

Effect of Egg Size and Strain and Age of Hens on the Solids Content of Chicken Eggs¹

D. U. AHN,^{*}2 S. M. KIM,^{†,3} and H. SHU[‡]

^{}Animal Science Department, Iowa State University, Ames, Iowa 50011, [†]Food Science Department, KyungSan University, KyungSan, Korea, and [‡]Department of Statistics, Iowa State University, Ames, Iowa 50011*

ABSTRACT A study was conducted to determine the effect of egg size and the age and strain of hens on the content of egg solids. Eggs were obtained from commercial farms from four strains of hens with similar age groups and received diets formulated to contain the same dietary energy and protein levels across the strains within a farm. Eggs were collected on 2 different d when the flocks reached the average ages of 28, 55, 75, and 97 wk. The eggs collected from each farm were pooled and sorted by size. Each individual egg was used as a replicate for yolk:white ratio; however, five yolks, five whites, and five whole eggs from each strain at each age period were pooled, homogenized, and then used as a replicate to determine the solids contents of yolk, white, and whole eggs.

The yolk:white ratio of eggs from 28-wk-old hens was the lowest, that from 55- and 78-wk-old hens was the highest, and that from 97-wk-old hens was intermediate;

however, the solids content (percentage) of whole eggs increased with the age of the hens. The solids content of egg white was highest in eggs from 28-wk-old hens. The white solids content of extra large eggs was greater than that of medium eggs, and yolk solids increased with egg size; however, the solids of whole egg were not affected by egg size. The strain of hens had a significant effect on the solids of whole egg, white, and yolk; however, the strain effect on yolk:white ratio was not significant. The results showed that young (28-wk-old) and old birds (97-wk-old) produced eggs with low solids content and intermediate aged hens (55- to 78-wk-old) produced eggs with high solids content. Therefore, it may be more beneficial for egg producers and processors to use young (28-wk-old) and old birds (97-wk-old) for table egg production and birds of intermediate age (55- to 78-wk-old) for liquid egg production.

(Key words: egg size, strain of hens, age of hens, egg solids, yolk to white ratio)

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INTRODUCTION

There has been an increasing proportion of eggs broken out for liquid whole egg, liquid white, liquid yolk, and dried egg products in recent years. In 1994, 26% of total egg production, equivalent to 61 eggs per capita egg consumption in U.S., were broken for use as liquid egg products. The number of eggs broken for use as liquid egg products increased over 10% during past few years, and egg use in egg products is projected to constitute 50% of total egg consumption by the year 2,000 (Owings, 1995). Many chickens are now being placed just for the purpose of processing eggs for liquid egg products, with few if any eggs from these flocks being sold for use as table eggs. With this trend,

processors have become more concerned about the factors that affect the solids content of the liquid eggs, and some purchasers specify minimum standards for the solids content. General composition of large eggs, reported decades ago, consisted of 58% white, 31% yolk, and 11% shell (Stadelman and Cotterill, 1977). When calculated on the basis of interior contents, 65% of egg content is white and 35% is yolk. The major constituent of egg white is water, approximately 88% of total weight. The total solids content of white is approximately 12%, and protein is the major component of the solids at 11%. The total solids content of egg yolk is generally 50%, and the major constituents of yolk are protein (16%) and lipid (32%). Therefore, eggs with larger yolks will have higher total solids content than those with smaller yolks.

The content of solids in whole egg is affected by factors such as the ratio of yolk to white, and the solids content in yolk and white (Washburn, 1979). The ratio of yolk to white varies widely with the size of eggs (Marion *et al.*, 1964). The age of hens can affect egg solids because egg weight increases with the age of hens (Fletcher *et al.*, 1983). The proportion of yolk is reported

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²To whom correspondence should be addressed.

³Visiting Scientist at Iowa State University.

to be less in small eggs than in larger ones (Kaminska and Skraba, 1991). Therefore, the yolk size increases proportionally with egg size, and solids content of eggs from older or forced molted hens, which lay larger eggs, may be significantly different than those from younger birds. Rose *et al.* (1966) found significant differences in percentage solids among several commercial strains of Leghorns. Most of these differences could be explained by differences in egg weight, which would change the proportions of yolk and albumen. However, genetic differences also may exist in solids content of eggs, especially as a result of intense genetic selection programs for egg size and production in recent years. The variations in solids content of white and yolk are also important factors that can influence the total solids in whole egg.

Total solids content of yolk can be influenced by the age and strain of the hens and the conditions under which eggs have been stored. The loss of CO₂ and moisture from egg white and the loss of moisture during storage may increase the solids content of white, and the proportion of major yolk components, lipid, and protein in the yolk. Solid content of the yolk can also be affected by the moisture mobilization from egg white; however, the effect of variety, age, diet, and other conditions on the protein and lipid content of egg yolk is not clear.

Considering all these facts, studies on the effect of egg size, and variety and age of hen on yolk:white ratio and the solids content of yolk and white should be valuable for both egg producers and processors. The objective of this work was to determine the effect of egg size, and hen age, and hen strain on egg solids content.

MATERIAL AND METHODS

Sample Preparation

About 800 to 1,600 eggs from four strains of Single Comb White Leghorn types (Delta, H&N, Hy-Line® W36, and Hy-Line® W77) were collected from 28-, 55-, 75- and 97-wk-old (average age) hens. Eggs from each strain were from four locations in Iowa and Minnesota. Eggs from four locations were pooled and sorted by size. Three or four egg size groups, according to USDA size requirements (medium, large, extra large, and jumbo), were selected per each age group. When the number of eggs from each size, from each strain of hen at each age was fewer than 50, that size was not included in this study. Eggs were transported to Iowa State University within 7 d (stored at 10 C) after laying, and the weight of each egg was recorded. To determine yolk:white ratio, 44 to 150 eggs of from each size, from each strain of hen at each age group were broken, and yolk and white were separated. Yolk was weighed after rolling it on a paper towel to

remove extra egg white and the chalaza. When the chalaza was not removed by this process, a razor was used to remove it from the yolk. Shell weight was also measured after draining all the leftover egg white from the inner surface of the eggshell. Weight of white was calculated by subtracting the total egg, yolk, and shell weights.

Due to the limited availability of jumbo eggs in 28-wk-old and medium in 78-wk-old hens, only three egg size groups were used to analyze solids content in the eggs for those two age groups, whereas four were used for the other age groups. Five yolks, five whites, and five whole eggs were pooled in separate containers and homogenized to make composite samples. Yolk was homogenized using a spatula, and whole egg and white were homogenized in a Waring blender for 15 s. The homogenized samples were transferred to 20-mL sample vials and stored (less than 2 d) in a cold room (4 C) and used for chemical analysis. Four separate pools from each size, from each strain at each age were prepared for each yolk, white, and whole egg sample.

Chemical Analysis

Moisture content was analyzed by using the AOAC method (AOAC, 1980). Three to four grams of white, yolk, or whole egg homogenates were transferred to an aluminum dish and reweighed after drying in an electric oven at 110 C for 20 h.

Lipid content of egg yolk was determined by the Folch's extraction method (Folch *et al.*, 1957). Egg yolk (approximately 2 g) was weighed into a test tube containing 20 mL Folch 1 solution (chloroform:methanol = 2:1). The sample was homogenized by vigorous shaking for 20 s. The homogenate was filtered through a Whatman Number 1 filter paper⁴ into a 100-mL graduated cylinder (with glass stopper), rinsed twice with each 10 mL Folch 1 solution, 8 mL of 0.88% NaCl solution was added, stoppered, and mixed. The inside of the cylinder was washed twice with 5 mL of Folch 2 solution (3:47:48/CHCl₃:CH₃OH:H₂O). After the phase separation, the lipid layer volume was recorded, and the top layer (methanol and water) of the solution was completely and carefully siphoned off so as not to contaminate the CHCl₃ layer. The organic layer (10 mL) was put in a glass scintillation vial, dried in a block heater (1 h at 50 C), and used for total lipid determination.

Protein content of yolk was analyzed by using a Nitrogen analyzer (LECO, FP-428).⁵ A factor of 6.25 was used to calculate protein content from the nitrogen values.

Statistical Analysis

The experiment was a split-plot design, and egg size was used as repeated measurements. Size by strain was used as an error term for the age and strain, and age by strain by size was used as an error term for egg size, age by size, and strain by size. The General Linear Models procedure was used to analyze the data, and the

⁴Whatman Inc., Clifton, NJ 07014.

⁵Leco Corp., St. Joseph, MI 49085-2396.

TABLE 1. Effect of hen's age on the solids content of whole egg, white, and yolk; the lipid and protein content of yolk; and the ratio of yolk and white¹

Age (wk)	Solids			Yolk		
	Whole egg	White	Yolk	Lipids	Protein	Yolk:white ²
				(%)		
28	23.23 ^c	12.72 ^a	50.69 ^b	30.70	16.97	36.58 ^c
55	24.03 ^b	11.25 ^c	50.64 ^{bc}	30.95	16.96	46.42 ^a
78	24.29 ^{ab}	11.90 ^b	50.38 ^c	30.66	16.75	46.65 ^a
97	24.59 ^a	11.57 ^{bc}	51.55 ^a	30.61	16.75	40.82 ^b
SEM	0.06	0.08	0.05	0.14	0.05	0.03

^{a-c}Means in a column with no common superscript differ significantly ($P < 0.05$).

¹Egg solids, and yolk lipids and proteins: $n = 48$ for 28- and 78-wk-old hens, and 64 for 55 and 97-wk-old hens.

²Yolk:white ratio: $n = 655, 818, 1,156$, and $1,486$ for 28-, 55-, 78-, and 97-wk-old hens, respectively.

differences in the mean values of yolk:white ratio, solids content of white, yolk, and whole egg, and the lipid and protein content of yolk among strain, age, and egg size groups were compared by the least significant difference test. Each individual egg was used as a replicate for yolk:white ratio; five yolks, five whites, and five whole eggs from each strain at each age period were pooled, homogenized, and then used as a replicate for the solids contents of yolk, white, and whole eggs. Interaction effects were analyzed only when significant interactions were observed (SAS Institute, 1986).

RESULTS AND DISCUSSION

Effect of Hen's Age

Age of the hens had a significant effect on the whole egg, white, and yolk solids, and on yolk:white ratio of eggs. The solids content of whole egg ranged from 23.2 to 24.6%, and was 1 to 2% lower than that reported by Posati and Orr (1976). The solids content of whole egg increased with the age of hens, and the eggs from 28-wk-old hens had 0.8 to 1.4% lower whole egg solids content than other age groups. The solids content of white was the greatest in the eggs from 28-wk-old hens and the least in 55-wk-old hens, differing by 1.5%. The solids content of yolk was the greatest in the eggs from 97-wk-old hens and the least in 78-wk-old hens. The solids content of yolk was 5 to 6% higher than the reported value of Posati and Orr (1976). Lipid and protein content of yolk varied within a narrow range, and were not affected by the age of birds. The yolk:white ratio varied widely by the age of hens. Rossi and Pompei (1995) reported that albumen and yolk average weights and the proportion of yolk in the edible part of the egg increased with hen's age. Our results also indicated that the yolk:white ratio in eggs from 28-wk-old hens was the lowest, whereas that of 55- and 78-wk-old hens was the highest; however, the yolk:white ratio of eggs from 97-wk-old hens was intermediate, indicating a gradual decrease in yolk:white ratio after a certain age. The percentage difference in yolk:

white ratio between the highest and the lowest was approximately 10%. Because egg yolk contains approximately 50% solids and 12 % white, a 10% difference in yolk:white could be as large as a 2% difference in whole egg solids; however, the calculated and actual analysis in the solids content of whole eggs from 97-wk-old hens did not agree well. In fact, the solids of whole eggs from 97-wk-old hens were greater than those of 55- and 78-wk-old hens. High solids content in the white of 28- and yolk of 97-wk-old hens might have contributed to the unexpectedly high whole eggs solids in those eggs (Table 1).

Effect of Egg Size

The solids contents of whole egg, white, and yolk varied within a narrow range among egg sizes. Although significant differences were found in the solids of white and yolk by egg size, the solids content of whole egg was not affected by egg size. The solids content in the whites of extra large eggs was greater than that of medium eggs, and yolk solids increased with egg size. The lipid content of egg yolk in jumbo eggs was greater than that of large eggs, and the protein of yolk from medium size eggs was greater than that from extra large eggs. Yolk:white ratio, an important parameter in determining solids content in whole egg, was significantly affected by egg size. Yolk:white ratio was the greatest in medium eggs and this ratio decreased gradually as egg size increased. However, yolk:white ratio was not directly related to whole egg solids content as in the age effect. Higher yolk solids content in larger eggs may have compensated somewhat for the low yolk:white ratio of larger eggs (Table 2).

The percentage of egg yolk gradually decreased and that of egg white increased as the weight of egg increased in all age groups (Figure 1). The percentage of yolk in the eggs from 28-wk-old hens was lower than that of the other age groups. However, the decrease in percentage yolk as the size of egg increased was greater than that of 55- and 78-wk-old hens. The proportion of egg yolk in the eggs from 97-wk-old hens was as relatively high as in 55- and 78-wk-old hens but decreased similarly to that of 28-wk-old hens as the weight of egg increased. This result

TABLE 2. Effect of egg size on the solids content of whole egg, white, and yolk; the lipid and protein content of yolk; and the ratio of yolk and white¹

Egg size	Solids			Yolk		Yolk:white ²
	Whole egg	White	Yolk	Lipids	Protein	
	(%)					
Medium	24.14	11.67 ^b	50.58 ^b	30.83 ^{ab}	16.98 ^a	45.41 ^a
Large	24.08	11.83 ^{ab}	50.71 ^b	30.55 ^b	16.85 ^{ab}	43.78 ^{ab}
Extra large	23.95	11.92 ^a	50.95 ^{ab}	30.62 ^{ab}	16.78 ^b	41.93 ^b
Jumbo	24.16	11.71 ^{ab}	51.22 ^a	31.01 ^a	16.84 ^{ab}	39.38 ^c
SEM	0.04	0.04	0.06	0.07	0.03	0.03

^{a-c}Means in a column with no common superscript differ significantly ($P < 0.05$).

¹Egg solids, and yolk lipids and proteins: $n = 48$ for medium and jumbo, 64 for large and extra large eggs.

²Yolk:white ratio: $n = 850, 1,346, 1,293$, and 626 for medium, large, extra large, and jumbo eggs, respectively.

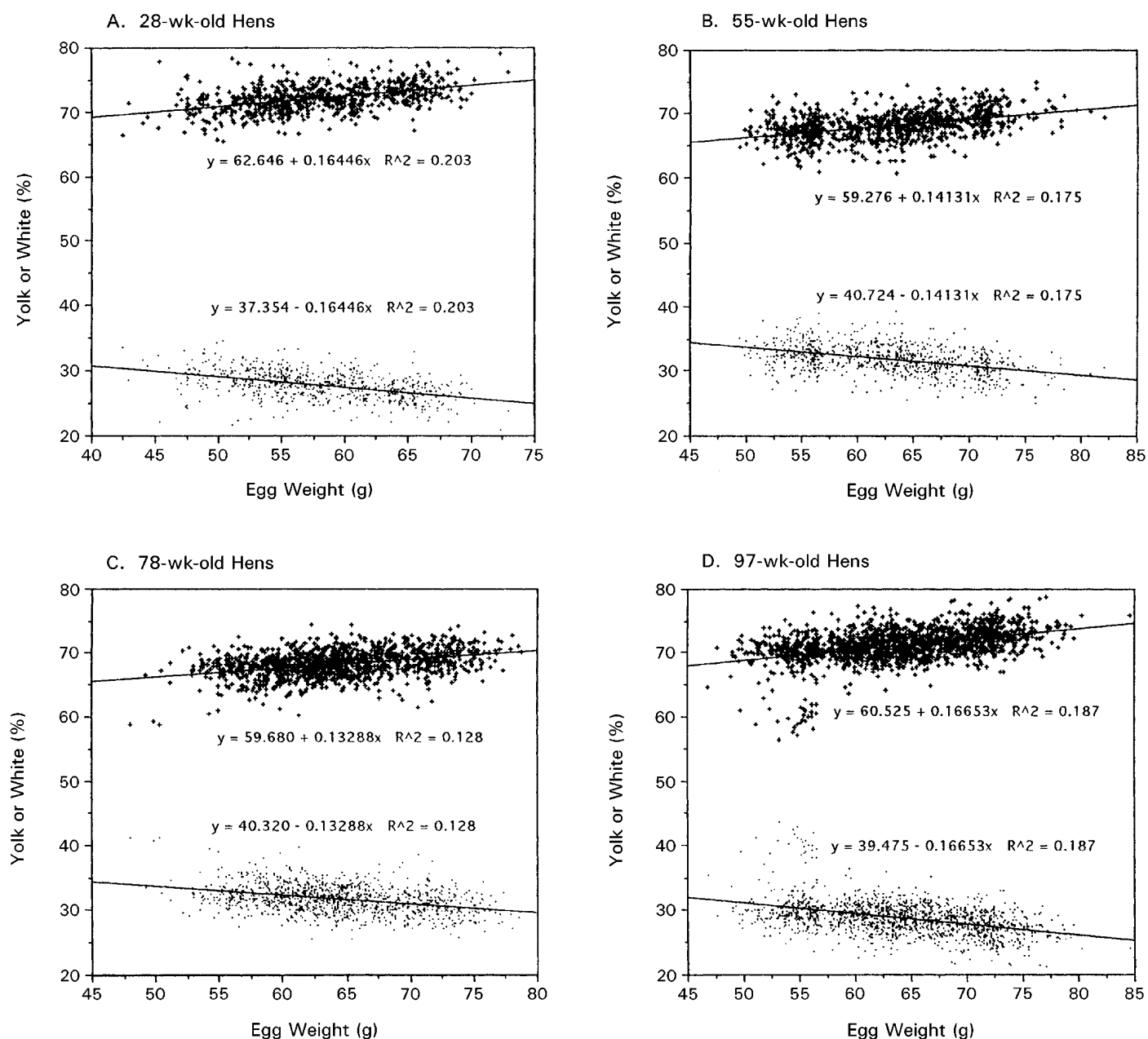
**FIGURE 1.** Effect of egg size on the proportion of egg yolk or egg white (percentage) in whole egg (·, yolk; +, white).

TABLE 3. Effect of hen strain on the solids content of whole egg, white and yolk; the lipid and protein content of yolk; and the ratio of yolk and white¹

Hen strain	Solids			Yolk		
	Whole egg	White	Yolk	Lipids	Protein	Yolk:white ²
	(%)					
H&N	23.97 ^b	11.51 ^b	50.68 ^{bc}	30.87	16.75	42.72
Delta	23.44 ^c	11.65 ^{ab}	50.45 ^c	30.56	16.89	43.06
W-36	24.52 ^a	11.99 ^{ab}	50.89 ^b	31.05	16.79	42.47
W-77	24.36 ^a	12.03 ^a	51.41 ^a	30.44	17.00	41.95
SEM	0.06	0.08	0.05	0.14	0.05	0.03

^{a-c}Means in a column with no common superscript differ significantly ($P < 0.05$).

¹Egg solids, and yolk lipid and protein: $n = 56$.

²Yolk:white ratio: $n = 1,018, 1,047, 917$, and $1,133$ for H&N, Delta, W36, and W77, respectively.

indicated that the effect of egg size on the egg solids and yolk:white ratio of eggs from 28-wk-old hens would be greater than those from 55- and 78-wk-old hens, and suggests that the larger eggs from 28- and 97-wk-old hens would be ideal for table eggs rather than liquid eggs because consumers are not concerned about yolk size or solids content in their table eggs. Comparatively high yolk percentages in the eggs from 55- and 78-wk-old hens suggested that they would be better used for processing than for table eggs. Figure 2 also suggests that eggs from 28-wk-old and 97-wk-old hens would be more suitable for table eggs than for whole liquid egg production. Large eggs would be ideal for table egg and jumbo eggs for liquid egg preparation.

Effect of Hen's Strain

Solids of whole egg, white, and yolk were significantly affected by the strain of hens. Delta had the lowest percentage of whole egg solids of all, H&N the next, and Hy-Line® W36 and W77 the highest (Table 3). The solids content of white in H&N was lower than that of others. Yolk solids content was the highest in Hy-Line® W77 and the lowest in Delta. Yolk lipid and yolk protein were not influenced by the strain of hens, and the sums of yolk lipid and protein were almost the same in all strains. Strains of hens also had a significant effect on the yolk:white ratio but the differences were small. Yolk:white ratio among different strains varied from 42 to 43%, and were not significantly different from each other. The yolk:white ratio of the hen's strain did not agree with whole egg solids. Considering the number of samples used to determine yolk:white ratio (over 10 times those for solids content), however, yolk:white ratio would be more accurate and reliable than the solids value presented here. Of course, direct determination of whole egg solids would be a better method than an indirect method (yolk:white ratio) in getting accurate information on the factors affecting egg solids if the sample size is large enough (Table 3).

Interaction Effects

Strain by size interaction in whole egg solids was the only significant ($P < 0.05$) interaction observed in this

study. Each strain had different relationships between egg size and whole egg solids content (Figure 2). In H&N, whole egg solids gradually decreased as the size of egg increased. Delta has similar trends as H&N but the whole egg solids increased in jumbo eggs. However, in Hy-Line® W36, the whole egg solids content was hardly influenced by egg size except for the sharp increase in jumbo eggs. Unlike other strains, in Hy-Line® W77, the whole egg solids content in larger eggs was higher than that of medium eggs.

Conclusion

The most clear and important trend from the statistical analysis of the data were the differences in yolk:white ratio by egg size and age of hens. Differences as large as 6 and 10% in yolk:white ratio were observed among egg sizes and age groups, respectively. Larger eggs always have lower yolk:white ratios than smaller eggs in all age

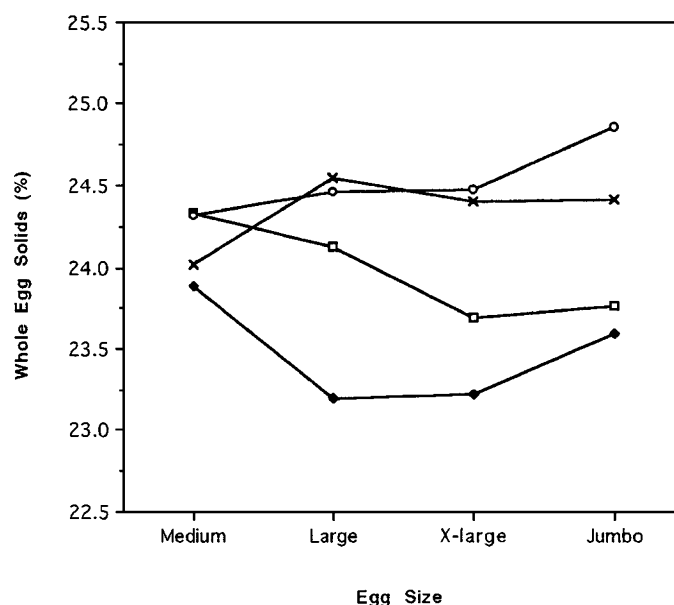


FIGURE 2. Effect of strain by size interaction on the content of whole egg solids (H&N, □; Delta, ◆; W36, ○; W77, ×).

groups. This finding suggests that the use of smaller eggs for whole liquid egg preparation and larger eggs for table egg use will be most beneficial for egg producers and processors. Also, considering the high yolk:white ratio in the eggs from 55- and 78-wk-old hens compared to those from 28- and 97-wk-old hens, eggs from young (28-wk-old) and forced-molted birds (97-wk-old) should be used as table eggs instead of liquid egg preparation for maximum profit. Although, the yolk:white ratio was not matched with the calculated whole egg solids in this study, yolk:white ratio would be the best indicator to predict solids content in whole egg. The trend of increased solids content of yolk as the size of egg increases, and the higher white solids in young birds (28-wk-old) compared with older birds also needs consideration in the final use of the egg.

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