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INCORPORATION OF DPW, UREA AND FISH MEAL WITH VARYING MOLASSES LEVELS IN CATTLE FEEDLOT RATIONS

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OPSOMMING: INSLUITING VAN DHM, UREUM EN VISMEEL MET VERSKILLENDE MELASSEPEILE IN VETMESTINGSRANTSOENE VIR BEESTE

Met die toenemende tekort en stygende koste van konvensionele proteïenbronne soos oliekoek en vismeel en met die steeds stygende koste van mielies, is daar besluit om alternatiewe bronne van proteïen en energie vir gebruik in beesvetmestingsrantsoene te ondersoek. Die proefontwerp was 'n 2 x 3 x 4 faktoriale rangskikking. Die drie faktore wat ondersoek is was 3 proteïenbronne, 4 melasse peile en vitamien A inspuitings. Twaalf diere is geslag om die aanvanklike karkasmassa te beraam terwyl die oorblywende 120 diere in die voedingsproef self gebruik is. Vismeel het betekenisvol beter liggaams- en karkasmassatoenames getoon as beide ureum en kunsmatiggedroogde lêhoendermis (DHM). Ureum het weer, op sy beurt, betekenisvol beter resultate as DHM gegee. Die vervanging van mieliemeel deur melasse teen peile van 7% en 14%op 'n droë basis, het geen uitwerking op enige van die maatstawe gehad nie maar teen 'n vervangingspeil van 21% het melasse 'n hoogsbetekenisvolle onderdrukkende invloed op diereproduksie gehad. Hierdie resultate steun die bevindings van andere wat bewys dat mielies en melasse, op 'n droë basis, 'n soortgelyke netto energiewaarde het mits melasse nie teen 'n hoër peil as ongeveer 14% by die rantsoen ingesluit word nie. Die vitamien A inspuitings het geen uitwerking op enige van die maatstawe gehad nie. Dit is dus duidelik dat met die toenemende koste van graan sowel as natuurlike proteïenbronne en met die voorspelde tekorte van hierdie grondstowwe, die gebruik van melasse as 'n energieverplaser van graan, en die gebruik van DHM en ureum as proteïenbronne groter erkenning moet ontvang.

SUMMARY:

With the increasing shortages and costs of conventional protein-rich feedstuffs such as oilcakes and fish meal, and with the ever increasing cost of yellow maize, it was decided to investigate alternative protein and energy sources for use in cattle feedlot rations. The experimental design was a 2 x 3 x 4 factorial arrangement. The 3 factors investigated consisted of 3 protein sources, 4 molasses levels and vitamin A injections. Twelve animals were slaughtered to estimate initial carcass mass and the remaining 120 animals were used in the feeding trial itself. Fish meal produced significantly superior rates of live plus carcass mass gain and feed conversion rates than either urea or artificially dried poultry layer manure (DPW). Urea, in turn, gave significantly better results than DPW. The replacement of maize meal by molasses at the 7% and 14% levels, on a dry matter basis, had no effect on the criteria measured, but it caused a highly significant depression in animal performance at the 21% level of replacement. This confirms previous reports that maize and molasses have similar energy values, when expressed on a dry matter basis, provided the molasses inclusion does not exceed approximately 14%. The vitamin A treatment had no effect on any of the criteria under investigation. It is thus evident that, with the increasing prices of grain as well as natural protein sources, and with the predicted shortages of both commodities, the use of molasses as an energy substitute for grain, and the inclusion of DPW and urea as a protein source, must receive more widespread recognition.

Conventional protein sources, such as oilcake meals and fish meal, have always been freely available at relatively low prices on the South African market. Due to the unprecedented expansion in recent years of the balanced feed industry, the demand for these protein sources has started to outstrip the supply. Unless protein production is considerably increased, Cloete (1976) predicts that South Africa will be unable to meet its feed protein requirements by the end of the present decade and will be faced with increasing feed protein deficits from about 1980 onwards. With this in mind, it is of vital importance to evaluate alternative and inexpensive protein sources such as urea and poultry manure which will relieve greater quantities of the conventional protein sources for use in monogastric diets. Poultry manure is now available in South Africa in a sterile and safe form which has been officially approved by the Department of Agriculture for use in animal feeds. Its acceptance as a protein source in ruminant rations would thus help alleviate the looming protein shortage and would reduce growing pollution problems associated with manure disposal of intensive poultry units. The feeding value of poultry manure for ruminants has been extensively investigated in several countries as is evident from the review by Bhattacharya & Taylor (1975). South African studies have been confined to either the use of poultry litter (Bishop, Wilke, Nash, Nell, McDonald, Compaan, Grobler & Kingman 1971 a, b; Bosman, 1973; Lyle, Muller & Dreyer, 1975) or to the use of air-dried poultry layer manure (Bishop *et al* 1971 b: van der Westhuizen & Hugo 1972 a, b; van der Merwe, Pretorius & du Toit, 1975).

Although molasses has, for many years, been included in animal feeds, mainly for its ability to increase palatability and to reduce dustiness, its main attribute, namely as an inexpensive energy source, has not been fully appreciated. This is partly due to the wide divergence of opinion regarding its energy value, as is evident from a scrutiny of commonly used reference standards such as Morrison's (1956) Feeds & Feeding, the N R C Standards for Beef Cattle (1970), Feedstuffs Reference Issue (1976–77), Atlas of Nutritional Data on United States and Canadian Feeds (1971). This problem was the subject of an earlier investigation by Van Niekerk & Voges (1976), where it was found that molasses can be used to replace up to 21% of the maize meal in beef fattening rations without significantly reducing the rate of live mass and carcass gain, although efficiency of feed conversion tended to decrease at the higher molasses levels. Considering that molasses is currently marketed at only about 20% of the cost of yellow maize and also that yellow maize is in great demand for export purposes, it is imperative that the question of the relative energy values of maize and molasses in production rations be resolved.

For these reasons it was decided to investigate, by means of a 2 x 3 x 4 factorial arrangement, the value of fish meal, urea and dried poultry waste as protein sources, as well as the value of molasses as a replacement for maize meal in beef fattening rations. Fish meal was used as one of the treatments, as this was considered the ideal protein reference standard with which to compare urea and DPW. It was furthermore decided to apply this experiment to confirm earlier findings (van Niekerk & Voges, 1976) regarding the value of vitamin A injections on feedlot performance.

Procedure

Experimental animals

One hundred and thirty two Hereford crossbred weaner steers were used.

Initial slaughter group

In order to arrive at an estimate of the initial carcass mass of the experimental animals, a representative group was selected and slaughtered at the beginning of the experiment. This was achieved by restrictive randomization of the experimental animals, according to initial body mass, into 11 groups of 12 animals each. One of these groups was selected, at random, slaughtered and the dressing percentage was determined. The average dressing percentage of this group was used to estimate the initial carcass mass of each of the remaining experimental animals.

Experimental design

The one hundred and twenty remaining experimental cattle were restrictively randomized, according to initial body mass, into 24 experimental groups. These 24 groups were used in a 2 x 3 x 4 factorial arrangement. The main effects investigated were the influence of vitamin A (2 levels), 3 different protein sources and 4 molasses levels.

Treatments

The experimental animals were fed in 12 seperate groups according to the different rations used in the experiment. Half of the animals in each of these groups were injected with a vitamin A product containing 500 000 I U vitamin A, 75 000 I U vitamin D and 50 I U vitamin E per ml, the other half acting as a negative control group. Treatment consisted of 3,75 million I U vitamin A injected at the beginning of the trial and again 75 days later, giving a total of 7,5 million I U vitamin A per animal.

The different protein sources compared were fish meal, urea and artificially dried caged poultry layer manure (DPW). The amount of supplementary crude protein derived from each of these 3 protein sources in the respective ration treatments was identical and amounted to 28,2% of the crude protein in the ration. The DPW used in this experiment originated as droppings from caged layer hens, mechanically removed from the houses, dried in a Marvo gas drier to a moisture content of approximately 10%. Droppings were collected at 48 hour intervals and immediately dried.

Molasses was included in the experimental rations at levels of either 0%, 7%, 14% or 21%, directly replacing maize meal on a dry matter basis. The molasses used consisted of low-moisture, high-brix sugarcane molasses with an average total sugar content of 53,5%.

The ration treatments and composition are summarised in Table 1. Based on initial raw material analysis (Table 2), rations were formulated to identical specifications for crude protein (12,2%), crude fibre (9,8%), calcium (1,0%), and phosphorus (0,4%), all expressed on a dry matter basis. The rations were also made isocaloric (4,90 MJ/kg NE_g) with ingredient energy values taken from NRC (1970) wherever possible. However, no net energy gain (NE_g) values could be found in this publication for DPW, dried sugarcane bagasse pith and maize bran with the result that the following values, arrived at after consulting a variety of sources, were assumed:

DPW	=	2,93 MJ/kg
Dried sugarcane bagasse pith	=	0,84 MJ/kg
Maize bran	=	4,19 MJ/kg

Bagasse pith was included at a constant level of 12,5% (DM basis) as a roughage source. Maize bran was used at varying levels as a low-energy filler to equalize the energy concentration of the rations. Because molasses replaced maize meal and therefore also protein, solvent extracted peanut oilcake meal was used to equalize the protein levels in the various rations.

A protein level of 12,2% (DM basis), used in all rations, is as recommended in the NRC (1970) tables. It will be noted that both the calcium and phosphorus levels exceed the minimum levels as specified by these tables. However, since DPW and, to a lesser degree, fish meal are relatively rich sources of these two minerals, it was necessary to use limestone and monocalcium

Table 1

Percentage composition of the 12 experimental rations (dry matter basis)

Protein source	Urea				Fish meal				* D P W			
Molasses level	0	7	14	21	0	7	14	21	0	7	14	21
Yellow maize meal	65,00	58,00	51,00	44,00	60,00	53,00	46,00	39,00	63,80	56,80	49,80	42,80
Molasses	–	7,00	14,00	21,00	-	7,00	14,00	21,00	–	7,00	14,00	21,00
Maize bran	15,50	14,83	14,31	13,80	16,75	16,20	15,65	15,15	8,00	7,47	6,93	6,20
Bagasse pith	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50
Peanut oil-cake meal	2,70	3,40	4,05	4,70	3,40	4,10	4,75	5,40	3,90	4,60	5,30	6,20
Urea	1,20	1,20	1,20	1,20	–	–	–	–	–	–	–	–
Fish meal	–	–	–	–	5,00	5,00	5,00	5,00	–	–	–	–
D P W *	–	–	–	–	–	–	–	–	11,00	11,00	11,00	11,00
Monocalcium phosphate	0,60	0,74	0,77	0,80	0,10	0,10	0,20	0,20	–	–	–	–
Salt	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30
Limestone	2,20	2,03	1,87	1,70	1,95	1,80	1,60	1,45	0,50	0,33	0,17	–

* Dried poultry waste

Table 2

Chemical composition and energy value of ingredients used

		Dry matter basis				
	Moisture (%)	Crude Protein (%)	Crude Fibre (%)	NE_g (MJ/kg)	Ca (%)	P (%)
Yellow maize meal	10,0	9,5	2,7	6,19	0,02	0,20
Maize bran	13,0	8,7	14,8	4,19	0,04	0,40
Molasses	14,0	5,0	–	6,19	0,80	0,80
Bagasse pith	6,0	2,0	42,0	0,84	0,16	0,05
Peanut oilcake meal	8,0	48,0	6,5	4,86	0,22	0,65
Fish meal	6,0	68,0	1,0	4,52	3,90	2,60
D P W*	10,1	30,4	14,1	2,93	8,0	2,70
Monocalcium phosphate	–	–	–	–	22,80	21,0
Limestone	–	–	–	–	36,0	–

*Dry poultry waste

phosphate to equalize the calcium and phosphorus levels and thus eliminate this source of variation.

Parameters measured

Live mass was determined at fortnightly intervals. Both the initial and final body masses were determined after 15 hour fasts, intermediary live mass being taken on full stomachs. Dressing percentages and carcass mass were determined at time of slaughter. Feed conversion rates are based on average group feed intake.

To reduce variation in final body composition, the various groups were fed to a fixed final live mass of approximately 360 kg at which stage the groups were slaughtered.

Results

Feed analysis

The mean chemical composition of the 12 diets, based on representative samples of the rations fed, is presented in Table 3. It will be noted that the levels of the major nutrients showed little variation between rations with the exception of ether extract which decreased in direct proportion to increases in the molasses level.

Initial slaughter group

The average dressing percentage of the 12 animals slaughtered at the beginning of the trial amounted to 50,48% . This value was used to estimate the initial carcass mass of each of the experimental animals.

Statistical analysis

An analysis of variance showed that there were no significant interactions between any of the 3 factors used in this experiment. Because of this, it is possible to compare the main effects of vitamin A, molasses levels and protein sources, as is summarised in Tables 4, 5 and 6, respectively.

Table 3

The mean chemical analyses of the 12 experimental rations

		Dry matter basis				
Ration	Moisture (%)	Crude protein (%)	Crude fibre (%)	Ether extract (%)	Calcium (%)	Phosphorus (%)
1	88,96	12,41	9,45	3,81	0,97	0,42
2	88,74	12,54	9,52	3,49	1,03	0,44
3	88,24	12,24	9,25	2,64	1,07	0,41
4	87,71	12,97	9,70	1,82	1,03	0,43
5	88,71	12,87	9,48	4,33	0,94	0,41
6	88,10	12,37	9,42	3,97	1,01	0,43
7	86,72	12,30	9,57	3,18	1,08	0,41
8	86,06	12,61	10,12	2,24	1,02	0,46
9	89,19	12,37	10,13	3,50	1,09	0,50
10	88,50	12,60	9,94	2,88	1,02	0,50
11	87,98	12,70	10,91	1,92	1,11	0,51
12	86,81	12,66	10,37	1,43	1,07	0,49

Vitamin A

It is obvious from Table 4 that the injection of animals at the beginning of the experiment and again 75 days later had no measurable influence on rate of live or carcass mass gain or on carcass dressing percentages.

Table 4

Influence of vitamin A (main effect) on growth rate and dressing percentages

	Control	Vitamin A
Number of animals	60	60
Live mass gain per day (kg)	1,00 ± 0,20	1,01 ± 0,20
Carcass mass gain per day (kg)	0,64 ± 0,15	0,64 ± 0,14
Dressing %	55,84 ± 1,34	55,68 ± 1,33

Molasses levels

The main effects of molasses on days to slaughter, rate of gain, feed intake, feed conversion ratio and dressing percentage are recorded in Table 5. The replacement of maize meal with molasses at the 7% and 14% levels did not have any significant effect on any of the abovementioned parameters. However, at the 21% level, molasses had a marked depressing effect ($P < 0{,}01$) on the rate of live and carcass mass gain. It will also be noted that days to slaughter and feed conversion rates were adversely influenced at the 21% molasses levels. The inclusion of molasses, particularly at the 7% and 14% levels, tended to increase feed dry matter intake.

Molasses level did not appear to have any consistent effect on dressing percentages.

Table 5

Main effects of increasing levels of molasses, as a replacement for maize meal, on animal performance

	Molasses level (dry matter basis)			
	0%	7%	14%	21%
Number of animals	30	30	30	30
Days to slaughter	140	134	135	162
Initial livemass (kg)	214,9	214,6	216,5	214,9
Final livemass (kg)	359,2	355,1	358,3	354,6
Daily livemass gain (kg)	1,03 ± 0,17	1,06 ± 0,20	1,05 ± 0,14	0,87 ± 0,22
Initial carcass mass (kg)	108,5	108,3	109,3	108,5
Final carcass mass (kg)	201,0	198,5	200,7	195,8
Daily carcass mass gain (kg)	0,66 ± 0,10	0,67 ± 0,12	0,68 ± 0,10	0,54 ± 0,15
Daily feed intake (kg DM)	6,86	7,11	7,29	6,95
Kg feed (DM) per kg livemass gain	6,66	6,70	6,94	8,00
Kg feed (DM) per kg carcass gain	10,39	10,56	10,78	12,89
Dressing %	55,95 ± 1,50	55,90 ± 1,41	56,02 ± 1,34	55,20 ± 1,97

Protein source

Table 6 summarises the main effects of protein source on days to slaughter, rate of gain, feed intake, feed conversion ratios and dressing percentages. Fish meal proved to be significantly superior in rate of gain to both urea ($P < 0,05$) and DPW ($P < 0,01$), whilst urea in turn produced significantly better ($P < 0,01$) results than DPW. Similar tendencies were noted for days to slaughter and feed conversion rates. Protein source had no significant effect on carcass dressing percentages.

Urea and fish meal resulted in almost identical feed intakes whilst the inclusion of DPW depressed feed intake.

Table 6

Main effects of urea, fish meal and D P W as protein sources on animal performance*

	Protein source		
	Urea	Fish meal	DPW*
Number of animals	40	40	40
Days to slaughter	141	131	156
Initial live-mass (kg)	216,1	215,3	214,3
Final live-mass (kg)	358,4	357,1	354,8
Daily live-mass gain (kg)	1,02 ± 0,18	1,09 ± 0,22	0,91 ± 0,20
Initial carcass mass (kg)	109,9	108,7	108,2
Final carcass mass (kg)	202,5	199,3	195,1
Daily carcass mass gain (kg)	0,67 ± 0,12	0,70 ± 0,14	0,56 ± 0,14
Daily feed intake (kg DM)	7,24	7,18	6,74
Kg feed (DM) per kg livemass gain	7,18	6,60	7,49
Kg feed (DM) per kg carcass gain	10,94	10,33	12,09
Dressing %	56,50 ± 1,60	55,82 ± 1,50	55,00 ± 1,96

* Dried poultry waste

Discussion

In spite of the fact that the feed ingredients used in this trial, with the exception of yellow maize meal, are poor sources of carotene, the cattle injected with vitamin A at the beginning of the experiment and again 75 days later did not show any measurable response in rate of gain or in any of the other criteria under investigation. This finding is in agreement with previous results obtained under similar conditions as reported by Van Niekerk & Voges (1976), as well as with earlier unpublished results by the same authors.

Although no statistically significant interaction between molasses level and protein source was observed, it is nevertheless of interest to record (Table 7) that molasses, at the 7% and 14% levels, improved rate of gain and efficiency of feed conversion when combined with fish meal. Also at the 21% level molasses had less of a depressing effect on performance in combination with fish meal than with the other protein sources. In the presence of D P W, however, increasing levels of molasses tended to produce progressively poorer animal performance.

Because ingredient levels within each protein source differed so little, with the obvious exception of maize meal replacing molasses, and because molasses up to at least the 14% level did not depress animal performance, it is clear that the assumptions made, according to NRC (1970) standards, regarding the relative energy values for these ingredients, are essentially correct. It can therefore be concluded that molasses and maize meal, on a dry matter basis, have comparable net energy (gain) values, provided levels of approximately 14% are not exceeded. The results of this experiment are thus in general agreement with the conclusions reached by Lofgreen (1965), Preston, Willis & Martin (1969) and Hatch & Beeson (1972) regarding the energy replacement value of increasing levels of molasses in beef fattening rations and confirm the results of a previous experiment by Van Niekerk & Voges (1976), conducted at this research unit.

With the various rations formulated to identical specifications for crude protein, crude fibre, the major minerals and estimated net energy (gain), it is obvious from the results that fish meal is a superior protein source to either non-protein nitrogen in the form of urea or to DPW, which is a mixture of true protein and NPN (uric acid). This finding is in agreement with earlier unpublished results of Van Niekerk & Voges (1974) where it was found that fish meal produced superior gains when compared with DPW plus urea or with urea as sole source of supplementary protein in feedlot rations. In this experiment DPW was included at a level of 10,5% , supplying 20% of the protein in the fattening meal. The superiority of fish meal as a protein source is thought to be due to its excellent amino acid composition and to its resistance to rumen degradation (Whitelaw, Preston & MacLeod, 1964). As the different rations were both isocaloric and isonitrogenous the relatively poor results obtained with DPW are probably largely due to its depressing effect on feed intake. It is of interest to record that the adverse effect of DPW on feed intake was found to be more pronounced during the early phases of the fattening period. The reasons for the lower feed intake on DPW are not clear but it can be postulated that both

Table 7

Effect of protein source and molasses level on animal performance

Protein source	Urea				Fish meal				DPW*			
Molasses levels (%)	0	7	14	21	0	7	14	21	0	7	14	21
Number of animals	10	10	10	10	10	10	10	10	10	10	10	10
Days to slaughter	131	131	137	166	137	118	123	145	152	152	145	175
Initial live-mass (kg)	216,5	215,1	216,3	216,5	214,6	214,3	216,2	216,0	213,5	214,4	216,9	212,2
Final live-mass (kg)	357,4	354,7	358,3	363,2	360,3	357,0	358,7	352,5	359,9	353,5	357,9	348,0
Initial carcass mass (estimated) (kg)	109,3	108,6	109,0	109,3	108,4	108,1	109,0	108,8	107,7	108,2	109,5	107,1
Final carcass mass (kg)	200,9	202,1	203,3	203,7	201,0	198,5	201,5	196,3	201,0	194,9	197,3	187,3
Final dressing %	56,21	56,98	56,74	56,08	55,79	55,60	56,18	55,69	55,85	55,13	55,13	53,82
Livemass gain per day (kg)	1,08	1,07	1,03	0,88	1,06	1,21	1,16	0,94	0,96	0,92	0,97	0,78
Carcass mass gain per day (kg)	0,70	0,71	0,69	0,57	0,68	0,77	0,75	0,60	0,61	0,57	0,61	0,46
Daily feed (DM) intake (kg)	7,25	6,99	7,35	7,36	6,92	7,77	7,08	6,95	6,41	6,58	7,45	6,58
Kg feed (DM) per kg livemass gain	6,74	6,56	7,08	8,32	6,50	6,42	6,10	7,38	6,65	7,15	7,68	8,37
Kg feed (DM) per kg carcass mass gain	10,35	9,85	10,68	12,94	10,20	10,09	9,44	11,58	10,44	11,55	12,22	14,24

*Dried poultry waste

the unpleasant odour and high mineral content could be responsible. Furthermore, it is noteworthy that the animals on rations supplemented with DPW developed a depraved appetite and were sometimes observed eating soil or chewing the wooden fence posts. This type of behaviour is often attributed to mineral deficiencies, but this would be an unlikely explanation in view of the high mineral content (28%) of DPW, although the presence of mineral imbalances cannot be ruled out.

The poorer live and carcass mass gains on DPW in relation to urea are at variance with earlier results obtained at this research unit (Van Niekerk & Voges, 1974) where 10,5% DPW in the fattening concentrate, although promoting poorer mass gains than fish meal, proved to be superior to urea as a protein source. DPW inclusion in the concentrate also did not depress feed intake. It is also interesting to compare the results on DPW with studies carried out with sun-dried poultry layer manure. Van der Westhuizen & Hugo (1972) compared low-energy growth rations for cattle containing either fish meal or fish meal plus urea with rations supplying 25% or 29% air-dried poultry layer manure. On poultry manure an initial adaptation period was experienced and feed intakes tended to be lower. Both fish meal and fish meal plus urea produced better rates of gain than poultry manure. These differences in mass gain can probably be largely attributed to the fact that the rations fed were not isocaloric. Bishop & Grobler (1969) and Bishop *et al* (1971 b), however, found no marked differences in feed intakes when sun-dried poultry layer manure replaced 0%, 15% and 30% maize meal in isonitrogenous (but not isocaloric) fattening rations for cattle, but a progressive decrease in rate of live mass gain with increasing increments of poultry manure was noted. The authors attribute this poorer performance to the lower energy content of the poultry manure rations. Further experiments by Bishop, Nash & Nell (1969) and Bishop *et al* (1971 b) in which concentrates, containing 0% , 20% and 40% sun-dried poultry layer manure, were fed *ad lib* showed no difference in concentrate intake or live mass gain. The poultry manure rations, which supplied less energy but more protein and mineral matter, resulted in greater silage intake. Van der Merwe *et al* (1975) used air-dried poultry layer manure to replace lucerne hay in metabolism studies with sheep. The rations contained 0%, 14%, 29% and 47% layer manure. The inclusion of poultry manure up to the 29% level did not influence voluntary feed intake but at the 47% level of inclusion feed intake was depressed.

Although the majority of results reviewed above show that poultry manure depressed rate of gain and/or feed intake, it should be remembered that the results are confounded by the fact that in all cases the poultry manure rations also supplied less energy. Furthermore, despite the lower rates of gain, most authors reported a saving in feed costs per unit gain where poultry manure was included in the feed.

The economic implications of the present experiment are obvious. The results on the energy replacement value of molasses are of great significance in view of the ever increasing cost of grain in relation to molasses. The demand for grain in human or monogastric diets will gain momentum so that cattle will in future increasingly be fed on by-products which have limited application in non-ruminant diets. Although fish meal produced the best animal performance, its use in beef fattening rations, with current feed cost structures, cannot be justified on economic grounds, as it proved to be the most expensive ration in terms of cost per unit carcass gain. Both urea and DPW, although somewhat inferior to fish meal in terms of animal performance, gave economically superior results and can thus serve as acceptable alternative sources of protein in beef fattening rations. These, and other research findings, suggest that there are obvious limits to which DPW can be included in beef fattening rations and future research work should be directed towards establishing the ideal combination between urea and DPW which is necessary for obtaining optimum animal performance.

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