

The cholesterol content of the yolks of chicken eggs can be controlled by adding certain chemicals to chicken feed. For health reasons, many people want to eat eggs with low-cholesterol yolks. A poultry scientist wishes to compare the effect of 8 chemical additives on yolk cholesterol. 160 chickens were randomly allocated to 8 treatments groups so that there was a different group of 20 chickens consuming each chemical additive. The mean cholesterol content of the eggs produced by each of the 160 chickens was recorded during the study. Are there significant differences among the 8 chemical additives? If so, describe the differences.

```
proc glm;
  class chemical;
  model cholesterol=chemical;
  means chemical / tukey cldiff alpha=0.05;
  lsmeans chemical / adjust=tukey pdiff cl alpha=0.05;
  means chemical / tukey lines alpha=0.05;
run;
```

The GLM Procedure

Dependent Variable: cholesterol

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	13122.78184	1874.68312	56.20	<.0001
Error	152	5070.00758	33.35531		
Corrected Total	159	18192.78942			

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	152
Error Mean Square	33.35531
Critical Value of Studentized Range	4.34676
Minimum Significant Difference	5.6135

Comparisons significant at the 0.05 level are indicated by \*\*\*.

chemical Comparison	Difference Between Means	Simultaneous 95% Confidence Limits
1 - 8	0.152	-5.461 5.766
1 - 6	5.834	0.221 11.448 ***
1 - 5	7.693	2.079 13.306 ***
1 - 4	10.808	5.195 16.422 ***
1 - 7	12.029	6.416 17.643 ***
1 - 2	22.896	17.283 28.510 ***
1 - 3	26.421	20.808 32.035 ***
8 - 1	-0.152	-5.766 5.461
8 - 6	5.682	0.069 11.295 ***
8 - 5	7.540	1.927 13.154 ***
8 - 4	10.656	5.042 16.269 ***
8 - 7	11.877	6.263 17.490 ***
8 - 2	22.744	17.131 28.358 ***
8 - 3	26.269	20.655 31.882 ***
6 - 1	-5.834	-11.448 -0.221 ***
6 - 8	-5.682	-11.295 -0.069 ***
6 - 5	1.858	-3.755 7.472
6 - 4	4.974	-0.640 10.587
6 - 7	6.195	0.581 11.808 ***
6 - 2	17.062	11.449 22.676 ***
6 - 3	20.587	14.973 26.200 ***
5 - 1	-7.693	-13.306 -2.079 ***
5 - 8	-7.540	-13.154 -1.927 ***
5 - 6	-1.858	-7.472 3.755
5 - 4	3.115	-2.498 8.729
5 - 7	4.336	-1.277 9.950
5 - 2	15.204	9.590 20.817 ***
5 - 3	18.728	13.115 24.342 ***
4 - 1	-10.808	-16.422 -5.195 ***
4 - 8	-10.656	-16.269 -5.042 ***
4 - 6	-4.974	-10.587 0.640
4 - 5	-3.115	-8.729 2.498
4 - 7	1.221	-4.392 6.834
4 - 2	12.088	6.475 17.702 ***
4 - 3	15.613	10.000 21.226 ***
7 - 1	-12.029	-17.643 -6.416 ***
7 - 8	-11.877	-17.490 -6.263 ***
7 - 6	-6.195	-11.808 -0.581 ***
7 - 5	-4.336	-9.950 1.277
7 - 4	-1.221	-6.834 4.392
7 - 2	10.867	5.254 16.481 ***
7 - 3	14.392	8.779 20.005 ***
2 - 1	-22.896	-28.510 -17.283 ***
2 - 8	-22.744	-28.358 -17.131 ***
2 - 6	-17.062	-22.676 -11.449 ***
2 - 5	-15.204	-20.817 -9.590 ***
2 - 4	-12.088	-17.702 -6.475 ***
2 - 7	-10.867	-16.481 -5.254 ***
2 - 3	3.525	-2.089 9.138

3	- 1	-26.421	-32.035	-20.808	***
3	- 8	-26.269	-31.882	-20.655	***
3	- 6	-20.587	-26.200	-14.973	***
3	- 5	-18.728	-24.342	-13.115	***
3	- 4	-15.613	-21.226	-10.000	***
3	- 7	-14.392	-20.005	-8.779	***
3	- 2	-3.525	-9.138	2.089	

Least Squares Means  
Adjustment for Multiple Comparisons: Tukey

chemical	cholesterol LSMEAN	LSMEAN Number
1	219.828050	1
2	196.931750	2
3	193.406950	3
4	209.019950	4
5	212.135450	5
6	213.993800	6
7	207.798950	7
8	219.675800	8

Least Squares Means for effect chemical  
Pr > |t| for H0: LSmean(i)=LSmean(j)

Dependent Variable: cholesterol

i/j	1	2	3	4	5	6	7	8
1		<.0001	<.0001	<.0001	0.0011	0.0354	<.0001	1.0000
2	<.0001		0.5327	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	0.5327		<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		0.6835	0.1236	0.9977	<.0001
5	0.0011	<.0001	<.0001	0.6835		0.9712	0.2616	0.0015
6	0.0354	<.0001	<.0001	0.1236	0.9712		0.0195	0.0450
7	<.0001	<.0001	<.0001	0.9977	0.2616	0.0195		<.0001
8	1.0000	<.0001	<.0001	<.0001	0.0015	0.0450	<.0001	

chemical	cholesterol LSMEAN	95% Confidence Limits	
1	219.828050	217.276599	222.379501
2	196.931750	194.380299	199.483201
3	193.406950	190.855499	195.958401
4	209.019950	206.468499	211.571401
5	212.135450	209.583999	214.686901
6	213.993800	211.442349	216.545251
7	207.798950	205.247499	210.350401
8	219.675800	217.124349	222.227251

Least Squares Means  
Adjustment for Multiple Comparisons: Tukey

Least Squares Means for Effect chemical

i	j	Difference Between Means	Simultaneous 95% Confidence Limits for LSMean(i)-LSMean(j)	
1	2	22.896300	17.282812	28.509788
1	3	26.421100	20.807612	32.034588
1	4	10.808100	5.194612	16.421588
1	5	7.692600	2.079112	13.306088
1	6	5.834250	0.220762	11.447738
1	7	12.029100	6.415612	17.642588
1	8	0.152250	-5.461238	5.765738
2	3	3.524800	-2.088688	9.138288
2	4	-12.088200	-17.701688	-6.474712
2	5	-15.203700	-20.817188	-9.590212
2	6	-17.062050	-22.675538	-11.448562
2	7	-10.867200	-16.480688	-5.253712
2	8	-22.744050	-28.357538	-17.130562
3	4	-15.613000	-21.226488	-9.999512
3	5	-18.728500	-24.341988	-13.115012
3	6	-20.586850	-26.200338	-14.973362
3	7	-14.392000	-20.005488	-8.778512
3	8	-26.268850	-31.882338	-20.655362
4	5	-3.115500	-8.728988	2.497988
4	6	-4.973850	-10.587338	0.639638
4	7	1.221000	-4.392488	6.834488
4	8	-10.655850	-16.269338	-5.042362
5	6	-1.858350	-7.471838	3.755138
5	7	4.336500	-1.276988	9.949988
5	8	-7.540350	-13.153838	-1.926862
6	7	6.194850	0.581362	11.808338
6	8	-5.682000	-11.295488	-0.068512
7	8	-11.876850	-17.490338	-6.263362

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher

Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	152
Error Mean Square	33.35531
Critical Value of Studentized Range	4.34676
Minimum Significant Difference	5.6135

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	chemical
A	219.828	20	1
A			
A	219.676	20	8
B	213.994	20	6
B			
C B	212.135	20	5
C B			
C B	209.020	20	4
C			
C	207.799	20	7
D	196.932	20	2
D			
D	193.407	20	3