Effects of Eggshell Pigmentation and Egg Size on the Spectral Properties and Characteristics of Eggshell of Meat and Layer Breeder Eggs

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ABSTRACT : The effects of eggshell pigmentation and egg size (medium and large) on the spectral properties and characteristics of eggshells were examined in eggs from two genetic groups of breeder flocks. Birds from meat (Hybro, pigmented eggshell, PES) and layer (Leghorn, non-pigmented eggshell, NPES) at 40 and 46 weeks of age, respectively, were used. Measurements of per cent shell (PS), shell thickness (ST), shell volume (SV), shell density (SD), egg shell conductance (EC) and physical dimensions of eggs were made. The spectral properties of eggshells were measured over the wavelength (WL) range of 200 to 1,100 nm. Eggshell absorbed approximately 99.8 percent of the light and transmitted only about 0.12 percent with a maximum light transmission at the near-infra-red region of about 1075 nm. It attenuated shorter WL and transmitted longer WL. Eggshell pigmentation and egg size influenced light transmission into the egg. The NPES had higher EC and transmission of light and lower PS and SD than those of the PES. Large size eggs had higher EC, SD, SV, transmission of light and egg physical dimensions than those of medium size eggs. It is concluded that genetic make up of birds and egg size influenced eggshell characteristics including EC and that, as a consequence, the difference in the spectral properties of eggshells. The pigmentation of eggshell influenced the amount and WL transmitted into the egg. The size and EC of eggs influenced the amount of light transmitted through the eggshell. EC is a good indicator for the ability of eggshell to transmit light. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 2 : 297-302)***

Key Words : Egg Size, Shell Characteristics, Shell Pigmentation, Spectral Characteristics, Breeder Flocks

INTRODUCTION

Investigations on the effects of illumination of incubated chickens'eggs upon embryonic growth and hatchability have been inconsistent. The growth rate of chick embryo increases (Garwood et al., 1973; Lowe and Garwood. 1977). hatching period decreases (Shutze et al., 1962; Lauber and Shutze, 1964; Siegel et al., 1969; Walter and Voitle, 1972); and hatchability percentage improves (Shutze et al., 1962; Gimeno et al., 1967; Walter and Voitle, 1972) indicating a beneficial role for incubating eggs under light. In contrast, Lauber and Shutze (1964), Siegel et al. (1969) and Zakaria (1989) found no effect on hatchability when eggs were exposed to light during incubation period. Whilst, Tamimie (1967) and Tamimie and Fox (1967) reported a delay in hatching time, reduced hatchability and increased incidence of embryonic abnormalities in those chicks exposed to light during incubation. This disagreement among authors suggests that there are some factors influencing the quantity and quality of light that reaches the embryos and consequently the outcome of incubated eggs under light.

The characteristics of eggshell may influence its ability to reflect. absorb and transmit light. These include shell pigmentation, thickness, density and conductance. Several factors such as egg size and genetic make up of birds are known to influence eggshell characteristics (Marshall and Cruickshank. 1938; Christensen and Nestor. 1994; Christensen et al., 1995) and consequently could influence the spectral characteristics of eggshells and the outcome of incubated eggs under light. The objectives of this study were to assess the effects of eggshell pigmentation and egg size on the characteristics of eggshell including spectral properties. and physical dimensions of eggs from two genetic groups of birds. A commercial meat-type (Hybro, brown eggshell. pigmented eggshell. PES) and a layer-type (Leghorn, white eggshell, non-pigmented eggshell, NPES) breeder flocks were used.

MATERIALS AND METHODS

A total of 56 freshly laid eggs obtained from a commercial meat-type (Hybro. brown eggshell. pigmented eggshell. PES) and a layer (Leghorn. white eggshell. non-pigmented eggshell. NPES. King Saud University flock) breeders at 40 and 46 weeks of age. respectively, were used in this study. Birds were fed a standard breeder ration (16% CP, 12 MJ of ME per kg. 3.4% calcium. 0.45% available phosphorus) and reared under standard husbandry conditions. A photoperiod of 14 h commenced when the birds were caged at 22 weeks of age and was maintained

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throughout the trials. Eggs were weighed individually and graded into two weight classes. Leghorn's eggs weighing between 58 and 64 g, and 64.1 and 70 g were considered medium and large sizes, respectively. Hybro's eggs weighing between 55 and 60 g, and 60.1 and 70 g were considered medium and large sizes, respectively.

Eggshell characteristics and spectral properties

Seven eggs selected at random from each weight class from both genetic groups were weighed individually and broken open. Eggshells were washed with water, dried with paper towels and then weighed. Eggshells were broken to obtain representative areas. Pieces from the three different areas (large end, equator and small end) of each shell were selected. Twelve measurements were taken from each eggshell with a micrometer (Ames, Waltham, MA). Measurements of shell weight (SW), per cent shell (PS)=SW/egg weight×100 and eggshell thickness (ST) were done with the membranes intact. Four eggshells from each weight classes from both genetic groups were selected and membranes were removed then spectral absorption of eggshells were determined using a spectrophotometer (Model UV-1601 PC). Eggshell spectral absorption was recorded every 2 nm over the wavelength (WL) range of 200 to 1,100 nm. Calculations were based on 25 nm-groups for WL absorption.

Eggshell conductance (EC)

Seven freshly laid eggs from each weight class from both genetic group were selected at random, individually weighed, placed in desiccators containing fresh desiccant ($CaSO_4$, Sigma Chemical Co., St. Louis, USA) and maintained at 25°C for 4 days. These eggs were weighed once a day to determine the EC, expressed as the milligrams of water lost per day per Torr. Weight loss was corrected to a standard barometric pressure of 760 Torr (mm Hg) (Ar et al., 1974). EC was also expressed per unit of egg weight (EC/EW) to adjust for the effect of egg weight on EC. Shell volume was calculated from the relationship: Volume = A × L; where A=surface area of the egg (cm^2), and L=thickness of the shell (cm). Surface area of the egg was estimated from the allometric relationship, area (cm^2) = $4.835\ W^{0.662}$ where W = initial egg weight (Paganelli et al., 1974).

Measurements included egg weight, egg length, egg width, PS, ST, egg surface area, shell volume, shell density, EC and spectral absorption of eggshell over the WL range of 200 to 1,100 nm.

Data collected were subjected to analysis of variance (SAS Institute, 1985). When significant variance ratios were detected, differences between treatment means were tested using the least significant difference (LSD) procedures.

RESULTS

The physical dimensions, eggshell characteristics and EC of medium and large sizes of eggs from the PES and NPES (Hybro and Leghorn birds, respectively) groups are shown in tables 1 and 2, respectively. Eggs produced by Hybro had higher weight, length, PS and shell volume and lower EC (expressed as mg day^{-1} $torr^{-1}$ or mg day^{-1} $torr^{-1}$ per 100 g egg weight (EC/EW)) than those produced by Leghorn birds. The physical dimensions (weight, length, width and surface area), eggshell thickness and volume and EC (expressed as mg day^{-1} $torr^{-1}$) of large size eggs were higher than those of medium size eggs. There were no

Table 1. Physical dimensions and eggshell characteristics of medium and large sizes of eggs from two genetic groups of birds (meat (Hybro, pigmented eggshell) and layer (Leghorn, non-pigmented eggshell) breeders)

Treatment	Physical dimensions of eggs				Egg shell characteristics			
	Weight (g)	Length (cm)	Width (cm)	Surface area (cm^3)	Per cent[1]	Thickness (mm)	Volume (cm^3)	Density (g/cm^3)
Genetic group (GG)								
Hybro	63.5	5.9	4.37	75.5	9.7	0.39	2.97	2.08
Leghorn	62.0*	5.7**	4.44	74.4	9.2**	0.38	2.81*	2.03
Egg size (ES)								
Medium	59.0	5.7	4.31	71.9	9.4	0.37	2.69	2.06
Large	66.4**	5.9*	4.49**	77.8**	9.5	0.40*	3.09**	2.06
SEM[2]	0.5	0.1	0.02	0.6	0.1	0.01	0.05	0.02
Probability (P)								
GG	0.0479	0.0006	0.0582	0.2051	0.0046	0.0832	0.0404	0.1966
ES	0.0001	0.0176	0.0001	0.0001	0.3219	0.0221	0.0001	0.9835
GG × ES	0.7011	0.3600	0.0690	0.7130	0.1004	0.1614	0.2821	0.4113

[1] As a percentage of egg weight, [2] Standard error of means.
* Significant difference (p<0.05), ** Significant difference (p<0.01).

differences between the two genetic groups of birds in egg width, egg surface area and shell thickness and density. No significant differences were detected between the medium and large sizes of eggs in PS, shell density and EC/EW.

Table 2. Egg weight and eggshell conductance (EC) of medium and large sizes of eggs from two genetic groups of birds (meat (Hybro, pigmented eggshell) and layer (Leghorn, non-pigmented eggshell) breeders)

Treatment	Egg weight (g)	EC (mg day^{-1} torr^{-1})	EC/100 g egg weight
Genetic group (GG)			
Hybro	61.9	10.83	17.49
Leghorn	60.8**	11.78*	19.36*
Egg size (ES)			
Medium	59.8	10.85	18.14
Large	62.9**	11.75*	18.71
SEM[1]	0.2	0.3	0.5
Probability (P)			
GG	0.0003	0.0451	0.0163
ES	0.0001	0.0498	0.4334
GG × ES	0.2402	0.7547	0.4694

[1] Standard error of means.
* Significant difference (p<0.05).
** Significant difference (p<0.01).

Spectral absorption of eggshells of medium and large sizes of eggs from the PES (Hybro) and NPES (Leghorn) groups are shown in table 3. The PES group had significantly (p<0.01) higher absorption and lower transmission percentages of light over the WL range measured (200 to 1,100 nm) than those of the NPES group. There was a significant interaction (p<0.01) between eggshell pigmentation and egg size on the spectral absorption of eggshell over the WL range measured (table 4). Eggshells of medium size eggs of the NPES group had a higher percentage of spectral absorption over the WL range measured than those of large size eggs of the same genetic group. Whilst, the percentage of spectral absorption of eggshells over the WL range between 200 and 470 nm was not influenced by egg size in the PES group. Eggshells of medium size eggs of the PES group had a higher percentage of spectral absorption over the WL range of 470 to 1,100 nm than those of large size eggs of the PES group and both sizes of eggs in the NPES group.

DISCUSSION

Results from the spectral absorption of PES and NPES of eggs (tables 3 and 4) revealed that eggshell absorbed approximately 99.8 percent of the light and exhibited approximately 0.12 percent transmission (Transmission percent=100-absorption percent) with a maximum light transmittance at the near-infra red (near-IR) region of about 1075 nm (figures 1 and 2). Whilst eggshell absorbed light maximally in the near-ultra violet (near-UV) range from 200-300 nm. Eggshell absorption reduced the ability of light to reach the embryo. Eggshell attenuated shorter WL

Table 3. The main effects of eggshell pigmentation and egg size on the spectral absorption percentage of eggshell over the wave length (WL) range of 200 to 1,100 nm

Treatment	WL< =380 (nm)	380 <WL< 450 (nm)	450 <WL< 470 (nm)	470 <WL< 560 (nm)	560 <WL< 590 (nm)	590 <WL< 630 (nm)	630 <WL< 780 (nm)	780 <WL< 1100 (nm)
Genetic group (GG):								
Hybro (PES)	99.957	99.957	99.957	99.956	99.947	99.932	99.895	99.877
Leghorn (NPES)	99.952**	99.910**	99.880**	99.872**	99.863**	99.857**	99.849**	99.848**
Egg size (ES):								
Medium	99.958	99.939	99.926	99.920	99.912	99.903	99.884	99.876
Large	99.951**	99.928**	99.912**	99.908**	99.898**	99.887**	99.860**	99.849**
SEM[1]	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Probability (P)								
GG	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
ES	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
GG × ES	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[1] Standard error of means.
** Significant difference (p<0.01).

Table 4. The combined effects of eggshell pigmentation and egg size on the spectral absorption percentage of eggshell over the wave length (WL) range of 200 to 1,100 nm

Wave length (WL) (nm)	Genetic group: Hybro (PES) Egg size: Medium	Large	Leghorn (NPES) Egg size: Medium	Large	SEM[1]
WL< =380	99.960[a]	99.955[a]	99.957[a]	99.947[b]	0.002
380 <WL< 450	99.959[a]	99.954[a]	99.919[b]	99.902[c]	0.002
450 <WL< 470	99.959[a]	99.956[a]	99.892[b]	99.868[c]	0.002
470 <WL< 560	99.959[a]	99.953[b]	99.881[c]	99.862[d]	0.001
560 <WL< 590	99.952[a]	99.942[b]	99.902[c]	99.889[d]	0.001
590 <WL< 630	99.938[a]	99.926[b]	99.868[c]	99.847[d]	0.001
630 <WL< 780	99.910[a]	99.881[b]	99.859[c]	99.840[d]	0.001
780 <WL< 1,100	99.894[a]	99.861[b]	99.858[c]	99.837[d]	0.001

[1] Standard error of means.

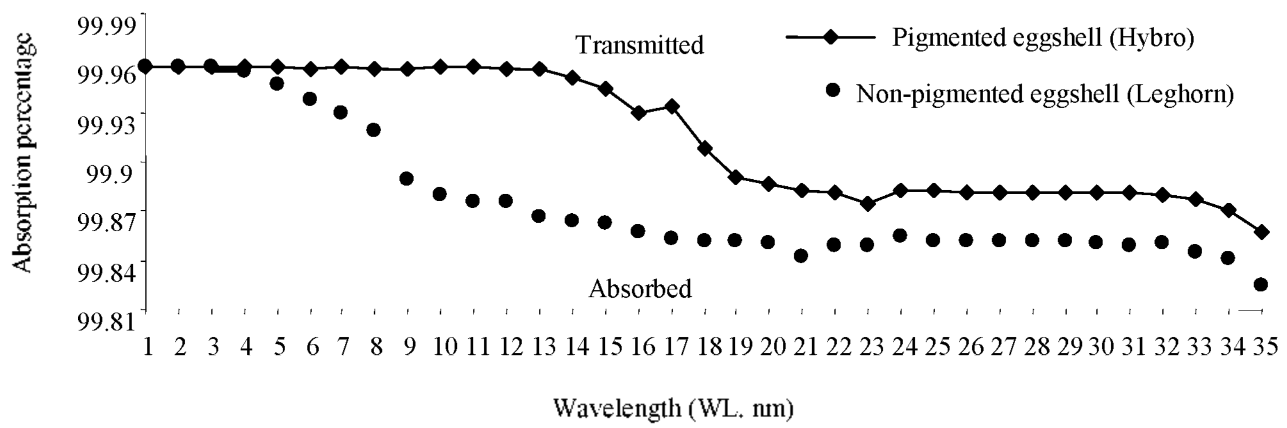
[a,b,c,d] Means within row followed by different superscripts are significantly different (p<0.05).

and transmitted longer WL. The absorption of eggshell in the near-IR region was relatively lower than that of the near-UV region. It seems that higher absorption rate of the near-UV light is a general property of chicken's eggshell. It serves as a shield against radiation and influences the amount and quality of light transmitted into the egg. This role of eggshell absorption of about 99.8% of light may be beneficial for the survival of the embryo, since in *Escherichia Coli* the number of mutants caused by near ultra-violet and visible light is directly proportional to the irradiant (Kubitschek, 1967; Webb and Malina, 1967).

There were consistent differences in the spectral absorption and transmission of eggshells produced by the two genetic groups of birds (figure 1). The pigmentation of eggshell altered the quantity and the WL transmitted into the egg. Generally, the PES group had significantly (p<0.01) higher absorption and consequently lower transmission of light than those of the NPES group. As the WL become progressively shorter, absorption increased eventually, reducing transmission near 525 nm for the PES group and 325 nm for the NPES group. The difference may be due to the absorption characteristics of protoporphyrin pigment of the brown eggshells when compared with the non-pigmented white eggshells. The interaction between eggshell pigmentation and egg size on the spectral absorption of eggshell, especially over the WL range 200-470 nm suggested that eggshell pigmentation played a major role in controlling the WL transmitted through the eggshell. The non-significant difference in spectral absorption of eggshells between medium and large eggs in the PES group over the WL range 200 to 470 nm when compared with their counterparts of the NPES group suggest a strong ability for eggshell pigmentation to absorb these WL, regardless to egg size. Consequently, the amount of pigment present in the eggshell may alter the spectral absorption. In addition, there is a considerable variation in the eggshell pigment of a breed (Butcher and Miles, 1995). These differences may influence light transmission into the egg. Further study based on variation in eggshell pigment and WL transmission may be needed to clarify this point.

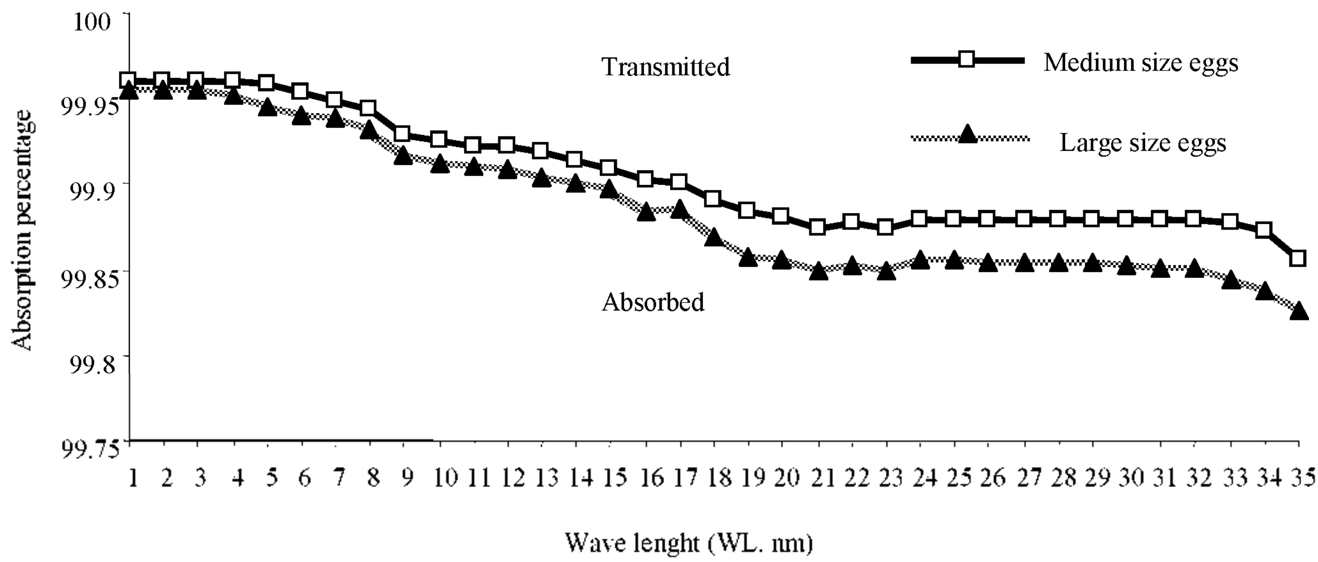
Results from this study and others showed that genetic make up of bird and egg size influenced egg physical dimensions, eggshell characteristics and EC in chickens and turkeys (Christensen and McCorkle, 1982; Christensen, 1983; Christensen and Nestor, 1994; Christensen et al., 1995, Shafey, 2001). Leghorn eggs had higher EC (mg day^{-1} torr^{-1} or per 100 g of egg weight) and light transmission over the WL range of 200 to 1,100 nm when compared with those of Hybros' eggs. Whilst, large size eggs had higher EC (mg day^{-1} torr^{-1}) and light transmission over the WL range of 200 to 1,100 nm than those of medium size eggs. The increase in EC of Leghorn eggs may be associated with the non-significant reduction in ST alone or in combination with an increase in pore area. ST and the total functional cross-sectional area of the pores are known to determine EC (Ar et al., 1974). However, it is interesting to note that the increase in EC and light transmission of large size eggs were associated with an increase in ST, which would have reduced EC. A negative relationship exists between ST and pore concentration (Tullett, 1984; Peebles and Brake, 1987). It seems that the improvement in EC and light transmission of large size eggs is associated with an increase in pore density or pore size. Birds have the constructional ability to change the conductance of their eggs and meet the conductance requirement for different egg sizes (Tullett and Board, 1977). The biological significance of the variation in eggshell spectral properties is not known. However, it could be adaptation to certain (unknown) environmental conditions. Light transmission of eggshell depend upon shell characteristics (shell pigmentation and EC) and the amount and WL provided. Presumably, the effect of light on chicken's embryo will depend upon the amount and WL reached the embryo. Coleman (1979) found that hatching weight of chick produced from large size broiler eggs was least affected by light. It is possible that the amount of light zgrowth response of the embryo.

It is concluded that egg size and eggshell characteristics (shell pigmentation and EC) influenced the spectral properties of eggshell. The pigmentation of eggshell



1=WL<=250, 2=250<WL<275, 3=275<WL<300, 4=300<WL<325, 5=325<WL<350, 6=350<<375, 7=375< WL<400, 8=400<WL<425, 9=425<WL<450, 10=450<WL<475, 11=475<WL<500, 12=500<WL<525, 13=525<WL<550, 14=550<WL<575, 15=575<WL<600, 16=600<WL<625, 17=625<WL<650, 18=650<WL<675, 19=675<WL<700, 20=700WL<725, 21=725<WL<750, 22=750<WL<775, 23=775<WL<800, 24=800<WL<825, 25=825<WL<850, 26=850<WL<875, 27=875<WL<900, 28=900<WL<925, 29=925<WL<950, 30=950<WL<975, 31=975<WL<1,000, 32=1,000<WL<1,025, 33=1,025<WL<1,050, 34=1,050<WL<1,075, 35=1,075<WL<1,100.

Figure 1. Spectral absorption percentage of pigmented and non-pigmented eggshells of eggs obtained from two genetic groups of birds (meat (Hybro) and layer (Leghorn) breeders



1=WL<=250, 2=250<WL<275, 3=275<WL<300, 4=300<WL<325, 5=325<WL<350, 6=350<<375, 7=375< WL<400, 8=400<WL<425, 9=425<WL<450, 10=450<WL<475, 11=475<WL<500, 12=500<WL<525, 13=525<WL<550, 14=550<WL<575, 15=575<WL<600, 16=600<WL<625, 17=625<WL<650, 18=650<WL<675, 19=675<WL<700, 20=700WL<725, 21=725<WL<750, 22=750<WL<775, 23=775<WL<800, 24=800<WL<825, 25=825<WL<850, 26=850<WL<875, 27=875<WL<900, 28=900<WL<925, 29=925<WL<950, 30=950<WL<975, 31=975<WL<1,000, 32=1,000<WL<1,025, 33=1,025<WL<1,050, 34=1,050<WL<1,075, 35=1,075<WL<1,100.

Figure 2. Spectral absorption percentage of eggshells obtained from medium and large sizes of eggs

influenced the amount and WL transmitted into the egg. The size and EC of eggs influenced the amount of light transmitted through the eggshell. EC is a good indicator for eggshell transmission of light.

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