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Wheat for Energy and Amino Acids in Layer Diets

C. W. CARLSON

Prior to the price support era beginning with the late 30's, there was considerable interest in the use of wheat for layer diets. For many years thereafter it wasn't feasible to use wheat. In recent years, the reduced cost of wheat as a feed grain has caused it to again become attractive for use in animal feeds. However the information at hand for laying hens on nutrient availability and utilization from wheat is either very old or found in just a few limited recent reports. This simplifies surveying the literature for such information, but leaves something to be desired as to obtaining confirmatory data for making reliable recommendations.

An early report from our laboratory by Poley & Wilson (1941) indicated that bushel test weight of wheat, corn or barley had little consistent influence upon their nutritional values for laying hens. The diets used were rather crude or deficient in some nutrients by today's standards—i.e. 79% grain, 10% meat and bone scraps, 5% buttermilk, 5% alfalfa meal, 1% salt and 0.5% fish oil concentrate. The latter was included only from Nov. 1 through April 1 of each year. The best performance of any group of hens was only 55.4% egg production on a hen-day basis with a diet using 60 lbs./ bushel test weight wheat. In 3 of 4 studies, the hens fed higher test weight wheat outperformed those on the lower test

C. W. Carlson is professor and leader of the Poultry Research and Extension Section in the Department of Animal Science, South Dakota State University, Brookings, South Dakota 57006.

Table 1. Effects of Leucine Supplements to a High Wheat Diet for Laying Hens.[1]

Exp.	Treatment	Egg Production	Feed/Doz. lbs.
		%	
1	High wheat[2]	60.9	5.0
	High wheat + 0.08% leucine[3]	64.2	4.6
2	High corn	51.5	5.5
	High wheat[2]	50.2	5.8
	High wheat + 0.08% leucine[3]	51.2	5.6
	Wheat and barley	45.9	6.3
	Wheat and barley + 0.08% leucine[3]	51.2	5.6
3	High wheat[2]	71.0	--
	High wheat + 0.3% leucine	74.0	--
4	High wheat[2]	68.8	4.2
	High wheat + 0.03% leucine	72.5	4.1

[1] From Anderson and Draper (1956).
[2] Contains in %, wheat 55.9, y. corn 14.5, barley 5, fish meal 2, meat and bone meal 3, 44% soybean meal 10, alfalfa meal 5, dried whey 2, bonemeal 1.5, limestone 0.5, salt 0.5 and vitamin and minerals supplements.
[3] From 3% corn gluten meal replacing soybean meal.

weight supplies, but for corn or barley there were no real differences. The diets were high in protein, from 18-23%, and when the high test weight wheat was used it lowered the protein levels of the diets because the wheat itself was lower in protein. This was probably a desirable effect and could perhaps explain the results obtained. Performances under these conditions were not greatly affected, whether corn, wheat or barley was used in the diet.

In a war-time report, Heuser (1943) showed that hens receiving diets containing wheat or wheat by-products and corn as the cereal component performed much better than those receiving a diet with only corn as the cereal component. The wheat diet was most palatable, hens on the corn diet did not eat as much feed, which probably influenced their performance. No differences were noted for mortality.

Amino Acids

A report by Anderson & Draper (1956) indicated a basically wheat diet to be slightly deficient in leucine. Data from this paper are given in Table 1. In every instance the leucine supplement elicited a response; the overall differences were statistically significant at the 5% level. The high wheat diet contained by calculations 1.26% leucine, whereas 1.35% had been indicated by Cravens (1948) to be the very minimum needed for maximum egg production. Increased levels of other amino acids in this high wheat diet perhaps may have accentuated the need for leucine. Further work which might substantiate this rather high requirement for leucine has been just recently conducted by Guenthner (1970) in our laboratory, see Table 2. In this work, hard spring wheat, corn, milo and

Table 2. Egg Production of Laying Hens as Affected by Dietary Cereal Component and Protein Level[1]

Grain[2]	Protein Level 12%[3]	15%[3]
Triticale	62	71
Wheat	65	79
Milo	68	79
Corn	79	80

[1] From Guenthner, Unpublished data, S.D.S.U., 1970.
[2] Diets were formulated to be adequate in all nutrients by N.R.C. standards except protein (see text). Essentially they were cereal-soybean meal diets supplemented with minerals and vitamins.
[3] Hen-day production of 3 hens in each of 16 cages and 4 hens in each of 12 cages per treatment over a 9-week period.

triticale were used as the basic energy source in formulating 12 and 15% protein diets. With the 15% protein levels there were no differences in hens' performances, but, with the 12% protein diets, performances of hens on the triticale and wheat diets were poorer than with corn or milo diets. In these 12% protein diets, all of the protein was derived from wheat or triticale whereas some soybean meal was used with milo and considerably more soybean meal was used with corn. Milo is in itself a good source of leucine, approximately twice that of wheat, and whereas soybean meal is also a good source, corn gluten meal could contain about three times as much or 10% leucine. By calculations, the low protein wheat or triticale diets only contained 0.7% leucine whereas the corn or milo diets contained 1.2% leucine. All diets had been supplemented with methionine, lysine and tryptophane to meet 125% of the requirements suggested by Johnson & Fisher (1958).

Wheat has long been the basic feed grain in northern North Dakota and the Canadian prairie provinces. March and Biely (1963) showed that the addition of lysine and methionine to a 14% protein diet containing 69% wheat elicited a marked increase in egg size. Glycine addition (0.255%) caused a sharp drop in egg sige that was not corrected by methionine (.25%) and lysine (0.25%) additions. The study was of such short duration that the egg numbers data were of limited value. However, they interpreted the glycine to have caused an amino acid imbalance, whereas the 14% protein wheat-soybean diet might have been slightly limiting, first in lysine and then in methionine.

Another report from Canadian workers showed that a 13.5% protein wheat-soybean ration was first limiting in lysine, see Table 3 (Sell and Hodgson, 1966). In two experiments, addition of methionine alone to a 13.5% protein diet was detrimental to the performance of laying hens, markedly reducing egg numbers. On the other hand, addition of lysine alone increased egg numbers in both studies and markedly increased egg size in the first study, which was of 308 days duration. In the second

Table 3. Lysine and Methionine Supplementation of a 13% Protein Wheat-Soybean Diet for Laying Hens.[1]

Treatment	H.-D. Egg Prod.	Feed/ Doz.	Egg Wt.	Consumption Protein	Meth.	Lys.
	%	Kg.	gm.	gm.	gm.	gm.
Exp. 1 (308 days)						
16.8% Protein[2]	78.2ab*	1.85	58.9a	20.2	.31	.76
13.5% Protein[3]	72.2bc	1.90	54.3b	15.4	.24	.52
13.5% Protein + Meth. (0.1%)	66.7c	1.93	55.5b	14.5	.34	.49
13.5% Protein + Lysine (0.1%)	77.4ab	1.85	57.7a	16.1	.25	.66
13.5% Protein + Meth. + Lys.	81.6a	1.80	59.2a	16.4	.38	.67
Exp. 2 (112 days—the study ran 196 days longer, but with higher protein wheat)						
Control (17.2% Protein)[4]	87.1a	1.48	55.7a	18.4	.28	.71
16.2% Protein[5]	83.4ab	1.50	55.6a	17.0	.28	.72
13.4% Protein[6]	80.2b	1.62	53.7ab	14.5	.24	.51
13.4% Protein + Meth. (0.1%)	73.7c	1.56	49.8d	12.9	.31	.45
13.4% Protein + Lysine (0.1%)	83.2ab	1.58	53.1bc	14.7	.24	.62
13.4% Protein + Meth. + Lys.	79.8b	1.55	51.5cd	13.8	.33	.59
Exp. 2 (cont.—196 days)						
Control (17.6% Protein)[4]	74.1a	1.75	58.6a	19.1	.29	.72
18.3% Protein[5]	72.6a	1.73	58.8a	19.1	.31	.78
16.4% Protein[6]	73.4a	1.80	56.8a	18.1	.29	.61
16.4% Protein + Meth.	63.9b	1.83	54.0b	16.0	.35	.53
16.4% Protein + Lysine	73.8a	1.79	56.5a	18.1	.29	.72
16.4% Protein + Meth. + Lys.	69.3ab	1.76	54.0b	16.6	.37	.66

[1] From Sell and Hodgson, 1966.
[2] Major ingredients included wheat 75.5%, 45% soybean meal 7%, meat meal 4%, alfalfa meal 2% and distiller solids 2% with mineral and vitamin supplements.
[3] Wheat 86.5% and soybean meal 4%.
[4] Wheat 71.5%, soybean meal 8%, meat meal 4%, alfalfa meal 2%, and distiller solids 2%.
[5] Wheat 70.5% and soybean meal 15.0%.
[6] Wheat 84.0% and soybean meal 4.5%.
*Numbrs not followed by the same superscript letter are significantly different at $P \leq 0.05$.

phase of the second experiment, lysine gave no response either in egg numbers or egg size, however methionine was again detrimental. This brings up a problem that we don't have the complete answer for at this time—i.e. should the higher protein content of certain supplies of wheat be considered and utilized? In the latter part of this second experiment, the "low protein" diet contained, by analysis, 16.4% protein, whereas the "low protein" diet contained 13.4% protein initially. This means that the wheat itself contained approximately 17 and 13.5% protein, respectively, for the two periods. In this study, the greater protein content supplied adequate lysine to meet the requirement. However, for younger birds one cannot depend on the greater amount of protein from a higher protein sample of grain to be well balanced in amino acids. To make a 20% protein diet using barley of 10.4 vs 15.9% protein or oats of 12.6 and 19.2% protein, we (Carlson, et al 1953) had to use widely differing amounts of soybean meal. The chicks grew fastest on the diets containing the low protein cereals; these diets contained the greatest quantities of soybean meal and by calulations supplied .94-.98% lysine. However, the diets with the high protein samples supplied only 0.71-

Table 4. Fish meal Supplementation of an all Wheat and Wheat-oats Diets for Layers.[1]

Grain	Fish meal	Egg Prod.	Egg Wt.	Body Gain	KCal/ Bird/ Day	Protein/ Bird/ Day	Mortality
	%	%	gm.	gm.		gm.	%
Wheat[2]	0[3]	58.5	57.8	54	404	20.3	18
Wheat	2	66.8	59.5	134	383	20.7	6
Wheat	5	70.5	60.6	173	372	22.5	8
Wheat-oats[4]	0	61.2	59.0	132	366	17.5	14
Wheat-oats	2	70.5	60.8	151	362	19.0	10
Wheat-oats	5	70.7	61.2	158	351	20.5	3

[1] From Table 4, Smith and Chancey, 1967.
[2] Containing, in percent, wheat 88, alfalfa meal 3, tallow 1.5, minerals 7 and vitamin supplements 0.5.
[3] Replacing a like amount of grain.
[4] As 2 above except oats replaced ½ of the wheat.

0.76% lysine. This, we concluded, accounted for the rather poor performance of chicks on these diets.

In the last part of the second layer study by Sell and Hodgson (1966), the lysine intake data show that the hens on the 16.4% protein diet were just barely receiving the lysine requirement. The hens were older too, so quite likely their lysine needs were met since Novacek and Carlson (1969) have shown that the need for lysine decreases with the age of the bird. Methionine supplementation of the 16.4% diet so upset the amino acid balance of the diet that the hens reduced feed intake and consequently were deficient in lysine, and probably leucine as well.

Smith and Chancey (1967) reported data to show that a largely wheat diet was not adequate for laying hens, see Table 4. Slightly better performance was noted when a wheat-oats diet was used, but both diets required supplements of fish meal to promote maximum egg size and egg numbers. Note that even though total protein intake was more than the theoretical requirement — i.e. 17.5 to 20 grams per hen per day — performance of the hens was subnormal. This is further substantial evidence that wheat protein alone is not completely balanced in amino acids, according to the needs of the laying hens, at least. Calculations indicate that lysine and leucine supplements should have been highly beneficial in this experiment. Calculations of the amino acid composition of the wheat vs. wheat-oats diets for lysine content, using the data in Table 5, shows that the diets contained 0.40 and 0.42% lysine, respectively. The 2% fish meal supplement would supply about 0.1% lysine which would have brought the lysine content up to the 0.5% level that Johnson and Fisher (1958) indicate is required. Similarly, the leucine content would have been about 0.6% in the all wheat and 0.7% in the wheat-oats diets. The 2% fish meal also would have supplied about 0.1% leucine which should have given a response. Note further from the data in Table 4 that

Table 5. Amino Acid Composition and Energy Content of Cereal Grains.[1]

	Midwest Barley %	No. 2 Corn %	Milo %	Midwest Oats %	Hard Wheat Spring %	Hard Wheat Winter %
Protein	11.5	8.7	11.0	12.0	14.0	13.0
Amino Acids						
Arginine	.53	.50	.36	.80	.70	.60
Cystine	.18	.18	.15	.22	.25	.22
Glycine	.36	.50	.40	.50	.70	.60
Histidine	.27	.20	.19	.20	.30	.26
Isoleucine	.53	.40	.46	.53	.70	.60
Leucine	.80	1.10	1.40	.90	.90	.80
Lysine	.53	.20	.20	.50	.45	.40
Methionine	.18	.18	.13	.18	.20	.17
Phenylalanine	.62	.50	.47	.60	.70	.60
Threonine	.36	.40	.36	.40	.42	.36
Tryptophane	.18	.10	.12	.16	.18	.10
Tryosine	.36	---	.70	.53	.60	.50
Valine	.62	.40	.53	.70	.60	.50
Metabolizable Energy						
kcal/lb.	1290	1560	1480	1190	1480	1480
kcal/kg.	2840	3430	3250	2620	3250	3250

[1] From Tables 9.6 and 9.7 Scott, *et al* 1969.

Table 6. Effect of Grain and Protein Level on Laying Hens.

Grain	Proportion of diet %	Protein Level[2] %	Egg Prod. %	Body Wt. Gain gm.	Feed Cons./Hen/Day gm.	Protein/Cons./Hen/Day gm.	Other Dietary Ingredients: Lard %	Other Dietary Ingredients: Cellulose %
Barley	70.0	10	40.5	41	106	10.6	2.0	12.5
	64.0	12.5	61.5	333	115	14.4	5.5	6.0
	58.0	15	63.3	525	108	16.2	9.0	.9
Oats	66.4	10	60.9	262	124	12.4	3.0	12.5
	62.9	12.5	67.7	459	116	14.5	6.3	6.3
	59.3	15	67.1	592	108	16.2	9.6	.0
Wheat	59.4	10	43.4	30	116	11.6	0.1	22.1
	65.5	12.5	65.3	379	121	15.1	0.8	11.5
	71.6	15	68.3	506	115	17.3	1.5	0.8
Corn	50.1	10	51.9	122	119	11.9	0.1	24.2
	57.2	12.5	66.3	310	118	14.7	0.1	12.8
	64.3	15	69.8	512	112	16.7	0.2	1.4

[1] From Lillie and Denton, 1968.
[2] Protein level attained by variations in the amount of soybean meal supplied. Cellulose and lard were used as indicated in the last columns to equilibrate the energy levels to 1388, 1618 and 1848 KCal of M. E./Kg. for the 10, 12.5 and 15% protein diets respectively, so the energy: protein rations were held somewhat in line.

wheat ranks above the other grains as a source of methionine, cystine, tryptophane and glycine. However, wheat would not supply the sulfur amino acid requirements of even the laying hen.

In a study repeated over a two-year period, Lillie and Denton (1968) reported that wheat and barley were inferior to corn and oats when used to formulate a 10% protein diet for laying hens, see Table 6. However,

with 12.5% or 15% protein diets, oats, wheat and corn were quite comparable, with barley being somewhat inferior. In this work, 15.1 gm. of protein/hen/day largely supplied by wheat was adequate for near maximum egg production. A level of about 16-17 gm. of protein from the oats, wheat or corn diets supported maximum performance. Regardless of protein level, the authors reported that for egg production the cereals ranked as follows: oats>corn>wheat>barley. However, on the 12.5 and 15.0% protein diets there were no real differences between the corn, oats and wheat diets. The large amount of lard used with the barley and oats diets probably accounted for their excellent performance with respect to feed requirements. Unfortunately no egg weight data were reported.

Table 7. Effect of Wheat, Corn or Wheat and Corn in Layer Rations.[1]

Treatment	Average of ten 28-day Periods: Egg Prod. %	Body Wt. Gain gm.	Egg Wt. gm.	Feed Doz. Egg Kg.
All Wheat	70.3	254	56.7	1.98
½ Corn, ½ Wheat	72.0	241	56.9	1.87
All Corn	70.9	259	57.8	1.87

[1] From Arscott, 1965.

Arscott (1965) reported that white Western No. 2 wheat could be used to replace all or half of the corn in a laying ration without adversely affecting egg production, see Table 7. No significant differences in numbers of eggs produced over ten—28 day periods were observed. Feed efficiency was reduced with the wheat diets, and from the data obtained he made the statement that wheat has 95% of the feeding value of corn for laying hens. The somewhat reduced egg size could have been due to the lower levels of linoleic acid supplied by the wheat, this will be discussed. Unfortunately data on protein or amino acid intakes were not included in this report. The diets were supplemented with protein from soybean and fish meals—in this case 13.75 and 3% respectively, irrespective of the grain source. The extra protein supplied by wheat was therefore disregarded.

Another report from our laboratory indicates that wheat contains a good balance of amino acids needed to supplement a 9.4% protein corn-soy-glucose diet for laying hens (Novacek, 1970). The data shown in Table 8 illustrate a marked response from 3% protein from wheat even though the lysine, tryptophane and sulfur amino acid requirements had been supplied. Corn, barley, soybean meal and milo supplied a similar improved balance of amino acids, but to a slightly lesser extent, perhaps. Note that a rate of nearly 70% production was obtained with 12.6 gm. of protein per day over a 10-month period. This calculates to be a protein

Table 8. Effect of 3% Protein from Various Sources in Supplementing a 9.4% Protein Layer Diet.[1]

Treatment	Egg Prod.	Body Wt.	Egg Wt.	Death Loss	Cons./Hen-Day Feed	Protein	Lys.	Meth. & Cys.
	%	kg.	gm.	%	gm.	gm.	mg.	mg.
Basal[2]	58.1	1.7	59.1	10	107	10.0	667	534
Yellow Corn[3]	65.0**	1.8	59.6	13	103	12.8	647	517
Milo[3]	62.9*	1.9	58.3	11	104	13.0	652	522
Hard Spring Wheat[3]	67.8**	1.9	58.6	8	102	12.6	636	508
Barley[3]	65.5**	1.8	58.3	13	100*	12.3	622	496
Oats[3]	59.2	1.8	59.6	9	92**	11.3	573	458
Soybean Meal[3]	65.1**	1.9	59.5	9	104	12.9	651	520

[1] From Novacek, 1970. (Ph.D. Thesis).
[2] Basal diet contained in percent yellow corn 41.8, 50% soybean meal 11.2, glucose 34, yellow grease 5 and mineral and vitamin supplements with added methionine to supply 0.30%, tryptophane to supply 0.15% and lysine to supply 0.63%, respectively.
[3] Used to supply 3% protein equivalents, replacing glucose.
*, ** denotes significance at the 0.05 and 0.01 level, respectively.

Table 9. Fatty acid composition of cereal grains.[1]

	Barley %	Corn %	Milo %	Oats %	Wheat %
Total Lipids (L)	1.9	3.9	2.9	4.6	2.2
Fatty Acids, % of L.					
14:0	0.5	0.1	0.1	0.1	0.1
16:0	27.6	16.3	20.0	18.9	25.2
16:1	---	---	5.2	1.3	0.3
18:0	1.5	2.7	1.0	1.1	1.7
18:1	20.5	30.9	31.7	39.5	24.7
18:2	43.3	47.9	40.2	34.1	39.2
18:3	4.3	2.3	2.0	1.9	5.9
L x 18:2	0.78	1.77	1.11	1.49	0.82

[1] From Table 4, Edwards, 1967.

efficiency in excess of 40% whereas on conventional diets 25% efficiency is the typical figure for protein utilization. Further work is under way to elucidate which of the amino acids were essential to obtain these responses.

Energy

A factor in the Smith and Chancey (1967) study and in the Arscott (1965) study that may have accounted in part for the egg size deficiency is the smaller amount of linoleic acid supplied by wheat vs. oats or corn. According to the data of Edwards (1964) for fatty acid composition of cereal grains, see Table 9, wheat doesn't look too poor, except that total lipid content is only 2.2% compared to 4.6 or 3.9% for oats and corn, respectively. On this basis, the wheat-oats diet used by Smith and Chancey (1967) supplied 1.02% linoleic acid, whereas the all-wheat diet contained 0.72% linoleic acid. Similarly, the wheat vs. corn diets of Arscott would

have contained about 0.7% and 1.4% linoleic acid, respectively. Edwards (1966) has further indicated that the linoleic acid requirement for maximum egg size is over 1.25%, so that this could well account for the smaller egg sizes noted for all-wheat diets. We have noted similar effects of smaller egg sizes with largely milo diets, and this also could be due to a linoleic acid deficiency.

Replacing one-half the wheat with oats would also have decreased the energy content of the diets used by Smith and Chauncey (1967) by about 10% or 277 Kcal/Kg. of diet. They noted no differences in food intake, however total food consumption for all groups was quite high. The 351 Kcal per day was excessive, perhaps even for the cool conditions of Newfoundland. With regards to total energy content, wheat ranks fairly high — equal to milo and about 200 Kcal below good No. 2 corn — see Table 5. Arscott's data (1965) for feed efficiency corresponded closely to the differences in energy content of wheat and corn.

Table 10. Composition of Samples of Western Canadian Grains.[1]

Grain	Bu. Wt. lbs.	Energy KCal ME/Kg	Protein %	Crude Fiber %	Ether Ext. %	Ash %
Wheat	57	3390	17.8	3 8	2.6	1.8
Wheat	61	3190	17.7	3.2	2.5	1.7
Wheat	65	3260	16.8	3.1	2.6	1.6
Barley	46	2530	15.1	6.6	2.6	2.4
Barley	50	2360	12.7	6.7	2.5	2.5
Barley	55	2710	14.0	4.8	2.4	2.2
Oats	39	2820	12.0	10.7	6.9	3.0
Oats	42	3120	12.9	12.3	5.5	3.4
Oats	46	3300	12.7	12.2	5.6	3.4
Rye	--	2550	11.8	2.9	2.0	1.6

[1] Taken from Table 1, Sibbald & Slinger, 1963.

Examination of the data in Table 10 for several Canadian samples of grain shows that the variation in energy content is not correlated with bushel weight or protein content, whereas there may be a positive relationship for the other grains, at least oats. Nonetheless, wheat is a good energy source and fits in very well with our modern concern for higher energy feeds. Note also, however, the relatively low lipid content of wheat, barley and rye samples compared to that of oats. When wheat is used as the major source of energy in the laying hen diet, it would be desirable to include some good source of linoleic acid. Tallows that contain only 1-2% linoleic acid would not be very valuable for this purpose, but yellow grease which contains 12-15% linoleic acid could be quite useful. About 3-4% stabilized yellow grease would be recommended with a largely wheat diet to supply the additional linoleic acid requirements, at least for the early part of the hen's laying cycle. Sometime after large egg size had been attained, it would seem possible that the linoleic acid content could be lowered. However, further work should be conducted on this point, i.e. would egg numbers be cut down with a reduced intake of linoleic acid? Jensen and Shutze (1963) showed that egg numbers were not adversely affected by a linoleic acid deficiency, only egg size was reduced. However they were working with hens that only averaged 45% production in either case. Conceivably a low linoleic acid diet as obtained with wheat could be desirable in reducing excessive egg size in later stages of the production cycle.

Summary

There is no doubt but that considerable improvement in protein utilization for production of meat, milk and eggs are going to be essential if we are to see animal protein continue to be produced for human consumption. Wheat can make a great contribution towards meeting the energy and amino acid needs of laying hens when properly used. On the caution side however are the data which have been discussed to show that wheat protein in itself is deficient in the sulfur amino acids, methionine and cystine and in lysine and leucine, and the data indicating wheat to be inadequate in linoleic acid for laying hens. These shortcomings can be overcome with the proper use of supplements or mixtures of feed grains or by feeding excess protein. Wheat ranks high as a source of glycine, tryptophane and metabolizable energy. For energy purposes, *per se,* wheat has about 95% of the feeding value of corn and is equal to the energy value of milo for laying hens. Wheat can be satisfactorily used in layer diets in place of corn or other grains to supply the major energy requirements, however the extra protein should be largely disregarded, and a good source of linoleic acid should be included in the diet.

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