sel. Anim., 4: 183-215.

Bordas, A. and P. Merat, 1984. Correlated responses in a selection experiment on residual feed intake of adult Rhode-Island Red cocks and hens. Ann. Agri. Fenn. 23: 233-237.

Burghelle-Mayeur, C., Y. Demarne and P. Merat, 1989. Influence of the sex-linked dwarfing gene (dw) on the lipid composition of plasma, egg yolk and abdominal fat pad in white Leghorn hens: effect of dietary fat. J. Nutr., 119: 1361-1368.

Cahaner, A., N. Deeb and M. Gutman, 1993. Effect of the plumage-reducing naked-neck (Na) gene on the performance of fast-growing broilers at normal and high ambient temperatures. Poult. Sci., 72: 767-775.

Chen, C.F., A. Bordas, D. Gourichon and M. Tixier-Boichard, 2004. Effect of high ambient temperature and naked neck genotype on performance of dwarf brown-egg layers selected fpr improved clutch length. Br. Poult. Sci., 45: 346-354.

Darras, V.M., T.J. Visser, L.R. Berghman and E.R. Kuhn, 1992. Ontogeny of type I and type II deiodinase activities in embryonic and posthatch chickens: relationship with changes in plasma triiodthyronine and growth hormone levels. Comparative Biochem. Physiol., 103A: 131-136.

Decuypere, E., P. Rudas, L. Huybrechts, P. Mongin and E.R. Kuhn, 1986. Endocrinological effects of the dwarf gene. II. Effect on tissue monodeiodination activity. In Proceeding of the 7th European Poultry Conference (Paris), 2: 955-959.

Deeb, N. and A. Cahaner, 1996. The effect of naked neck (Na) gene on broilers stocks differing in growth rate. Proceeding of the XX World's Poultry Congress, New Delhi, Indian, IV: 102.

Demarne, Y., P. Merat and A. Pihet, 1984. Compostion des lipids de l'oeuf chez des poules Leghorn normales et naines. Genet. Sel. Evol., 16: 211-220.

Eisen, E.J., B.B. Bohren and H.E. McKean, 1962. The haugh unit as a measure of egg albumen quality. Poult. Sci., 41: 1461-1468.

Galal, A., 1999. Use of reducing plumage genes in improving some economic traits in chickens. Ph.D. Thesis, Ain Shams University, Egypt.

Galal, A. and H.H. Younis, 2006. Minimizing residual feed intake by introducing dwarf and naked neck genes in laying chicken. Egypyt. Poult. Sci., 25: 677-694.

Garces, A., N.H. Casey and P. Horst, 2001. Productive performance of naked neck (Na), frizzle (F) and dwarf (dw) laying hens under the climatic conditions of the tropical coastal plain of south-east Africa and two nutritional treatments. S. Af. J. Anim. Sci., 31: 174-180.

Gowe, R.S. and R.W. Fairfull, 1995. Breeding for resistance to heat stress. In: Poultry Production in Hot Climates. Ed. N.J. Daghir, CAB International, UK, pp: 11-29.

Guillaume, J., 1976. The dwarfing gene, dw, its effects on anatomy. Physiology, nutrition, management: its application in poultry industry. World's Poult. Sci. J., 32: 285-304.

Horst, P. and J. Peterson, 1981. The effect of the dwarf gene on the adaptability of laying hens to high environmental temperatures. Anim. Res. Develop., 13: 69-74.

Horst, P., P.K. Mathur and T.H. Foo, 1990. Significance of major gene interactions for productivity of layers in humid tropic. Proc. The 5th AAAP animal Sci. Cong. Taiwan, 3: 231.

Katongole, J.B.D., S. Ochetim and P. Horst, 1990. Effect of dwarf (dw) and naked neck (Na) genes on performance of layers under Zambian conditions. Zambian J. Agric. Sci., 1: 30-39.

Margaret, A.W., 2001. Avian Plasma Proteins. http://www.exoticpetvet.net.

Mathur, P.K. and P. Horst, 1992. Improving productivity of layers in the tropics through additive and non additive effects of major genes. World's Poultry congress, Amsterdam, the Netherlands, 20-24 Sept.

Mérat, P., 1971. Influence of the dw gene on egg laying and egg quality traits. World's Poult. Sci. J., 27: 282.

Mérat, P., 1972. Quelques effets du gene dw sur la ponte et sur la qualite des Oeufs. Ann. Genet. Sel. Anim., 4: 217-220.

Merat, P., 1986. Potential usefulness of the Na (naked neck) gene in poultry production. World's Poult. Sci. J., 42: 124-142.

Missohou, A., A. Dieng, P. Horst, V.A. Zarate, T. Nesseim and K. Tchedre, 2003. Effect of dwarf (dw) and frizzle (F) genes on the performance of layers under Senegalese conditions. Trop. Anim. Health Prod., 35: 373-380.

Patra, B.N., R.K.S. Bais, R.B. Prasad and B.P. Singh, 2002. Performance of naked neck versus normally feathered coloured broilers for growth, carcass traits and blood biochemical parameters in tropical climates. Asian-Australian J. Anim. Sci., 12: 560-563.

Rashid, M.A., M.A.R. Howlider, J. Alam, M. Abdur Rahid, M.H. Kawsar and S.A. Azmal, 2005. Effect of dwarfism on reproductive and meat yield parameters of crossbred chicken. Int. J. Poult. Sci., 4: 372-377.

SAS Institute, 2001. SAS/STAT User's Guide: Statistics. Ver. 8.2, SAS Institute Inc., Cary, NC.

Scanes, C.G., S. Harvey, J.A. Marsh and D.B. King, 1984. Hormones and growth in poultry. Poult. Sci., 63: 2062-2074.

Singh, B., B.P. Singh, S. Singh, D. Chaudhary and S. Malik, 1998. Naked neck: a noble gene for broiler production in tropical climate. Appl. Anim. Res. J., 13: 37-48.

Younis, H.H. and A. Galal, 2006. Impact of dwarf (dw), rapid feathering (k+) and naked neck (Na) genes on growth and egg production of laying hen chickens. Egypt. Poult. Sci., 26: 17-38.

Younis, H.H., 2001. Genetic studies to improve productive performance of laying hubrid by single genes. 2- influence of dwarf and naked neck genes on egg production. Egypt. Poult. Sci., 21: 165-181.

Zulkifli, I., Y. Yamada, W. Khadijah, M.K. Vidayadaran and I. Dahlam, 1992. The effect of sex-linked dwarf, naked neck and frizzle genes on egg quality traits of laying hens under tropical conditions. J. Vet. Malaysia, 4: 33-39.