63. Shepard, J. H. and W. B. Richard. 1906. Fattening steers on barley and rejected wheat. North Dakota Agr. Expt. Sta. Bul. 73.
64. Singleton, H. P., M. E. Ensminger and W. W. Heinemann. 1945. Dried molasses for fattening cattle. Washington Agr. Expt. Sta. Bul. 469.
65. Skinner, J. H. and F. G. King. 1935. Cattle feeding-winter steer feeding, 1931-32. Indiana Agr. Expt. Sta. Bul. 396.
66. Taylor, B. R. and W. L. Blizzard. 1943. Ground wheat versus ground shelled corn for fattening beef calves. Oklahoma Agr. Expt. Sta. Mimeo. Rpt. of 17th Annual Livestock Feeders Day.
67. Taylor, B. R. and A. E. Darlow. 1944. Substituting ground wheat for all the corn and part of the protein supplement in fattening steer calves. Oklahoma Agr. Expt. Sta. Mimeo. Rpt. of 18th Annual Livestock Feeders Day.
68. Thalman, R. R. 1944. Corn and alfalfa substitutes for fattening cattle. Nebraska Agr. Expt. Sta. Bul. 355.
69. Totusek, R., L. Franks, J. R. Newsom and E. C. Nelson. 1968. Milo versus wheat for fattening cattle. Oklahoma Agr. Expt. Sta. MP 80.
70. Trowbridge, E. A. and H. C. Moffett. 1933. Wheat as a cattle feed. Missouri Agr. Expt. Sta. Bul. 325.
71. Vinke, L. and P. Pearson. 1931. Alfalfa hay and small grains for fattening yearling steers. Montana Agr. Expt. Sta. Bul. 251.
72. Weber, A. D. and W. E. Connell. 1932. Wheat as a fattening feed for cattle. Kansas Agr. Expt. Sta. Bul. 26.
73. Weber, A. D. and W. J. Loeffel. 1931. Wheat for fattening lambs. Nebraska Agr. Expt. Sta. Bul. 257.
74. Whitehorn, C. D. 1931. The possibility of substituting wheat for corn in fattening beef cattle. Oklahoma A and M College Master's Thesis.
75. Woods, W. and L. Varner. 1970. Influence of wheat upon in vitro and in vivo lactic acid levels (Abr) J. Animal Sci. (in press).

Comparative Net Energy Values of Rations Containing Wheat and Other Grains for Beef Cattle

G. P. Lofgreen

Introduction

Historically wheat has not been used extensively as a feed for beef cattle in comparison to other grains such as corn, barley, and sorghum grains. This is partially responsible for the almost complete lack of information on the net energy (NE) value of wheat. Morrison (1956) lists an estimated net energy for maintenance plus production (NEm+p) of 80 megcal. per 100 lb. The comparable values for corn (dent. No. 2), barley and milo are 80.1, 70.5, and 77.8. Morrison states that in the hands of an experienced feeder wheat may be fully equal to corn in value although no direct NE comparisons are reported. Brethour (1966) presents an excellent review of results of trials in which wheat has been compared to other grains for beef cattle. He has calculated the amount of grain replaced by one pound of wheat by converting other feeds to a grain equivalent. Although these replacement values will vary depending on the factors used to convert non-grain ingredients to the grain equivalent, his comparisons are of interest. In these tests one pound of wheat replaced the equivalent of 1.10 pounds of barley, 1.09 pounds of corn, 1.06 pounds of rye, and 1.15 pounds of sorghum grain. With wheat as 100 the other grains would, therefore, have relative values of 91, 92, 94, and 87 for barley, corn, rye, and sorghum grain, respectively. Although NE was not determined in any of these trials, the comparisons certainly demonstate wheat is a very good energy source for beef cattle.

G. P. Lofgreen is a nutritionist with the Department of Animal Science, University of California Imperial Valley Field Station, El Centro, California 92243.

Net Energy Trials

Garrett, *et al* (1968), determined the NE for maintenance (NEm) and NE for weight gain (NEg) of rations containing 64% or 84% of barley, corn, milo, or wheat. All grains were steam processed in the same manner. Although the trials were not designed to determine NE values of the grains, the NE values of the entire rations should be indicative of the value of the grains since all other ingredients were constant. The results of this study are shown in Table 1. At both grain levels the NE values are highest for corn followed by wheat, milo, and barley although in the 84% grain rations milo and barley appeared to be of approximately equal value. It is of interest to note that for maintenance wheat rations were only slightly lower than those containing corn while for gain the rations containing wheat had 94% the energy of the corn rations but approximately 7% and 8% more energy than rations containing milo or barley.

Table 1. Net Energy Value of Rations Containing Barley, Corn, Milo, or Wheat as the Only Grain.

Level of grain	Energy measure	Grain			
		Barley	Corn	Milo	Wheat
%			(megcal. per 100 lb. of DM)		
64	NEm	76	84	79	82
	NEg	54	63	57	60
84	NEm	85	92	86	90
	NEg	65	74	65	69
Means	NEm	81	88	83	86
	NEg	60	69	61	65

At the Imperial Valley Field Station of the University of California three trials have recently been conducted in which the NEm and NEg of wheat has been determined alone and in combination with other grains.

Trial 1: A study was made of Sonora 64 wheat fed alone and in combination with California Mariout barley. The four experimental rations are shown in Table 2. The whole wheat weighed 64 pounds per bushel and the barley 51 pounds.

After steaming for approximately 15 minutes and rolling, the bushel weights were 29 and 22 pounds for wheat and barley respectively, a 55% reduction in weight per unit volume for wheat and 57% reduction for the barley. All cattle were fed for 154 days.

Table 3 presents some of the performance data from this study. It is apparent that the cattle did well on all rations. The cattle fed wheat

Table 2. Composition of Rations.[1]

Ingredient	All wheat	2/3 wheat 1/3 barley	1/3 wheat 2/3 barley	All barley
	%	%	%	%
Alfalfa hay	5.0	5.0	5.0	5.0
Sudan hay	5.0	5.0	5.0	5.0
Rolled barley	0	23.0	46.0	69.0
Rolled wheat	69.0	46.0	23.0	0
Beet pulp	10.0	10.0	10.0	10.0
Urea	1.0	1.0	1.0	1.0
Fat	3.0	3.0	3.0	3.0
Molasses	7.0	7.0	7.0	7.0
Totals	100.0	100.0	100.0	100.0

[1] One pound of limestone and 100,000 IU of vitamin A were added to each 100 pounds of the above rations.

Table 3. Performance of Cattle Fed Wheat and Barley Rations.

Item	All wheat	2/3 wheat 1/3 barley	1/3 wheat 2/3 barley	All barley
Number of steers	16.	16.	16.	16.
Initial weight, lb.	557.	561.	540.	548.
Daily feed intake, lb.	18.05b	18.90c	18.22b	17.56a
Daily weight gain, lb.	3.11	3.20	3.22	3.03
Feed per pound gain, lb.	5.80	5.91	5.66	5.80
Yield, %	60.4	61.0	60.0	61.7
Carcass grade scores:				
Quality grade[1]	8.2	8.4	8.3	8.2
Cutability grade[2]	2.4	2.3	2.3	2.5

[1] 8 = low choice, 9 = choice
[2] Grade 1-5, with 1 being the highest cutability.
a, b, c means having different superscripts are significantly different ($P<0.05$).

as the entire grain consumed more feed than those fed barley and gained slightly more and thus the conversion was the same. There appears to be a somewhat larger feed intake with a resultant increased gain on the two mixed grain rations compared with the two pure grains. When such a comparison is made, the results shown in Table 4 are obtained. Although there was significant increase in feed consumption and weight gain obtained by mixing the grains, the feed conversion was not significantly influenced. The data from this study indicate that wheat can be

Table 4. Comparison of Pure and Mixed Grains.

Item	Pure	Mixed
Number of steers	32.	32.
Initial weight, lb.	553.	556.
Daily feed intake, lb.	17.81a	18.56b
Daily weight gain, lb.	3.07a	3.21b
Feed per pound gain, lb.	5.80	5.78
Yield, %	61.1	60.5
Carcass grade scores:		
Quality grade	8.2	8.4
Cutability grade	2.5	2.3

fed satisfactorily as the only grain in a high energy ration or that a mixture of barley and wheat will also yield satisfactory results and may stimulate a somewhat higher rate of gain but with no benefit on feed conversion.

The NE values of the 4 rations are shown in Table 5. The values determined in this study from the data on energy deposition are compared to predicted values of the ration calculated from the NEm and NEg values of the ration ingredients published by Lofgreen and Garrett (1968a). The differences between determined and predicted values and the differences among rations are all well within experimental error and show no differences among rations or between the determined and predicted values. The NEm and NEg values for wheat and barley of Lofgreen and Garrett (1968) are 90 and 59 for wheat and 87 and 58 for barley. Since there was essentially no difference between the determined and predicted values of the entire rations, these data furnish no evidence that the values for wheat and barley are different than the values quoted above. The data, however, also gives no evidence that the NE values of wheat and barley are different since there were no real differences among rations. The results of this trial differ somewhat from those of Garrett *et al* (1968) in which wheat had somewhat higher energy values than those obtained for barley. It is important to note, however, that the barley used in this study was high quality. The bushel weight was 51 pounds and the crude protein was 12.4% for the barley and 12.5% for the wheat.

Table 5. Net Energy of the Rations.

		All wheat	2/3 wheat 1/3 barley	1/3 wheat 2/3 barley	All barley
			(megcal. per 100 pounds)		
NEm	Determined	83	83	82	84
	Predicted	85	84	83	83
NEg	Determined	55	56	55	56
	Predicted	55	54	54	54

Trial 2: The design of this trial was similar to trial 1 but involved a comparison of Sonora 64 wheat with a red Texas milo of unknown variety. The wheat in this study again weighed 64 pounds per bushel while the milo weighed 60 pounds. The wheat was steamed approximately 15 minutes prior to rolling and the milo approximately 20 minutes. The weights following rolling were 30 and 28 pounds per bushel for the wheat and milo respectively. The crude protein content of the wheat was 12.3% and the milo 10.4% on an air dry basis. Because of this difference in protein content, the nitrogen content of the rations was equalized by increasing the urea content of the ration as the milo content increased. The composition of the rations is shown in Table 6.

The determined crude protein content of the four rations was 10.6, 11.2, 11.3, and 11.1 for the all wheat, ⅔ wheat, ⅓ wheat, and all milo rations, respectively.

Table 6. Composition of Rations for Trial 2.

Ingredient	All wheat No milo	2/3 wheat 1/3 milo	1/3 wheat 2/3 milo	All milo
		(percent composition)		
Alfalfa hay	5.00	5.00	5.00	5.00
Sudan hay	5.00	5.00	5.00	5.00
Rolled wheat	67.67	45.04	22.46	0
Rolled milo	0.	22.50	44.93	67.27
Beet pulp	10.00	10.00	10.00	10.00
Urea	0.49	0.63	0.77	0.89
Fat	3.00	3.00	3.00	3.00
Molasses	7.00	7.00	7.00	7.00
Minerals	1.84	1.84	1.84	1.84
Vitamin A		1000 IU per lb. of ration		

All cattle were fed for a period of 28 days on an intermediate energy ration containing 45% roughage prior to starting on the four experimental rations which were fed for 196 days.

The performance data are shown in Table 7.

Table 7. Performance Date for Trial 2.

Item	All wheat No milo	2/3 wheat 1/3 milo	1/3 wheat 2/3 milo	No wheat All milo
Number of steers	15.	15.	15.	15.
Initial weight, lb.	392.	396.	401.	392.
Daily feed consumed, lb.	15.61a	15.83a	16.64b	16.54b
Daily weight gain, lb.	2.84	2.85	2.91	2.82
Feed per pound gain, lb.	5.50a	5.55a	5.72ab	5.87b
Yield, %	60.4	60.2	62.2	61.1
Carcass grades:				
Quality grade[1]	8.5	8.6	9.1	8.9
Cutability grade[2]	2.9	2.9	3.3	2.8

a, b means having different superscripts are significantly different ($P<0.05$).
[1] Low choice = 8, choice = 9, top choice = 10.
[2] Graded 1-5, with 1 being the highest cutability.

It is apparent that the cattle fed rations in which the grain was either all wheat or ⅔ wheat ate significantly less feed than those fed the higher levels of milo. It is a commonly observed fact that when the energy concentration of a ration increases feed consumption tends to decrease. This is because within the zone of thermal neutrality animals eat to satisfy their energy needs. Thus, if palatability is no problem, as energy concentration increases, feed consumption decreases. From this observation one would conclude that the high wheat rations had a higher energy content than the high milo rations, or that the feed consumption was reduced because of a reduced acceptability of the rations. The feed conversion adds evidence that increasing the wheat concentration

increased the energy since the feed conversion was improved with each increase in wheat.

Although the yields tended to be somewhat lower on the two high wheat rations, these differences were not statistically significant. There were no significant differences among either the quality grades or the cutability grades.

From data developed at the California station it is possible to determine the NE of the rations from the daily gains, mean body weight, and feed consumption. This procedure differs somewhat from that used in previously published trials and is illustrated in the following example:

	All wheat ration	All milo rations
Daily feed intake, lb.	15.61	16.54
Daily weight gain, lb.	2.84	2.82
Mean body weight, lb.	710.	708.
Daily NEm intake, megcal.[1]	5.91	5.90
Daily NEg deposited, megcal.[2]	5.66	5.61
NE per 100 lb. of feed, megcal.		
NEm	37.86	35.67
NEg	36.26	33.92

Calculations

1. 100 lb. of wheat ration = 100 lb. of milo ration + 2.19 megcal. NEm and + 2.34 megcal. NEg.
2. Since the only variable in the rations is the source of grain, all differences can be attributed to the approximately 67.5% grain in the ration.
3. Thus, 67.5 lb. of wheat = 67.5 lb. of milo + 2.19 megcal. NEm and + 2.34 megcal. NEg.
4. Therefore, 100 lb. of wheat = 100 lb. of milo + 3.24 megcal. NEm and + 3.47 megcal. NEg.
5. Previously determined values of NEm and NEg for milo are 87 and 58 megcal. /100 lb.
6. Therefore, 100 lb. of wheat = 87 + 3.24 megcal. NEm and 58 + 3.47 megcal. NEg or approximately 90 and 61 megcal. per 100 lb. for NEm and NEg respectively.

[1] $NEm = 0.043\ W_{lb.}^{0.75}$

[2] NEg = 2.0385g + 0.006061 W lb. − 4.4288.
(Determined by Garrett and Lofgreen from the relationship of NEg deposited, daily weight gain, and body weight from the data on 1742 steers.)

Using this procedure, the NE values shown in Table 7 were determined.

Table 8. Net Energy Content of the Grains Used in Trial 2.

Grain	NEm	NEg
	(megcal./100 lb.)	
All wheat	90	61
2/3 wheat, 1/3 milo	90	61
1/3 wheat, 2/3 milo	88	60
All milo (standard)	87	58

Thus, in this trial wheat had a NEm approximately 3% greater than

milo and a NEg approximately 5% greater. These findings agree well with those reported by Garrett *et al* (1968) in which wheat had an average NEm approximately 4% higher than milo and NEg approximately 7% higher. The addition of milo did not depress the NE values at the 1/3 level but did at the 2/3 milo level.

Trial 3: Since the results of Garrett *et al* (1968) suggested that steam processing may not be beneficial to the energy value of wheat, a trial was conducted to compare a ground wheat with steam rolled wheat. Milo was again used as a standard but rolled to two degrees of flatness after steaming for 30 minutes. The wheat was ground in a hammer mill through a 3/8" screen and the steam rolled wheat was steamed approximately 15 minutes and rolled to a flake weighing an average of 28 pounds per bushel. The weight of the whole grain was 64 pounds per bushel. The whole milo weighed 60 pounds per bushel and was rolled to either 36 or 28 pounds per bushel after 30 minutes of steaming. The rations contained 7.0% alfalfa hay, 3.0% sudan hay, 58.33% wheat or milo, 5.5% hominy feed, 6.67% cottonseed meal, 8.0% wheat mill run, 3.0% fat, 7.0% molasses, and 1.5% minerals. The test ran for 168 days. The performance data are shown in Table 9.

Table 9. Performance of Cattle in Trial 3.

Item	Wheat		Milo	
	Ground	Steam rolled	36 lb. per bu.	28 lb. per bu.
Number of steers	12.	12.	12.	12.
Initial weight, lb.	612.	637.	646.	595.
Daily feed consumed, lb.	17.51a	17.60a	18.68b	17.22a
Daily weight gain, lb.	2.94	2.88	2.88	2.96
Feed per pound gain, lb.	5.95a	6.10a	6.48b	5.82a
Yield, %	61.4	61.0	60.4	60.4
Carcass grade scores:				
Quality grade[1]	8.6	8.1	8.0	8.1
Cutability grade[2]	2.4	2.6	2.8	2.7
Marbling grade[3]	6.3	5.9	6.3	6.3

[1] 8 = low choice, 9 = choice.
[2] Cutability is scored 1 through 5 with 1 being the highest.
[3] 5 = small minus, 6 = small, 7 = small plus.

These results confirm the suggestion of Garrett *et al* (1968) that steaming may not improve the value of wheat since the gains and feed conversion on the steam rolled wheat were not significantly different from those observed on the ground wheat.

There were no significant differences among the daily gains of any of the four treatments. The cattle on the milo rolled only to a 36 pound per bushel product ate significantly more feed which resulted in a lowered efficiency on this treatment. One would conclude that the wheat fed

in this study was approximately equal to well processed milo and superior to milo not adequately processed.

It is possible to determine the net energy of the grains using the previously described procedure. In this case the 28 pound milo was used as the standard and assigned the previously determined NEm and NEg values of 87 and 58 megcal. per 100 lb., respectively. Using this procedure the following values were obtained:

	NEm	NEg
	Megcal. per 100 lb.	
Ground wheat	87	57
Steam rolled wheat	88	57
36 lb. rolled milo	84	54
28 lb. rolled milo	87	58

These values confirm the earlier conclusion that the NE of the wheat was equal to properly processed milo and superior to the milo not adequately rolled. They also confirm the lack of influence of 15 minutes of steaming and rolling on the utilization of wheat.

Another means of comparing the energy values of the grains fed in the trials discussed is to calculate the expected rate of gain based on the feed consumption, mean body weight, and previously published energy values. This procedure has been described by Lofgreen and Garrett (1968). The previously published energy values for the grains in question are

	NEm	NEg
	Megcal. per 100 lb.	
Wheat	90	59
Barley	87	58
Milo	87	58
Corn	92	60

Table 10 presents a comparison of the expected and observed gains for all four trials discussed in this paper. The observed gains obtained on the wheat rations ranged from 97 to 103% of the expected gains with the average of all rations containing wheat as the only grain being 100%. This means the NEm and NEg values of 90 and 59 megcal. per 100 pounds accurately expresses the NE value of wheat. The comparison of the expected and observed gains achieved on the milo rations indicates that rolling to a final weight of 36 pounds per bushel did not permit optimum energy utilization. Rolling to 28 pounds per bushel allowed the milo ration to be utilized at the expected rate. If the 36 pounds per bushel milo is eliminated from the comparison, the mean observed gain on the other three all milo rations is 100% of the expected. This indi-

Table 10. Comparison of expected and Observed Rate of Gain.

Trial	Daily empty weight gain		
	Expected	Observed	Observed as % of expected
	lb.	lb.	%
Garrett *et al* (1968)			
Wheat	2.28	2.25	99
Barley	2.26	2.18	96
Milo	2.33	2.40	103
Corn	2.24	2.47	110
Trial 1			
All wheat	2.86	2.78	97
2/3 wheat, 1/3 barley	2.97	2.90	98
1/3 wheat, 2/3 barley	2.90	2.89	100
All barley	2.70	2.86	106
Trial 2			
All wheat	2.52	2.49	99
2/3 wheat, 1/3 milo	2.48	2.53	102
1/3 wheat, 2/3 milo	2.56	2.65	104
All milo	2.65	2.51	95
Trial 3			
Ground wheat	2.54	2.62	103
Steam rolled wheat	2.46	2.49	101
Steam rolled milo:			
36 lb. per bu.	2.69	2.48	92
28 lb. per bu.	2.48	2.51	101

cates that the NEm and NEg values of 87 and 58 megcal. per 100 pounds accurately predict the performance of properly processed milo. For the two rations containing barley as the only grain, the observed gain was 96% of the expected in one comparison and 106% in the other. The ration containing ⅔ barley and ⅓ wheat produced the expected rate of gain. These studies, therefore, give no evidence that the NEm and NEg values of barley are different than those used. In the one trial involving corn the observed gain was 110% of the expected. If repeated trials result in the same finding, the NE values for corn will need to be revised upward.

Summary

In the four tests discussed in which NE values were determined either for the complete ration or the grain portion of the ration, wheat was slightly superior to milo in the test of Garrett *et al* (1968) and in one of the Imperial Valley Field Station tests and equal to well processed milo in the second Imperial Valley Field Station test. Compared to barley wheat was slightly superior in the test of Garrett *et al* and equal to barley in the Imperial Valley Field Station test. In the one comparison involving corn and wheat the wheat had slightly lower NE values. On the basis of these studies there appears to be no valid reason for modify-

ing the NE values for beef cattle published by Lofgreen and Garrett (1968a) which give wheat a NEm value approximately 3% higher than barley or milo but 2% lower than corn, and a NEg value 2% higher than barley or milo and 2% lower than corn.

Literature Cited

Brethour, J. R. 1966. *Feeding Wheat to Cattle.* Kan. Agr. Expt. Sta. Bul. 487.

Garrett, W. N., G. P. Lofgreen and J. L. Hull. 1968. Factors Affecting the Utilization of Corn, Milo, Barley, and Wheat in Rations for Beef Cattle. Report of Investigations Under Contract USDA 12-14-100-7753 (44).

Lofgreen, G. P. and W. N. Garrett. 1968. A System for Expressing Net Energy Requirements and Feed Values for Growing and Finishing Beef Cattle. Jour. An. Sci. 27: 793.

Lofgreen, G. P. and W. N. Garrett. 1968a. *Net Energy Tables for Use in Feeding Beef Cattle.* Department of Animal Science, University of California, Davis.

Morrison, F. B. 1956. *Feeds and Feeding.* 22nd ed. The Morrison Publishing Company, Ithaca, New York.