

## ENERGY EFFICIENCY OF GRAIN PROCESSING SYSTEMS

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Efficient energy utilization has become a major concern in our country today. This is reflected in decisions made in the private sector to reduce overall energy use and to find more energy efficient methods to do the same tasks. Governmental regulations also dictate energy conservation. Because agricultural producers are one of the most efficient in the world, agricultural operations should be most concerned about energy utilization. This concern is a result of desire to preserve our natural energy resources and to increase the efficiency and, therefore, the profitability of agricultural enterprises. One agricultural practice, the feeding of grain to cattle, has been criticized for the energy inefficiency of feeding grain to livestock in order to convert grain to human food. This argument has not always considered that many of the feedstuffs fed to livestock are inedible and, thus, unsuitable for human food. However, corn and other grains are being fed to livestock to produce finished cattle. A substantial amount of piecemeal work has been done on this topic. Studies have been conducted to measure and compare the energy efficiency of various grains. Other research has determined those processing methods which improve energy availability to the animal. This research has led to the development of equipment, such as the steam flaker, which is routinely used in most feedyards in the large cattle feeding areas of this country. This machine requires fairly sizeable amounts of electricity to run the rollers as well as natural gas or propane to fire the boilers to generate steam for grain treatment. This is a high energy consuming operation and, thus, must be evaluated in light of present day priorities for energy use. Another common agricultural practice is the use of irrigation water pumped from deep wells with natural gas or electric motors to produce grain which could not ordinarily be grown in the more arid areas of the United States. With readily available and cheap energy, this was a very profitable and worthwhile production method. Today, however, this practice must be evaluated in terms of energy return on energy investment as well consideration of alternate grains which could be produced using less water and thereby be more energy efficient. Therefore, it is imperative that researchers find those methods of raising, storing and processing grains which will provide the greatest amount of available energy to the animal, and thus to the consumer, for the least amount of energy expenditure in the total system.

### Procedure

In the summer of 1978, two fields, one planted with a single variety of milo and the other planted with one variety of corn, were secured for use in this project. Each field contained approximately 50 acres. When the moisture level of the grain was considered optimum for high moisture harvesting, 25 acres in each field were harvested, and the grain treated with an organic acid combination and stored in piles for approximately 6 months with no roof or cover. Corn harvest began when the corn grain reached 28.5% moisture, whereas milo harvest began at 24.0% moisture. Milo had to be harvested at a lower moisture in order for the grain to thresh out of the heads. The harvesting of each high moisture grain took approximately 8 hours. The remaining 25 acres of each grain

were harvested when the moisture level in the grain reached field dry or elevator storable moisture (15%). The grain from each harvesting method was weighed as it was removed from the field so that field losses could be calculated. The grains harvested under field dry conditions were stored in separate bins for approximately 6 months at a local elevator with the normal storage rate applied to each grain. Grain prices were \$3.77 for 100 lbs. of field dry milo and \$4.00 for 100 lbs. of field dry corn. The high moisture grains were purchased on a field dry weight equivalent basis. At the end of approximately 6 months storage, the finishing trial was begun.

Two hundred and ten Hereford x Angus steers were purchased and shipped to Texas Tech University Center, Pantex, Texas. Cattle were weighed, individually identified, given routine feedlot vaccinations, poured with a grubicide, wormed with an injectable wormer, and then given two weeks to adapt to their new surroundings and recover from shipping stress. The steers were stratified by weight and randomly allotted to 42 pens of 5 steers each. Five pens were placed on each treatment. Two pens of 5 steers each were designated the initial kill group and were slaughtered on day 1 of the finishing trial at the Texas Tech University Meat Lab, Lubbock, Texas and specific gravity data obtained.

The eight treatments of this 2 x 2 x 2 factorial experiment are shown in Table 1. Composition of the rations is shown in Table 3. The rations were formulated to be isonitrogenous at 11.5% crude protein. Variation in formulation within grain type was due to difference in moisture content. The high moisture and field dry milo and corn were hauled to the Texas Tech University Center at Pantex and processed through the feed mill. Grain processing was carried out by first dry rolling a sufficient amount of a particular grain, then stopping the rollers, applying steam to the grain in the steam jacket and then continuing the rolling process to produce a steam flaked product. Electricity consumption of the rollers and natural gas consumption of the boiler were measured.

Rations were fed in fence line bunks once daily at levels which allowed free-choice consumption between feedings. Water was available at all times from automatic waterers. Initial weights were taken after an 18 hour fast from feed and water. After weighing, the cattle were placed back on water and fed 80% of the previous day's consumption. Interim weights were taken at 28 day intervals. Final weights were taken after an 18 hour fast from feed and water.

At the conclusion of the 145 day finishing trial the remaining steers were slaughtered and carcass data obtained at the Gooch Packing Company, Abilene, Texas. Eight steers were selected from each treatment group of 25 on the basis that their performance and final weight approximated the average of each treatment. These carcasses were then subjected to specific gravity analysis to determine the amount of protein, ether extractable material and total energy deposited by each of the treatments during the trial. The net energy calculations of Lofgreen and Garrett (1968) and Garrett and Hinman (1969) were used to evaluate the data from this finishing trial. Data collected included the amount and cost of diesel used to operate tractors for crop production, the amount and cost of natural gas used to irrigate the two crops, field yields, crop storage costs, utility costs for grain processing, net energy of the rations, average daily gain, feed efficiency, feed intake, and carcass data. These data were then used in calculating energy efficiency of the various grain processing systems.

## Results and Discussion

Agronomic production data are given in Table 2. Milo harvested at high moisture was 6.4% higher in field loss than the field dry milo. This additional field loss was attributed to difficulty in threshing the high moisture grain out of the heads. High moisture corn, on the other hand, produced 13.3% more dry matter per acre than corn harvested field dry. Lodging and shattering of the very dry grain accounted for the difference in corn lost in the field. Of course, amount of field loss for both corn and milo fluctuates according to variety and maturity date. Feedlot performance of the steers during the 145 day feeding period is shown in Table 4. Although the average final weight is perhaps somewhat lighter than normal, it was felt that the cattle had reached low choice grade and were thus ready for slaughter. Average daily gain was similar for all treatments except the high moisture corn treatments. The high moisture corn treatments produced somewhat lower average daily gains than any of the other treatments which was probably due to decreased dry matter intake. This decreased intake was a result of the physical properties of the rations since this corn with its high moisture content and long storage time was difficult to process. It was very difficult to regulate the rollers to prevent an explosion of the corn which resulted in an accumulation of fines in the feed bunks. Thus, it was very difficult to maintain a high consumption for these cattle. Feed to gain ratios indicated that steam flaking field dry milo, high moisture milo and high moisture corn improved efficiency of feed conversion. Steam flaking field dry corn did not improve feed to gain efficiency. Feed cost per 100 lbs. of gain was lowest for cattle fed steam flaked high moisture milo. As shown in Table 5, there were no differences in the carcass data. Quality grade averaged low choice, marbling scores averaged small, and no differences occurred in rib eye area or fat thickness. The incidence of liver abscesses was very low, with only two treatments, steam flaked field dry corn and dry rolled high moisture corn, having any abscesses. Costs for storing the four grains are given in Table 6. The high moisture grains were preserved with an organic acid mixture costing 53¢/lb. at the rates of 10 lbs./ton of high moisture corn and 14 lbs./ton of high moisture milo. A greater amount of the acid mixture was used on the milo in order to assure adequate penetration of its harder seed coat. The elevator storage cost of 3¢/100 lbs. of grain/month is typical for elevators in the Texas High Plains. The energy cost of grain processing is shown in Table 7. Electrical cost to dry roll the grain was approximately 5¢ per 100 lbs. of grain or \$1.00/ton. Steam flaking required the same 5¢/100 lbs. of grain plus an additional 10.8¢ per 100 lbs. of grain in natural gas to generate steam to flake the material, resulting in a total cost of \$3.22/ton of steam flaked grain. Table 8 contains a summary of energy costs to produce 100 lbs. of processed field dry and high moisture milo and corn. Cost of grain production was calculated using the gallons of diesel fuel expended by the tractors for all operations needed to produce the grain. In addition, the production charges include the amount of natural gas used to power the deep well motors which produced the irrigation water. Cost of production was considerably higher for corn than for milo primarily due to increased amount of irrigation required to produce corn. The totals at the bottom of the table are the total energy costs in dollars/100 lbs. of grain for the operations. The least expensive grain to feed in the trial was dry rolled field dry milo which had the smaller amount of irrigation and processing. The most expensive was steam flaked field dry corn which took more energy to grow and to process. These totals reflect yield, storage, and processing charges. In Table 9, feed

costs, processing costs and storage charges have been related to animal gain. Therefore, the total at the bottom of each column is the cost/100 lbs. of gain including the charges incurred for grain production, storage, processing and other feed ingredients. Steers fed dry rolled high moisture milo had the lowest cost of gain. The value for steam flaked high moisture milo was slightly higher. The most expensive cost of gain was for steers fed steam flaked field dry corn because cattle fed steam flaked field dry corn did not convert as well as those fed dry rolled field dry corn. The cost of gains for dry rolled and steam flaked high moisture corn was quite comparable to that of the dry rolled and steam flaked field dry milo. After having examined energy costs and cost/100 lbs. of gain, one must now consider energy deposition and the net energy values of each of the rations.

In Table 10 energy deposition is shown as the energy retained per animal in Mcal/day. This is based on specific gravity analysis of the initial kill cattle and the final kill cattle. The maximum energy retained per animal was on dry rolled field dry corn while the minimum amount was on dry rolled high moisture corn. When these values are broken down to energy retained per pound of dry matter fed, the picture changes. The maximum amount of energy retained per pound of dry matter was on dry rolled high moisture milo while the minimum amount retained was on dry rolled field dry milo. This would be as expected because of the lower availability of starch in the dry rolled dry milo. Table 11 shows the net energy values for the 8 rations. These values are on a dry matter basis in Mcal/lb. It is obvious from an examination of this data that the net energy predictability for all corn rations was more accurate than that for the milo rations. The net energy of maintenance and net energy of gain was a great deal higher than calculated values for all of the milo rations. The highest net energy value for maintenance and gain was for steam flaked high moisture milo. These values thus take into account consumption, gain and energy retention. Table 12 summarizes the energy efficiency of the various grain systems. The energy use per acre, in Mcal, is the amount of Mcal of energy consumed in the farming operations and in irrigation. The corn required a great deal more Mcal per acre than did the milo as would be expected. The  $Nem+g$  per acre in Mcal is the net energy value per 100 lbs. of grain calculated back to the yield per acre. Thus, a net energy production per acre could be calculated. The corn, because of higher yield per acre, had an increased amount of Mcals produced per acre. The total energy used per 100 lbs. of grain in Mcals was calculated by adding together the processing costs per 100 lbs. as well as the production cost per 100 lbs. The highest production cost per 100 lbs. was for steam flaked field dry corn which was partially due to the amount of field loss of field dry corn which occurred. Energy efficiency was thus calculated using the equation the Mcals of energy as net energy of maintenance plus gain per 100 lbs. divided by the Mcals of production energy used per 100 lbs. plus the energy of processing per 100 lbs. times 100. This data indicates that the greatest energy efficiency occurred on the dry rolled high moisture milo, followed closely by dry rolled field dry milo. The least efficient ration in terms of total energetic efficiency was steam flaked field dry corn. In each case, it should be noted that steam flaked rations were less efficient than dry rolled rations. Generally, the four milo rations were more efficient than the four corn rations. Table 13 shows the energy efficiency of the milo and the corn calculated on a per acre basis. The energetic efficiency of milo was 62.27 which means that 62.27 Mcals of energy were produced per 100 Mcals of input. The corn treatments, however, only produced 110 Mcals of energy per 52.92 Mcals input. This was a reflection

of the amount of energy needed for production and the net energy values of the rations. Table 14 defines the energy efficiency of grain processing. In table 14 it is obvious that the greatest improvement in net energy of maintenance plus gain due to steam flaking occurred on the field dry milo. The high moisture milo had only a 2.6% increase in net energy of maintenance plus gain while the field dry corn showed a negative response to steam flaking. The high moisture corn showed a very small, 1.4%, response to steam flaking. When the cost/100 lbs. of grain for steam flaking is included and the net energies of the rations taken into account, one can calculate the economic value of a Mcal of net energy. When the improvement of net energy availability is evaluated against the cost/100 lbs. for steam flaking, one can develop a cost:benefit ratio. This ratio is shown at the bottom of the table. The only grain which gave a positive cost:benefit ratio was field dry milo. All other grains gave a cost:benefit ratio of less than 1. This means that field dry milo is the only grain which returns more dollars from steam flaking than it consumes. This is not to say that one should not steam flake other grains, however, because many other factors must be taken into consideration before a decision on steam processing is made. These include whether or not the feedlot is a custom feedyard and must compete in an area where other yards are flaking. One must also consider moisture content of the ration, and the price of utilities in a given area. But as far as returning available energy for dollars spent, only the dry milo demands steam flaking. The energy efficiency of harvesting methods is given in Table 15. And as would be suspected from the previous data, the highest energetic efficiency is shown in the high moisture milo. Even though high moisture milo incurred more field loss than field dry, it had a much higher net energy value and thus, a higher overall energetic efficiency. The lowest energetic efficiency was for field dry corn because of its high field loss and production cost.

### Summary

A 2 x 2 x 2 factorial design experiment was conducted to evaluate the energy costs and energy values of various grain systems. An examination of the data indicates that for milo, high moisture harvest is preferable to that of field dry. The high moisture milo can be dry rolled and is comparable in net energy value to that of other grains which require a larger expenditure of energy for processing. The obvious disadvantage to high moisture harvest is that the moisture level in milo drops rapidly during a harvest season and it is difficult to obtain milo at the optimum moisture over a long period of time. In addition, there is a slightly increased field loss with high moisture milo as compared to that of field dry, which must be taken into account. If corn is to be produced under irrigated conditions, the energy needed to produce it should be extremely cheap. An analysis of the data indicates that the net energy values for corn are not enough higher to justify the increased irrigation cost to produce it in arid areas. The data indicated that steam flaking did pay for itself when used on field dry milo. However, steam flaking did not pay for itself on any of the other three grains. This cost analysis was based strictly on the cost of processing versus the increased energetic value of the ration. This cost analysis did not consider other intrinsic factors in a feedyard operation which may lead to the use of a steam flaking procedure. When one considers the total energetic efficiency of a grain system, the highest energetic efficiency obtained was with dry rolled high moisture milo. The lowest energetic efficiency was obtained with steam flaked field dry corn. The factors which played the greatest

roles in differentiating these two values are yield, cost of crop production, field losses, and energy cost of processing. By using the equations and values expressed here one can make decisions based on his own unique circumstances as to which grain processing system may fit a particular feedyard or area.

#### Literature Cited

- Garrett, W. N. and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1
- Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Anim. Sci. 27:793.

TABLE 1. EXPERIMENTAL DESIGN

Grain	Milo				Corn			
	High Moisture		Field Dry		High Moisture		Field Dry	
Harvesting Method								
Grain Processing Method	Dry Roll	Steam Flake	Dry Roll	Steam Flake	Dry Roll	Steam Flake	Dry Roll	Steam Flake
Steers/Treatment	25	25	25	25	25	25	25	25

TABLE 2. AGRONOMIC PRODUCTION DATA

Grain	Milo		Corn	
	Field Dry	High Moisture	Field Dry	High Moisture
Acres	31.8	25.0	23.2	26.4
Date harvested	11-09-78	10-16-78	10-17-78	9-18-78
Yield, lb./acre (as is)	4,772.4	5,050.0	6,258.5	8,382.1
Moisture, %	15.0	24.5	15.5	28.5
Yield, lb/acre (DM)	4,056.5	3,812.8	5,288.4	5,993.2
Field loss, %	---	6.4	13.3	---

TABLE 3. COMPOSITION OF RATIONS (As Is Basis).

Grain	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Milo	72.0	72.0	76.6	76.6	--	--	--	--
Corn	--	--	--	--	69.0	69.0	76.6	76.6
Cottonseed Meal	4.0	4.0	3.4	3.4	7.0	7.0	5.3	5.3
Cottonseed Hulls	15.0	15.0	12.5	12.5	15.0	15.0	11.3	11.3
Supplement	6.0	6.0	5.0	5.0	6.0	6.0	4.5	4.5
Cane Molasses	<u>3.0</u>	<u>3.0</u>	<u>2.5</u>	<u>2.5</u>	<u>3.0</u>	<u>3.0</u>	<u>2.3</u>	<u>2.3</u>
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4. FEEDLOT PERFORMANCE.

Grain	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Initial wt., lb.	595.2	603.5	598.1	605.7	594.4	590.9	607.4	605.5
Final wt., lb.	985.7	978.0	970.5	976.2	981.5	984.8	934.4	960.8
A.D.G., lb.	2.69	2.65	2.57	2.56	2.67	2.72	2.30	2.45
Feed/hd/day lb., (DM)	19.53	17.76	16.81	16.44	18.53	19.77	16.51	17.03
Feed/gain (DM)	7.26	6.70	6.54	6.42	6.94	7.27	7.18	6.95
Feed cost/cwt gain <sup>a</sup>	\$ 35.66	32.60	30.11	29.64	35.44	37.13	32.32	31.36

<sup>a</sup>Without mark up.

TABLE 5. CARCASS DATA.

Grain	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Warm carcass wt., lb.	602.1	591.0	585.4	587.0	608.4	589.2	563.8	588.3
Quality grade <sup>a</sup>	12.2	11.9	12.0	12.0	12.0	12.2	12.0	12.1
Marbling score <sup>b</sup>	5.2	4.9	5.0	5.3	5.0	5.2	5.0	5.1
Rib eye area, sq. in.	11.6	11.8	11.6	11.9	11.8	11.4	11.5	11.2
Fat thickness, %	0.46	0.44	0.41	0.41	0.50	0.48	0.41	0.44
Liver Abscesses, %	--	--	--	--	--	2.0	2.0	--

<sup>a</sup>Choice (thirds) = 12, 13, 14.

<sup>b</sup>Slight = 4; small = 5; modest = 6.

TABLE 6. STORAGE COSTS FOR GRAINS.

Grain	Milo		Corn	
	Field Dry	High Moisture	Field Dry	High Moisture
Acid cost/cwt grain <sup>a</sup>		\$ .371		\$ .265
Elevator cost/cwt grain/month	\$ .03		\$ .03	

<sup>a</sup>Acid - \$.53/lb.

TABLE 7. ENERGY COST OF GRAIN PROCESSING.

Processing Method	Dry Roll	Steam Flake
Cost/cwt grain		
Electrical <sup>a</sup>	\$0.053	\$0.053
Natural gas <sup>b</sup>	---	0.108
Total	\$0.053	\$0.161
Cost/ton grain, total	\$1.06	\$3.22

<sup>a</sup>KWH/cwt grain - 1.25  
Cost/KWH - \$0.0421

<sup>b</sup>MCF/cwt grain - 0.18  
Cost/MCF - \$0.59

TABLE 8. SUMMARY OF ENERGY COSTS PER CWT OF GRAIN.

	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
	<u>\$/Cwt.</u>							
Grain Production	.743	.743	.791	.791	.911	.911	.804	.804
Acid Costs	--	--	.371	.371	--	--	.265	.265
Storage	.25	.25	--	--	.25	.25	--	--
Processing	<u>.053</u>	<u>.161</u>	<u>.053</u>	<u>.161</u>	<u>.053</u>	<u>.161</u>	<u>.053</u>	<u>.161</u>
Total	1.046	1.154	1.215	1.323	1.214	1.322	1.122	1.230

TABLE 9. FEED COSTS PER CWT OF GAIN.

Costs	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Feed (w/o markup)	\$ 35.66	32.60	30.11	29.64	35.44	37.13	32.32	31.36
Processing	.31	.87	.34	1.02	.28	.92	.38	1.14
Storage	<u>1.47</u>	<u>1.34</u>	<u>2.36</u>	<u>2.32</u>	<u>1.34</u>	<u>1.41</u>	<u>1.92</u>	<u>1.86</u>
Total	\$ 37.44	34.81	32.81	32.98	37.06	39.46	34.62	34.36

TABLE 10. ENERGY DEPOSITION.

	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Energy retained/ animal Mcal/Day	4.23	4.31	4.47	4.27	4.60	4.42	4.10	4.21
Energy retained/ lb. DM fed	.219	.246	.266	.260	.253	.225	.248	.247

TABLE 11. NET ENERGY VALUES.

	Dry Matter Basis							
	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
	<u>Mcal/lb.</u>							
NEm calculated	.760	.760	.760	.760	.894	.894	.894	.894
NEm actual	.837	.911	.942	.967	.883	.837	.883	.895
NEg calculated	.467	.467	.467	.467	.545	.545	.545	.545
NEg actual	.513	.559	.578	.592	.541	.513	.541	.549

TABLE 12. ENERGY EFFICIENCY OF GRAIN SYSTEMS.

Grain	Milo				Corn			
	Field Dry		High Moisture		Field Dry		High Moisture	
Harvest								
Processing Method	Roll	Flake	Roll	Flake	Roll	Flake	Roll	Flake
Energy use/acre, (Mcal)	4,485.2		4,485.2		7,191.11		7,191.11	
NEm+g/acre, (Mcal)	2,588.0	2,827.0	2,760.5	2,996.2	3,564.4	3,368.7	4,135.3	4,153.3
Total energy used/ cwt of grain, (Mcal) <sup>a</sup>	111.65	159.94	118.72	167.01	137.06	185.35	121.07	169.36
NEm+g/cwt grain, (Mcal)	63.8	69.7	72.4	78.6	67.4	63.7	69.0	69.3
Energy efficiency, % <sup>b</sup>	57.14	43.58	60.98	47.06	49.18	34.37	56.99	40.92

<sup>a</sup>Crop production and processing.

<sup>b</sup> 
$$\frac{\text{Mcal energy as NEm+g/cwt}}{\text{Mcal production energy/cwt} + \text{energy of processing/cwt.}} \times 100$$

TABLE 13. ENERGY EFFICIENCY OF GRAIN PRODUCTION.

Grain	Milo	Corn
Energy efficiency, % <sup>a</sup>	62.27	52.92

<sup>a</sup> 
$$\frac{\text{Mcal energy as NEm+g/acre}}{\text{Mcal production energy/acre}} \times 100$$

TABLE 14. ENERGY EFFICIENCY OF GRAIN PROCESSING.

	<u>Field Dry</u>		<u>High Moisture</u>		<u>Field Dry</u>		<u>High Moisture</u>	
	<u>Roll</u>	<u>Flake</u>	<u>Roll</u>	<u>Flake</u>	<u>Roll</u>	<u>Flake</u>	<u>Roll</u>	<u>Flake</u>
% Improvement in NEm+g due to flaking	0	8.9	0	2.6	0	-5.2	0	1.4
Cost/cwt for flaking (\$)	0	.16	0	.16	0	.16	0	.16
Value added in energy availability/cwt (\$)	0	.36	0	.10	0	-.21	0	.06
Cost:Benefit ratio		2.25		.63		-1.31		.375

TABLE 15. ENERGY EFFICIENCY OF HARVESTING METHODS.

	Milo		Corn	
	<u>Field Dry</u>	<u>High Moisture</u>	<u>Field Dry</u>	<u>High Moisture</u>
Energy Efficiency <sup>a</sup>	60.36	64.17	48.21	57.63

<sup>a</sup>  $\frac{\text{Mcal NEm+g/acre}}{\text{Mcal production energy/acre}} \times 100$