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ABSTRACT

Three series of trials using a total of 112 pigs were conducted to determine the maximum amount of cane molasses that can be utilized efficiently by pigs from weaning to a weight of 70 pounds. Rations containing levels of 10, 20, 30, and 40 percent molasses were compared with check rations containing no molasses.

The results indicate that, with the rations fed, 20 percent is the maximum amount that will allow satisfactory gains and efficient feed utilization. With feed prices prevailing in Hawaii, the feed cost per pound of gain is lowered considerably. Above this level of molasses both the rate of gain and efficiency of feed utilization decreases markedly.

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INTRODUCTION

Cane molasses is produced in large quantities in the Territory of Hawaii. The annual production has averaged close to 200,000 tons. Of the various livestock feeds fed in the Territory, it is one of the cheapest sources of total digestible nutrients or energy. At prices prevailing during the last 10 years its cost was rarely more, and frequently less, than one-sixth that of barley, the chief cereal grain fed in the Territory. It is good business for a livestock feeder in the Territory, therefore, to include in livestock rations the maximum amounts of molasses which will permit efficient production.

In a survey of the literature, the authors found only reports of investigations concerning the feeding of cane molasses to pigs weighing 60 or more pounds. No reports of studies with smaller pigs could be found. Although experiments with the larger animals are helpful when formulating rations for weanling pigs, feeding trials were initiated at the University of Hawaii Agricultural Experiment Station to obtain more exact information. In this bulletin are presented the results of these investigations.

PREVIOUS WORK

In early work at the Hawaii Station (*11*) it was found that pigs could utilize molasses efficiently in levels at least up to 20 percent of the concentrate mixture. Later work (*10*) has indicated that satisfactory gains and feed utilization can be obtained when as much as 40 percent cane molasses is fed to pigs weighing over 100 pounds. Wisconsin workers (*2, 4*) found that, when replacing corn to the amount of 10 percent of the ration, cane molasses was equal on the basis of total digestible nutrient (T.D.N.) content, to corn. In later investigations (*3*) these workers found that when molasses replaced one-third of the corn, the molasses was worth only one-half that of corn, pound for pound. In Oregon (*8*) the mixing of one part cane molasses with four parts of mill run gave greater gains than with mill run alone, thus "making cane molasses equal in efficiency to mill run and at the same time inducing greater consumption." In another trial at the same station, molasses proved equal to barley when fed at a level of 20 percent of the concentrate mixture. At the Washington station (*9*), when cane molasses made up about 37 percent of the concentrate mixture including barley and mill run, somewhat lower gains and lower efficiency of feed utilization were obtained than when no molasses was fed in dry lot. On pasture, however, when less than one-half as much concentrate was required per pound of gain, the results were reversed. When fed at levels of 25 and 36 percent in one experiment at the Mississippi station (*1*) somewhat lower gains and feed utilization resulted when compared with a no-

molasses ration. Illinois workers (*5*) found that pigs made significantly lower gains and utilized their feed less efficiently when part of the corn was replaced by 20 or 30 percent molasses in the ration. At Oklahoma, Thompson (*14*) replaced corn with molasses and fed the molasses at levels of 20 and 40 percent of the ration. Shorts was also included in the mixtures. There were no significant differences in rates of gain. As the molasses was increased, more total feed, but no more total digestible nutrients, was required per pound of gain.

If all these findings are taken into consideration, the evidence indicates that, when small amounts of molasses are fed, satisfactory gains and efficient utilization of feed can be expected. At levels of 20 percent and higher there are considerable differences in results. Possibly differences in the ages of the pigs or the presence of different ingredients fed with cane molasses explains the differences obtained by various workers. It appears that better results were obtained when molasses was fed at high levels in rations including high-fiber concentrates such as barley or mill run than when they contained corn. Ferrin (*6, 7*) obtained better results when feeding rations containing oats and molasses than when he fed rations containing corn and molasses and postulated that the difference may have been due to the higher fiber content of oats.

GENERAL PROCEDURE

The feeding trials reported in this bulletin were divided into three series. The comparisons made in the different series were as follows:

Series I. Check ration (no molasses) and a ration containing 10 percent molasses.

Series II. Check ration and rations containing 10 and 20 percent cane molasses.

Series III. Check ration and rations containing 30 and 40 percent molasses.

The pigs used in these trials had been bred and raised in the herd of the University of Hawaii. Animals from the Berkshire, Duroc Jersey, Hampshire, and Tamworth breeds were represented. In alloting the pigs to the different rations, the pigs were distributed as equally as possible in regard to breed, sex, weight, and estimated outcome. Each pig was fed approximately 1 pound of fresh, green grass daily. The nutrients in this green roughage were not included in the data presented in the following pages, however, because the amount was small and the actual consumption was extremely difficult to determine.

In the first series of trials each of the two rations was formulated to contain 15 percent digestible crude protein. In the later trials the check rations contained 16 percent digestible crude protein, and the rations containing molasses were calculated to have the same nutritive ratio as the check ration. In the molasses rations, therefore, the digestible crude protein decreased with the increase in molasses, but this decrease was in proportion to the decreasing amounts of total digestible nutrients.

Chemical analyses were made of all the rations fed. The total digestible nutrient values presented in the tables were based upon these analyses and the digestion coefficients given by Morrison (*12*).

Statistical analyses of the data were carried out in accordance with the methods outlined by Snedecor (*13*).

EXPERIMENTAL COMPARISONS

SERIES I. COMPARISON OF A RATION CONTAINING 10 PERCENT MOLASSES WITH A CHECK RATION

This series of experiments was initiated and conducted by S. H. Work to determine if molasses fed at a level of 10 percent in the ration could be utilized efficiently by young pigs after weaning. In this series six separate trials, each using from 6 to 12 group-fed pigs, were carried out. The pigs were weighed for 3 consecutive days at the beginning and end of each trial. In addition, one weighing was made between each 2-week interval during the trials. Since some trouble had been encountered with necrotic enteritis, yeast produced from cane molasses was included in the rations in trials 5 and 6 with the thought that this feed would supply vitamins helpful in preventing this disease.

In table 1 are included the rations fed in this series. Raw cane sugar was included in the check ration as a replacement for the molasses to demonstrate that if any diarrhea occurred among the pigs receiving 10 percent molasses, the diarrhea was due to the high mineral of the molasses rather than the high sugar content. In a previous trial conducted with growing and fattening pigs at the Hawaii Station by Work,[1] raw cane sugar was utilized as efficiently as barley.

The results from the individual trials and a summary of the combined data from all the trials are presented in table 2.

[1] Unpublished data. Hawaii Agr. Expt. Sta.

TABLE 1. Rations fed in the first series of trials.

RATION	CHECK	10 PERCENT MOLASSES
	Pounds	*Pounds*
Rolled barley	48	48
Raw cane sugar	10	. . .
Cane molasses	. . .	10
Wheat standard middlings	20	20
Dry-rendered tankage	15	15
Soybean oil meal	5	5
Salt	1	1
Steamed bone meal	1	1
Totals	100	100

TABLE 2. Summary of individual trials in series I comparing the check ration with one containing 10 percent cane molasses, and a summary of the combined data from all six trials.

DATA RECORDED	TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4	
Duration (*Days*)	43		51		65		84	
Ration	Check	10% molasses	Check	10% molasses	Check	10% molasses	Check	10% molasses
Pigs beginning trial (*Number*)	4	3	3	3	4	4	4	4
Average body weight (*Pounds*)								
Beginning	38.9	38.4	36.1	35.9	37.1	36.4	19.5	19.3
End	78.4	76.4	73.9	81.0	88.9	74.5	77.5	81.7
Weight gain (*Pounds*)								
Total	158	114	113	135	207	153	232	250
Daily average per pig	0.92	0.88	0.74	0.88	0.80	0.59	0.69	0.74
Total feed consumed (*Pounds*)								
Experimental ration	511	432	630	684	1030	981	1158	1131
Yeast	....	....	....	....	....	....	....	....
Pounds consumed per pound gain								
Concentrate	3.24	3.79	5.56	5.06	4.97	6.43	4.98	4.53
Total digestible nutrients	2.38	2.61	4.05	3.47	3.63	4.41	3.63	3.11
Feed cost per pound gain* (*Cents*)	12.2	12.9	20.9	17.2	18.7	21.9	18.7	15.4

TABLE 2. (Continued)

DATA RECORDED	TRIAL 5		TRIAL 6		WEIGHTED TOTALS OR AVERAGES	
Duration (*Days*)	85		40		....	
Ration	Check	10% molasses	Check	10% molasses	Check	10% molasses
Pigs beginning trial (*Number*)	6	6	3	4	24	24
Average body weight (*Pounds*)						
Beginning	27.0	25.8	37.3	34.2	31.8	30.7
End	94.8	76.9	87.5	82.6	84.7	78.7
Weight gain (*Pounds*)						
Total	407	307	151	193	1268	1152
Average daily per pig	0.80	0.60	1.26	1.21	0.82	0.74
Total feed consumed (*Pounds*)						
Experimental ration	1920	1770	611	695	5860	5693
Yeast	51	45	17	23	68	68
Pounds consumed per pound gain						
Concentrate	4.84	5.92	4.17	3.71	4.67	5.00
Total digestible nutrients	3.54	4.07	3.05	2.55	3.39	3.44
Feed cost per pound gain* (*Cents*)	18.2	20.2	15.7	12.7	17.6	17.0

* Feed prices used in this and the following tables: barley, $83.20 per ton; raw cane sugar, $84.10; cane molasses, $12.80; wheat middlings, $63.00; soybean oil meal, $89.00; meat meal or meat and bone meal, $58.00; salt, $48.00; steamed bone meal, $56.80; and yeast (estimated because not a commercial product), $80.00 per ton.

The results indicate that there were few differences between the two rations in regard to average daily gain or efficiency of feed utilization. The check ration appeared to be slightly superior, but statistical analysis of the data showed that the differences were not significant. When comparing the differences in efficiency of feed utilization, it can be seen that somewhat less of the check ration was required per pound of gain than of the molasses ration. The moisture content of the molasses ration, however, is higher because molasses contains about 20 percent water while raw cane sugar and barley contain but 10 percent or less. The check ration, therefore, contained 10.4 percent water and the molasses ration 14.1 percent. To correct for differences in moisture content, the rations can be compared on the basis of the amount of either dry matter or total digestible nutrients required per pound of gain. If this correction is made by determining the amount of total digestible nutrients required per pound of gain, the values become 3.39 and 3.44 for the check and 10 percent molasses rations, respectively. These values are very close and indicate that the digestible nutrients in both rations were used with approximately equal efficiency. There was also a saving in feed cost per pound of gain by feeding the molasses.

SERIES II. COMPARISON OF RATIONS CONTAINING 10 PERCENT AND 20 PERCENT CANE MOLASSES WITH THE CHECK RATION

In some of the previous trials considerable trouble was experienced with necrotic enteritis with the result that the rates of gain and the efficiency of feed utilization were not satisfactory. It was decided, therefore, to repeat the above-described work and to add a third ration containing 20 percent molasses to the comparisons. The inclusion of the third ration would give information in regard to the ability of weanling pigs to utilize this higher level of molasses.

In the first two trials of this series, wheat standard middlings made up 20 percent of the ration. Due to its unavailability when the later trials were conducted, the 20 parts of middlings were replaced in each ration by 16 parts of barley and 4 parts of meat and bone meal.

The rations are given in table 3. A summary of the results of the individual trials and of the combined data from the five trials are presented in table 4.

TABLE 3. Rations fed in the second series of trials.

RATION	EXPERIMENTS 7 AND 8			EXPERIMENTS 9, 10, AND 11		
	Check	10% molasses	20% molasses	Check	10% molasses	20% molasses
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Rolled barley	44.5	48.0	37.0	60.5	64.0	53.0
Raw cane sugar	10.0	....	....	10.0	....	....
Cane molasses	....	10.0	20.0	....	10.0	20.0
Wheat standard middlings	20.0	20.0	20.0	....	....	....
Meat and bone meal	15.0	15.0	15.0	19.0	19.0	19.0
Soybean oil meal	9.5	6.0	7.0	9.5	6.0	7.0
Salt	1.0	1.0	1.0	1.0	1.0	1.0
Totals	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4. Summary of individual trials in series II comparing the check ration with rations containing 10 and 20 percent molasses, and a summary of the combined data from all five trials.

DATA RECORDED	TRIAL 7			TRIAL 8			TRIAL 9		
Duration (*Days*)	42			42			42		
Ration	Check	10% molasses	20% molasses	Check	10% molasses	20% molasses	Check	10% molasses	20% molasses
Pigs beginning trial (*Number*)	3	3	3	4	4	4	3	3	3
Average body weight (*Pounds*)									
Beginning	31.3	31.3	31.9	30.9	30.0	28.8	30.8	31.5	31.8
End	73.4	72.4	80.3	65.3	65.3	64.5	68.4	63.6	62.5
Weight gain (*Pounds*)									
Total	126	123	145	137	141	143	113	96	92
Average daily per pig	1.00	0.98	1.15	0.82	0.84	0.85	0.90	0.76	0.73
Total concentrate consumed (*Pounds*)	337	350	409	531	525	563	338	329	344
Pounds consumed per pound gain									
Concentrate	2.68	2.83	2.82	3.87	3.72	3.93	2.99	3.42	3.74
Total digestible nutrients	1.96	1.97	1.90	2.83	2.58	2.66	2.26	2.46	2.64
Feed cost per pound gain (*Cents*)	10.1	9.7	8.7	14.6	12.7	12.1	11.8	12.2	12.0

TABLE 4. (Continued)

DATA RECORDED	TRIAL 10			TRIAL 11			WEIGHTED AVERAGES OR TOTALS		
Duration (*Days*)	42			42			. . . .		
Ration	Check	10% molasses	20% molasses	Check	10% molasses	20% molasses	Check	10% molasses	20% molasses
Pigs beginning trial (*Number*)	3	3	3	3*	3	3	16	16	16
Average body weight (*Pounds*)									
Beginning	30.4	30.5	28.7	33.9	35.6	34.6	31.3	31.7	31.0
End	61.7	62.6	62.6	75.7	79.4	70.3	68.2	68.4	67.8
Weight gain (*Pounds*)									
Total	94	97	102	84	131	107	554	588	589
Average daily per pig	0.74	0.77	0.81	1.00	1.04	0.85	0.88	0.88	0.88
Total concentrate consumed (*Pounds*)	287	327	325	221	392	331	1714	1923	1972
Pounds consumed per pound gain									
Concentrate	3.06	3.39	3.20	2.64	2.98	3.09	3.10	3.27	3.35
Total digestible nutrients	2.31	2.43	2.26	1.87	1.99	1.98	2.31	2.30	2.30
Feed cost per pound gain (*Cents*)	12.0	12.1	10.3	10.4	10.6	9.9	11.9	11.4	10.5

* One pig was unthrifty so was removed from the trial. The data for this pig could readily be omitted, for the pigs in this trial were individually fed.

The data substantiate the results obtained in the first series in that there were no appreciable differences between the check and the 10 percent molasses rations in regard to average daily gains or efficiency of feed utilization when measured by the amount of total digestible nutrients required per pound of gain. Because of trouble with enteritis in the first series of trials, the average amount of feed required and the cost per pound of gain were lower in the second series than in the first.

In the second series, the gains of the pigs receiving the 20 percent molasses ration were as rapid and as efficient as the gains made by those receiving either of the other two rations. With each increase in the amount of molasses fed there was a decrease in feed cost per pound of gain.

There were some cases of diarrhea of short duration among the pigs in this series of trials. The incidence, however, was no greater among the pigs receiving 20 percent molasses than those receiving the check ration.

The pigs in trials 8 and 9 were group fed, and in trials 7, 10, and 11 they were individually fed. In these individually fed trials the pigs were weighed for 3 consecutive days between each 2-week period as well as at the beginning and end. In studying these data it was observed that, during the first 2-week period, the pigs receiving the check ration gained considerably more than the others. During the second and third 2-week periods, however, the situation was reversed with the pigs which received the molasses rations making the most rapid gains. The result was that at the end of the trials the pigs receiving the different rations had made approximately the same gains. The data are presented in table 5.

TABLE 5. Average daily gains during each 2-week period by pigs which were individually fed in trials 7, 10, and 11.

RATION	PIGS	FIRST AND SECOND WEEKS	THIRD AND FOURTH WEEKS	FIFTH AND SIXTH WEEKS	WEIGHTED AVERAGES
	No.	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Check . . .	8	0.80	0.91	1.00	0.90
10% molasses .	9	0.76	0.96	1.10	0.94
20% molasses .	9	0.68	0.95	1.32	0.98

When the data were analyzed by analysis of variance this interaction of ration and period was highly significant, indicating that there was less than 1 chance in 100 of such an interaction being due to chance alone. When the mean gains presented in the table were adjusted to the same total digestible nutrient intake by means of covariance, the interaction was no longer significant. These results would, therefore, explain the significant interaction on the basis of feed intake and palatability. Some time is required for weanling pigs to develop a liking for rations containing 10 and 20 percent molasses. Perhaps greater gains would have been made on these rations if the amounts of molasses had been gradually increased over a period of at least 2 weeks rather than changed abruptly to these levels.

SERIES III. COMPARISON OF RATIONS CONTAINING 30 PERCENT AND 40 PERCENT CANE MOLASSES WITH THE CHECK RATION

In the preceding series of trials it was demonstrated that weanling pigs could utilize cane molasses efficiently in their rations in amounts up to 20 percent. Additional trials were planned, therefore, to study the value of rations containing still larger amounts of molasses, namely 30 and 40 percent.

In the two trials of this third series the pigs were individually fed and handled in a manner similar to those individually fed in the second series.

The rations are given in table 6. A summary of the results of the individual trials and of the combined data from the two trials are presented in table 7.

TABLE 6. Rations fed in the third series of trials.

RATION	CHECK	30% MOLASSES	40% MOLASSES
	Pounds	*Pounds*	*Pounds*
Rolled barley	60.5	42.0	31.5
Raw cane sugar	10.0	....	....
Cane molasses	....	30.0	40.0
Meat and bone meal	19.0	19.0	18.5
Soybean oil meal	9.5	8.0	9.0
Salt	1.0	1.0	1.0
Totals	100.0	100.0	100.0

TABLE 7. Summary of individual trials in series III comparing the check ration with rations containing 30 and 40 percent molasses, and a summary of the combined data from the two trials.

DATA RECORDED	TRIAL 12			TRIAL 13			WEIGHTED AVERAGES OR TOTALS		
Duration (*Days*)	42			42			....		
Ration	Check	30% molasses	40% molasses	Check	30% molasses	40% molasses	Check	30% molasses	40% molasses
Pigs beginning trial (*Number*)	3	3	3	3*	3	3	6	6	6
Average body weight (*Pounds*)									
Beginning	34.7	36.6	36.6	26.5	26.7	25.6	31.4	31.6	31.1
End	62.9	55.7	53.6	63.7	51.4	41.4	63.2	53.6	47.5
Weight gain (*Pounds*)									
Total	85	57	51	75	74	47	160	131	98
Average daily per pig	0.67	0.46	0.40	0.89	0.59	0.37	0.76	0.52	0.39
Total concentrate consumed (*Pounds*)	266	220	206	192	247	218	458	467	424
Pounds consumed per pound gain									
Concentrate	3.15	3.82	4.03	2.57	3.32	4.61	2.88	3.54	4.31
Total digestible nutrients	2.38	2.54	2.62	1.97	2.39	3.00	2.18	2.46	2.80
Feed cost per pound gain (*Cents*)	12.4	11.0	10.2	10.1	9.5	11.7	11.3	10.2	10.9

* One pig was unthrifty so was removed from the trial. The data for this pig could readily be omitted, for the pigs in this series of trials were individually fed.

Upon inspection of the data it can be seen that when compared with the pigs receiving the check ration, the average daily gains of the pigs decreased when 30 or 40 percent molasses was included in the ration. The total feed or the total digestible nutrients required per pound of gain increased with the feeding of these large amounts of molasses.

The average daily gains were analyzed by analysis of variance. The difference between the check ration and either of the other two rations was highly significant. When the average daily gains were adjusted to the same total digestible nutrient intake by means of covariance, the difference in average daily gain between the check ration and either of the molasses rations was no longer significant. These results would indicate that the poor gains obtained when feeding the high levels of molasses were due largely to reduced feed consumption.

There was considerably more diarrhea among the pigs receiving molasses than those receiving none. The pigs receiving 40 percent molasses had especially severe diarrhea.

In spite of the reduced weight gains and the large amounts of feed required per pound of gain, the molasses rations cost somewhat less per pound of gain than the check ration. This lower cost is due to the presence in the feed of large amounts of the cheap molasses.

In these two trials there was no apparent adaptation to the high levels of molasses, as was observed with the 10 and 20 percent levels in the second series. The pigs receiving the check ration made greater gains in the same relative magnitude throughout the three periods of the trials when compared with those receiving 30 and 40 percent molasses.

DISCUSSION AND CONCLUSIONS

The three series of trials indicate quite conclusively that pigs from the time of weaning until they reach a weight of 60 or 70 pounds can utilize cane molasses efficiently up to levels of 20 percent of the ration. There were no appreciable differences in the amounts of total digestible nutrients required per pound of gain. These data indicate that molasses is equal to barley when fed at these levels and when compared on the total digestible nutrient basis. The feed cost per pound of gain decreased with the increase in the amount of molasses fed.

From the data presented it would appear, however, that still better gains would have resulted had the amounts been gradually increased rather than raised abruptly to the 10 and 20 percent levels. At least 2 weeks are required by the young pig to develop a liking for the molasses rations. No such adaptation could be observed with the rations containing greater amounts of molasses. Apparently these levels were so high that, at least during the 6 weeks of the trial, the pigs were never able to develop an appetite for such quantities.

With levels of 30 and 40 per cent molasses in the rations the rate of gain and efficiency in the utilization of feed or of total digestible nutrients decreased markedly. From an analysis of the data it would appear that the poor gains obtained when feeding these high levels of molasses were due largely to reduced feed consumption. This reduced consumption may be caused by either the bitter taste of the large amounts of molasses or the physical nature of the feed. The feed was extremely gummy and sticky immediately after mixing and became hard and lumpy after a few days.

Another factor causing the poor gains and poor utilization of the high molasses rations was probably the accompanying diarrhea. This condition would tend to lower the proportion of the feed digested.

The feed cost per pound of gain was considerably lower with the two highest levels of molasses than with the check ration. The cost was not, however, any lower in relation to the check ration than was the 20 percent level in the second series. Because of the much longer growing period that would be required by the pigs when receiving more than 20 percent molasses, considerably more labor and housing would be required per pound of gain. During this early and critical part of the pig's life it is good practice, also, to get at least reasonably good gains because the pigs then go into the feed lot at the weight of 60 or 70 pounds in a vigorous and thrifty condition and make rapid and efficient gains later. In spite of low feed costs when feeding 30 and 40 percent molasses, other factors, therefore, would still make the feeding of such large amounts unprofitable.

Whether the results obtained in these trials would apply to rations containing other ingredients is open to question. As pointed out in the literature review, it would appear that higher levels of molasses can be utilized by pigs when receiving rations fairly high in fiber than when receiving rations low in fiber. Barley, used in the rations fed in the trials reported in this bulletin, is considerably higher in fiber than is corn, the cereal commonly used in swine rations on the mainland.

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