WOOD MOLASSES AS COMPARED TO CANE MOLASSES IN FATTENING RATIONS FOR SWINE

by

WILLIAM KIMBALL OUSTERHOUT

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1949

APPROVED:

[redacted]

Associate Professor of Animal Husbandry

In Charge of Major

[redacted]

Chairman of Department of Animal Husbandry

[redacted]

Chairman of School Graduate Committee

[redacted]

Dean of Graduate School

ACKNOWLEDGEMENT

To Doctor William C. Weir, Associate Professor, Department of Animal Husbandry, Oregon State College, for his valuable assistance and suggestions in reporting and summarizing this experiment. To Doctor Fred F. McKenzie, Chairman, Department of Animal Husbandry, Oregon State College, for his aid in setting up and making this experiment possible. To Doctor J. R. Haag, Nutrition Chemist, Agricultural Experiment Station, Oregon State College, for his analyses of the feeds and molasses used in this experiment; and to Doctor Andrea C. Overman, Associate Professor, School of Home Economics, Oregon State College, for her aid and assistance in conducting the pork palatability tests.

The author is extremely grateful also to the Oregon Forest Products Laboratory of the Oregon State College School of Forestry and the Pacific Northwest Forest and Range Experiment Station of the U. S. Forest Service for furnishing the wood molasses and their support in making this experiment possible.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
HISTORICAL	4
CANE MOLASSES	4
WOOD MOLASSES	7
EXPERIMENTAL PLAN AND PROCEDURE	12
OBJECT	12
PLAN	12
ASSIGNMENT TO LOTS	12
RATIONS	12
INTRODUCTION TO RATIONS	13
METHOD OF FEEDING	13
QUALITY OF FEEDS	13
PENS	14
WEIGHTS	14
PROCEDURE IN CHANGING RATIONS	14
PORK PALATABILITY	15
THE FEEDING TRIAL	16
RESULTS	20
DISCUSSION	33
SUMMARY	34
APPENDIX	36
BIBLIOGRAPHY	45

LIST OF CHARTS, TABLES, AND FIGURES

		Page
Chart 1.	Growth of Pigs in Lots 1 and 2 Growth of Pigs in Lots 3 and 4	21
Chart 2.	Growth of Pigs in Lots 5 and 6 Growth of Pigs in Lots 7 and 8	24
Chart 3.	Comparison of Gains in Lots 1, 5, 6 . Comparison of Gains in Lots 1, 7, 8 .	26
Chart 4.	Comparison of Gains of Lots 1, 2, 3, and 5	27
Table 1.	Approximate Analyses of Douglas-fir Sugar Molasses	11
Table 2.	Rations Fed in Wood Molasses Experiment	16
Table 3.	Analysis of Feeds Fed	19
Table 4.	Results of Feeding Trial	22
Table 5.	Cost of Feeds Fed	28
Table 6.	Dressing Percentage by Lots	29
Table 7.	Pork Palatability Results	32
Figure 1.	Lot I, Basal Ration	37
Figure 2.	Lot II, Basal Plus 30 Percent Cane Molasses	38
Figure 3.	Lot III, Basal Plus 30 Percent Cane Molasses	39
Figure 4.	Lot IV, Basal Plus 30 Percent Cane Molasses Plus 5 Percent Dried Brewers Yeast	40

LIST OF CHARTS, TABLES, AND FIGURES
(continued)

		Page
Figure 5.	Lot V, Basal Plus 30 Percent Wood Molasses	41
Figure 6.	Lot VI, Basal Plus 30 Percent Wood Molasses Plus 5 Percent Dried Brewers Yeast	42
Figure 7.	Lot VII, Basal Plus 15 Percent Wood Molasses	43
Figure 8.	Lot VIII, Basal Plus 15 Percent Wood Molasses Plus 5 Percent Dried Brewers Yeast	44

WOOD MOLASSES AS COMPARED TO CANE MOLASSES IN FATTENING RATIONS FOR SWINE

INTRODUCTION

The establishment of new uses for low-grade wood and wastes is important for the practice of forestry and the full utilization of the timber resources in the United States. Millions of tons of wood waste are being lost each year through lack of markets. Some of the more recent attempts to put this wood waste into a useable form are the manufacture of wood-sugar, wood-yeast, alcohol, and wood-sugar molasses. All these products use acid hydrolysis of wood as the primary conversion, although the final conversion and purification processes vary widely from simple neutralization and evaporation to fermentation by various microorganisms. Some products are much more economically produced than others, but the unit value of the final product varies, as does the value of the by-products.

As the dry matter in wood-sugar molasses is composed of approximately 82 percent fermentable and 15 percent unfermentable sugars, it has been proposed that wood-sugar molasses may serve as a substitute for carbohydrate livestock feeds. Livestock feeds, particularly the carbohydrate feeds, are at a premium on the markets because of increased demand for human consumption, therefore an economical source of carbohydrates is needed as a grain substitute. McElhanney (34, p. 125-6) in an article on uses for wood wastes, points out that one should not overlook the possibility of utilizing the crude sugars of wood hydrolysis for purposes other than the production of alcohol. Some thought might be given to the

possibility of concentrating to molasses the dilute sugar solutions obtained for feeding livestock.

Blackstrap molasses from sugar cane has been used for years as a livestock feed, as has molasses from the beet sugar industry, but recent research by cane sugar chemists has indicated that new processes for purifying the syrup will increase the sugar and thereby greatly decrease the available blackstrap (21, p.5). In addition, much of the world's supply of glucose is made by the hydrolysis of starch, which is obtained from carbohydrate feeds.

The studies reported in this paper deal with the effects of feeding swine rations containing varying amounts of wood-sugar molasses and a comparison of the results with those obtained from similar rations containing cane molasses. Only a limited number of pigs was available and as the molasses is being produced at only one experimental pilot plant, it was felt that this experiment should be rather preliminary and not serve as an attempt to solve all the problems of the suitability of wood-sugar molasses as a stock feed, but merely serve as a guide in planning further experiments with larger numbers of animals so that statistically sound conclusions could be reached. As Rasmussen (38, p. 20) at the Utah Agricultural Experiment Station had found that beet molasses gave better results as a swine feed when 5 percent dried brewers' yeast was added to the ration, a ration containing 5 percent yeast was added to the cane molasses and to the two levels of wood molasses. It was also felt that, inasmuch as wood yeast can be produced from wood waste, this

might serve somewhat as a guide for future work with wood yeast. The wood molasses was fed at two levels, one of which was the maximum satisfactory level for cane molasses, and the other just half the higher level.

The original plan of this experiment was to compare wood molasses against both cane and beet molasses and it was set up and conducted as such. However, after the experiment was finished and the results tabulated, it was found that the beet molasses used in the feeding trial was actually cane molasses and not beet. Therefore, there are two lots, II and III, on the same ration throughout this experiment.

HISTORICAL

CANE MOLASSES. The majority of hog feeding experiments with molasses to date has been done with cane molasses. Results are conflicting, depending on concentrations fed and prices of molasses and the other feeds fed. In 1907, Lindsey, Holland and Smith (32, P. 22-23) in Massachusetts advised against using molasses for pigs except as an appetizer, for the price of the molasses was higher, according to feeding values, than other feeds. In 1910, Burns (7, p. 12) in Texas, found that the most rapid and economical gains were made by the hogs on a basal ration of corn, next were the hogs on 25 percent molasses and 75 percent corn, and least economical were the hogs on 50 percent molasses. Workers at Wisconsin (3, p. 119) in 1933-34 found that molasses was worth no more and often less than corn for pigs. In 1937 the Wisconsin station (4, p. 15) reported that molasses was worth about half as much as ground corn when used to replace one-third of the corn in the ration. Bohstedt and co-workers (6, p. 16) at Wisconsin in 1933 reported that with pigs fed on molasses, the feed per pound gain was increased and the cost of gain was higher than with pigs fed on corn. In another publication (5, p. 52), they stated that molasses was worth less than corn under usual price relationships and that in no case was it worth its purchase price.

At the Oregon station in 1919, Fjeldsted and Potter (16, p. 13) achieved fair gains using 20 percent molasses, 72 percent barley, and 8 percent tankage in one experiment; and 20 percent molasses and 80

percent millrun in another. However, they stated that molasses would not be economical to feed when bought by the barrel, as barreling added about 50 percent to the cost. This statement appeared in 1930 in another Oregon bulletin by Oliver and Potter (37, p. 19). Similar results were obtained in two other Oregon experiments (10, p. 1), (11, p. 1) in which molasses was substituted in part for barley and when molasses was added to oat shorts. At the Missouri Agricultural Experiment Station (13, p. 13) in 1935 workers concluded that hogs do not relish a sweet feed and that the use of molasses for fattening was therefore limited. They reported that, when molasses was used as a substitute for corn in the rations, gains were slow, more feed was required per unit gain, and in every case molasses was much less valuable than corn. Barnett and Goodell (1, p. 18-19) in 1923 at the Mississippi Agricultural Experiment Station, found with hogs weighing 160 pounds, that when the rations contained 25 percent or 37.5 percent molasses, with corn shorts and tankage, the basal lots made the most rapid and economical gains. Hackedorn and Sotola (19, p. 22-26) in 1916 at the Washington station reported that when molasses was substituted for barley or pea forage in growing and fattening rations, more rapid gains resulted. They concluded that molasses was a cheaper feed than barley. Henke (26, p. 14) in 1933 in Hawaii found that for growing pigs weighing from fifty to one hundred pounds, molasses was worth as much per pound as rolled barley, providing that molasses did not make up more than 20 percent of the ration. In the annual report for 1940

(2, p. 30-31), Hawaiian workers reported that for pigs over 100 pounds in weight, molasses can be used to replace barley in amounts up to 40 percent of the total ration if the hogs are gradually adjusted to the high level of molasses in the diet. Gervacio (18, p. 492) in the Philippines, in comparing molasses as a substitute for rice bran, found that the most efficient utilization of feed was made by the rice bran pigs but, due to a price difference, the most profitable gains were made by the 30 percent level of molasses, followed by 20 percent molasses, 10 percent molasses, and the rice bran lot last.

Willett and others (44, p. 13-14) in Hawaii found that pigs from the time of weaning until they reached a weight of 70 pounds could utilize cane molasses as efficiently as barley up to levels of 20 percent of the ration. On a total digestible nutrient basis, the pigs on the molasses ration were as efficient as those on the barley ration, and the feed cost per pound gain decreased with an increase in the amount of molasses fed. They reported that even better gains would have resulted had the pigs been gradually accustomed to the 10 and 20 percent levels rather than started abruptly. It took at least two weeks for these pigs to develop a liking for the molasses, and pigs on higher levels did not adjust themselves during the entire 6-week feeding period.

Thompson (42, p. 113-115) in 1937 fed levels of 20 percent and 40 percent cane molasses to hogs, substituting for oats and corn in fattening rations and found that with 20 percent molasses the pigs

made the most economical gains and that, although molasses cost 54 percent as much as corn, it was actually worth 84 percent as much. Thompson and Hillier (43, p. 146-149) in a subsequent experiment found that with similar rations, molasses increased the feed required per hundred pounds gain and that the most rapid and economical gains were made by pigs on corn, tankage, and alfalfa meal. The molasses value was less than half its cost in all cases. Kansas (9, p. 18) workers found that blackstrap molasses was not a satisfactory feed at 11.5 percent of the ration when substituted for corn. When 20.3 percent molasses was fed, they found that 100 pounds of molasses replaced only 7 pounds of corn; and that when 29.4 percent molasses was fed, 100 pounds of molasses replaced 18 pounds of corn.

Ferrin (15, p. 1-3) at the University of Minnesota found that oats and molasses were a better mixture than corn and molasses. He found that the molasses-corn ration was not as economical as the molasses-oats ration. Carroll and Burroughs (9, p. 1-3) at Illinois reported that pigs receiving 20 and 30 percent cane molasses gained more slowly and required more feed per pound of gain than the lot receiving no molasses. To have been profitable to feed the molasses, it would need to cost less than one-fifth the price of corn.

WOOD-MOLASSES. The feeding of wood sugar to livestock is not new. During World War I, the Forest Products Laboratory at Madison, Wisconsin, produced molasses from wood, and feeding experiments at the University of Wisconsin rated the molasses as an acceptable feed

(21, p. 2), (35, p. 319). After 1930, some wood sugar was fed to stock in Germany. The present wood molasses being produced at the Forest Products Laboratory is produced by a process known as "The Madison Wood-Sugar Process" (20, p. 244), (21, p. 1), (24, p. 890), (25, p. 1-20), which is an improved process much faster and yielding more sugar per ton of dry wood than previous processes, most of which were developed in Germany (36, p. 95), (39, p. 1-6), (40, p. 38-46).

No wood molasses has been produced commercially as yet, and few feeding trials have been run. The only commercial wood-sugar plant in the country is located in Springfield, Oregon, (14, p. 278) but it is not in operation at present. The Forest Products Laboratory, Madison, Wisconsin, has constructed a pilot plant and is producing considerable amounts of molasses for experimental use (21, pp. 1-2), (22, p. 157-161), (23, p. 8). A brief description of the process is given by E. E. Harris, Chemist Specialist (23, p. 4-5).

> "Wood chips, or a mixture of wood chips with shavings and sawdust, were charged into the hydrolyzer, filling it to the top. This was packed down by placing the cover on the hydrolyzer and applying steam through a quick-opening valve at the top of charge having a vent open at the bottom. The hydrolyzer was filled and packed alternately until full. The cover was then fastened down and with a vent open at the top, steam was introduced at the bottom to remove air and to heat the charge of wood. When steam flowed from the vent, the vent was closed and steaming continued until a pressure of 50 pounds was indicated in the hydrolyzer. The water pump, acid pump, and steam injector were started to produce dilute acid at a temperature of 150° C. and a concentration so as to produce 0.5 percent acid in the hydrolyzer when the moisture in the wood and that introduced by steaming

was taken into consideration. Dilute acid was introduced at a rate of one-twentieth of the dry weight of the wood per minute, or 20 pounds of dilute acid per minute for a charge of 400 pounds, dry basis, of wood. The temperature of the incoming acid was raised at a constant rate so as to provide for the introduction of dilute acid at 187° C. after about one and three-fourths hours, after which this temperature was maintained until the end of the hydrolysis. Thirty minutes after the introduction of acid was started, a valve at the bottom was opened, allowing sugar solution to flow from the hydrolyzer into the flash tank at a rate of about one-sixteenth of the weight of the charge of dry wood per minute. At the end of three hours, when the concentration of the sugar solution coming from the hydrolyzer fell to about one percent, the pumps and steam injector were shut off and the hydrolyzer drained of free liquor. When steam flowed through the output line, the valve was closed and the lignin discharge valve opened. While the lignin was being discharged, a steam line behind the screen upon which the charge rested was opened to assist in removing lignin from the screen.

"After about 100 pounds of the acid-sugar solution had collected in the flash tank, lime was introduced to bring the pH to 3.7 and then the neutralized solution was allowed to flow from the neutralizer at a rate equal to the rate solution was coming from the hydrolyzer while adding lime to keep the pH at 3.7. Calcium sulfate was removed by filtration. The average concentration of sugar for the total hydrolyzate ranged from 4.5 to 6 percent.

"Following neutralization the solution was evaporated to 50 percent sugar concentration."

The cost of the wood molasses has been estimated (23, p. 7-9) to be between $13.20 to $17.60 per ton, based on estimates of a plant designed to produce 50 tons of molasses per day.

The data on feeding experiments with wood molasses are extremely limited, however E. E. Harris (23, p. 3-4) of the Forest Products Laboratory states that feeding experiments are in progress or have just been completed at seven different colleges and experiment

stations throughout the country. In addition to the work done at Oregon State College, the following is in progress: Montana State College (12, p. 1-2) is conducting feeding tests on molasses from lodgepole pine for fattening cattle and sheep; the State College of Washington is feeding dairy cows with grass silage made with Douglas-Fir wood molasses; the Southern Forest Experiment Station (33, p. 1-2) has recently completed limited palatability tests by feeding range cattle from a trough containing red oak molasses, with favorable results, and a four-week feeding trial with hogs in which they found that the inclusion of large amounts of oak molasses caused the hogs to lose weight; Mississippi State College (17, p. 1) has found that red oak molasses when fed as 75 percent of the carbohydrate does not contain the equivalent of corn in food value for pigs. Partially neutralized Douglas-fir molasses was fed to cattle and pigs at the University of Idaho (30, p. 1) with poor palatability; the University of Wisconsin is starting to feed aspen molasses by adding it to roughage and as a preservative in grass silage. The State College of Washington is planning extensive experiments with the use of yeast made from wood molasses to determine the feeding value for chickens and turkeys and they also plan preliminary tests with hogs.

A preliminary trial has just been completed at Oregon State College by the Department of Dairy Husbandry (28, p. 1) in which it was shown that the total digestible nutrients of wood molasses were as well utilized as from cane molasses or from barley.

The accompanying table gives the approximate composition of Douglas-fir sugar molasses:

TABLE 1

Approximate Analysis of Douglas-Fir Sugar Molasses

Fermentable Sugars (consists of about 3.7 percent mannose, 1 to 2 percent galactose, and the remainder glucose)	41 percent
Unfermentable Sugars (mixture of xylose and arabinose)	7.5
Acetic acid	.5
Miscellaneous	1.0
Moisture	50.0
Total	100.0

Table modified from table in letter written by Dr. E. F. Kurth to Dean W. A. Schoenfeld (29, p. 1)

EXPERIMENTAL PLAN AND PROCEDURE

OBJECT. The experiments reported in this work were designed to compare the value of wood-sugar molasses with cane molasses as a feed for growing swine, and to determine if brewers' yeast is of value as a supplement to a ration in which part of the carbohydrate is supplied by wood-sugar molasses.

PLAN. Twenty-four fall-farrowed feeder pigs from the college herd were placed on experiment soon after weaning. All lots were kept under as nearly identical conditions as possible during the experiment. The experiment was terminated when the pigs in each lot reached an average weight of 200 ± 3 pounds. They were continued on experimental rations, however, until they were slaughtered.

ASSIGNMENT TO LOTS. The pigs were assigned to lots so as to make all lots as nearly identical as possible. Breed, sex, weight, and probable outcome were taken into consideration. The lots varied slightly in average weight as there was only a limited number of pigs to use for this experiment.

RATIONS. The basal ration for the experiment consisted of ground barley, tankage, ground alfalfa, steamed bonemeal, and iodized salt. The rations of all lots receiving molasses were adjusted to the same nutritive ratio as Lot I, basal, by substituting the molasses and yeast for tankage as well as barley. The nutritive ratio in all cases was adjusted to 1:5.9 to 1:6.0. In the wood molasses lots, the rations were computed to the proper nutritive ratio using cane molasses at the proper level, then

substituting wood molasses pound for pound, adjusted to the same dry matter content as the cane molasses. All lots received a commercial vitamin D preparation, irradiated animal sterols, in the feed. Enough was given to supply the total daily requirements as set forth by the National Research Council (27, p. 2).

INTRODUCTION TO RATIONS. For several days prior to the beginning of the experiment, all pigs were fed small amounts of cane molasses in the feed to get them used to the taste of the molasses. The wood molasses was not available for feeding until the experiment started.

METHOD OF FEEDING. All rations were hand fed twice daily. The dry ingredients for each lot were prepared in bulk well in advance, and the molasses was mixed approximately every other day. Each lot was fed only what it would clean up each feeding. The molasses-grain mixture was very gummy and sticky, so enough water was added to make a thick slop, which was stored in wooden tubs until fed, but never longer than four days, as the mixture began to ferment after that length of time. The basal ration, Lot I, was mixed with water to the same consistency as the other feeds. The pigs were fed in open troughs and, due to the consistency of the feed, there was considerable wasting of feed, which tended to make the efficiency of gains rather poor. Lots V and VI (30 percent wood molasses) seemed to waste more feed than the other lots.

QUALITY OF FEEDS. The feeds fed were those used by the Department of Animal Husbandry for feeding the swine herd and had

been purchased on the open market. The barley was Pacific coast barley, the tankage was designated as "Digester tankage, 60% protein," the alfalfa meal was adjudged to be comparable to "Alfalfa meal, good," in Morrison's feeding tables (35, p. 953-993). The cane molasses was purchased from a feed dealer and an analysis made by the Agricultural Chemistry Department. The wood molasses was Douglas-fir molasses and was supplied by the Forest Products Laboratory at Madison, Wisconsin.

PENS. Because of limited facilities, the pigs were kept inside at all times. The pens for each lot were approximately 13 feet by 15 feet, and occupied the entire floor of a small barn. The pens were kept bedded with straw or shavings at all times.

WEIGHTS. All pigs were weighed into the experiment by individual weighings on three consecutive days. The average weight of the three-day weighing was used and the second day of the weighing marked the beginning of the trial. Each pig was weighed every 14 days from the beginning to the end, with the exception of one period of 16 days. At the end of the trial, the pigs were again weighed on three consecutive days, the second day marking the end of the experiment, and the average weight for the three weighings was recorded as the final weight. Daily records were kept of feed fed, condition of pigs, occurrence of diarrhea, and any unusual conditions.

PROCEDURE IN CHANGING RATIONS. As the experiment progressed, it became increasingly evident that the pigs on the 30 percent

wood molasses ration, Lot V, were not doing well, while the pigs in Lot VI, 30 percent wood molasses plus 5 percent dried brewers' yeast, were doing somewhat better. By April 1, it appeared that the pigs in Lot V were going to die unless the ration was changed, so it was adjusted to contain 10 percent dried brewers' yeast, to determine if the yeast in excess of 5 percent would be more beneficial than 5 percent. The nutritive ratio of the new ration was the same as that of the previous ration. The pigs were weighed on the day the ration was changed.

PORK PALATABILITY. After the pigs were slaughtered, chops of a uniform thickness were taken from the center of the left loin on each pig and frozen. Dr. Andrea C. Overman of the Home Economics Department conducted palatability trials on the individual chops, keeping record of cooking loss, weight of drippings, tenderness as determined by a shear test, and palatability scores based on texture, preference, flavor, and aroma of the fat and lean of each chop.

THE FEEDING TRIAL

This experiment was begun on February 2, 1948. Eight lots of three pigs, each averaging approximately 59 pounds, were assigned to pens located in the small barn at the Wyatt ranch on the college farm.

All rations contained the same feeds, with the exception of molasses. The composition of the rations fed is given in Table 2. The analysis of the feeds fed is given in Table 3.

TABLE 2

RATIONS FED IN WOOD MOLASSES EXPERIMENT

LOT I, BASAL		
Ground barley	86.3	percent
Tankage	8.0	
Ground alfalfa	5.0	
Iodized salt	0.5	
Steamed bone meal	0.2	
Total	100.0	
LOT II, BASAL PLUS CANE MOLASSES (30%)		
Ground barley	54.3	percent
Tankage	10.0	
Ground alfalfa	5.0	
Cane molasses	30.0	
Iodized salt	0.5	
Steamed bone meal	0.2	
Total	100.0	

TABLE 2 (continued)

RATIONS FED IN WOOD MOLASSES EXPERIMENT

LOT III, BASAL PLUS CANE MOLASSES (30%)

Ground barley	54.3 percent
Tankage	10.0
Ground alfalfa	5.0
Cane molasses	30.0
Iodized salt	0.5
Steamed bone meal	0.2
Total	100.0

LOT IV, BASAL PLUS CANE MOLASSES (30%) PLUS DRIED BREWERS' YEAST (5%)

Ground barley	52.3 percent
Tankage	7.0
Ground alfalfa	5.0
Cane molasses	30.0
Dried brewers' yeast	5.0
Iodized salt	0.5
Steamed bone meal	0.2
Total	100.0

LOT V, BASAL PLUS WOOD MOLASSES (30%) (FED UNTIL APRIL 1, 1948) A

Ground barley	54.3 percent
Tankage	10.0
Ground alfalfa	5.0
Wood molasses	30.0
Iodized salt	0.5
Steamed bone meal	0.2
Total	100.0

LOT V, BASAL PLUS WOOD MOLASSES (30%) PLUS DRIED BREWERS YEAST (10%) B (FED FROM APRIL 1 TO JUNE 6, 1948)

Ground barley	50.3 percent
Tankage	4.0
Ground alfalfa	5.0
Wood molasses	30.0
Dried brewers' yeast	10.0
Iodized salt	0.5
Steamed bone meal	0.2
Total	100.0

TABLE 2 (continued)

RATIONS FED IN WOOD MOLASSES EXPERIMENT

LOT VI, BASAL PLUS WOOD MOLASSES (30%) PLUS DRIED BREWERS YEAST (5%)

Ground barley	52.3	percent
Tankage	7.0	
Ground alfalfa	5.0	
Wood molasses	30.0	
Dried brewers' yeast	5.0	
Iodized salt	0.5	
Steamed bone meal	0.2	
Total	100.0	

LOT VII, BASAL PLUS WOOD MOLASSES (15%)

Ground barley	70.3	percent
Tankage	7.0	
Ground alfalfa	5.0	
Wood molasses	15.0	
Iodized salt	0.5	
Steamed bone meal	0.2	
Total	100.0	

LOT VIII, BASAL PLUS WOOD MOLASSES (15%) PLUS DRIED BREWERS YEAST (5%)

Ground barley	68.3	percent
Tankage	6.0	
Ground alfalfa	5.0	
Wood molasses	15.0	
Dried brewers' yeast	5.0	
Iodized salt	0.5	
Steamed bone meal	0.2	
Total	100.0	

TABLE 3

ACTUAL ANALYSES OF FEEDS FED

Item	Dry Matter	Protein	Fat	Ash	pH	Fiber
	%	%	%	%		%
Ground barley	89.24	13.17	1.51	2.89	--	4-4.5
Tankage	90.24	56.40	9.43	19.23	--	--
Alfalfa meal	87.77	14.38	1.39	9.06	--	28-30
Dried brewers' yeast	91.70	43.76	.44	6.92	--	--
Cane molasses Lots II, III, & IV	60.1	2.42	--	10.37	5.4	
Wood molasses	55.2	0.61	--	2.84	4.0	

RESULTS

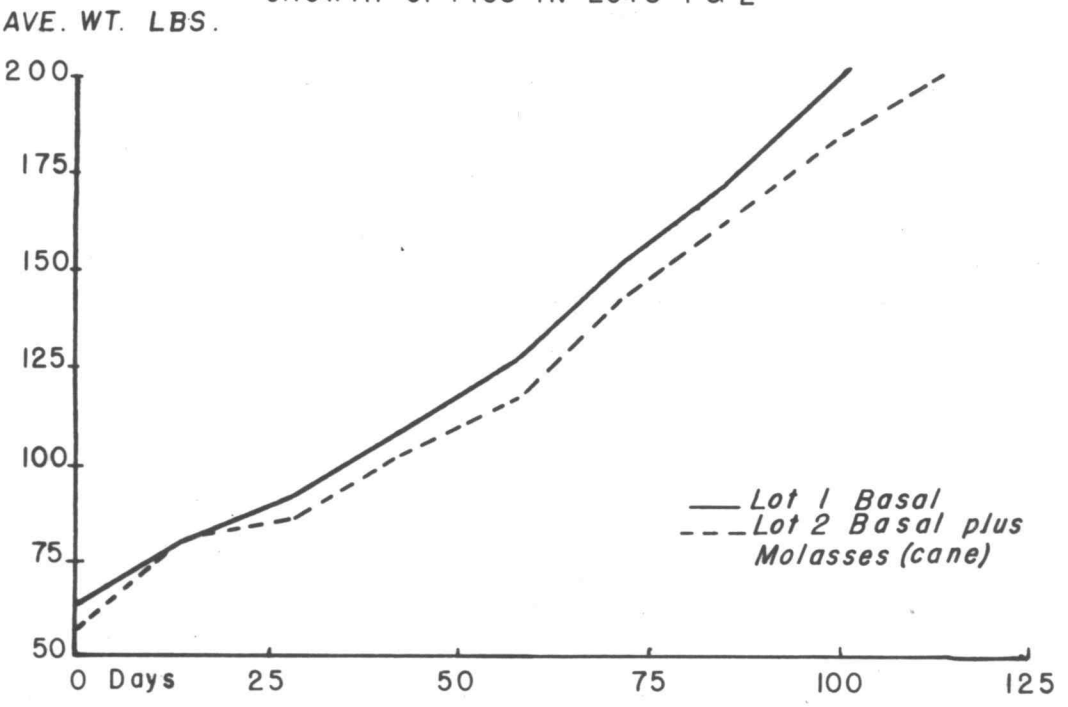
When the growth curves of Lots I and II are plotted (Chart 1), it may be seen that the basal ration (Lot I) gave consistently faster gains than the cane molasses ration (Lot II). The average daily gains for the entire period, as seen in Table 4, are 1.38 pounds per day for Lot I, and 1.29 pounds for Lot II. It took Lot II a little longer to reach finishing weight, and the cost of gain is somewhat higher because the cane molasses cost more on a dry matter basis than grain. This is in agreement with results obtained by the majority of the feeding experiments reviewed in the historical section of this paper.

In comparing Lot III, basal plus cane molasses, with Lot IV, basal plus cane molasses plus yeast, in Chart 1, it is shown that Lot IV made more rapid daily gains (1.35 lbs.) than Lot III (1.25 lbs.). It took Lot III nine days longer to reach finishing weight. In comparison of feed costs in Table 4, there is a difference of $3.20 per hundred pounds in favor of the slower gaining pigs. Efficiency of gain and the total feed consumed are very nearly the same for the two lots, therefore the increased cost is due to the high price of the yeast.

In comparing the growth curves of Lots V and VI, it may be seen in Chart 2 that for the first 10 to 25 days, the gains for Lot V were as good or better than Lot VI, then the gains dropped off until about the 45th day. The molasses-grain slop for Lot V was extremely unpalatable, so other methods of mixing the feed

CHART I

GROWTH OF PIGS IN LOTS 1 & 2



GROWTH OF PIGS IN LOTS 3 & 4

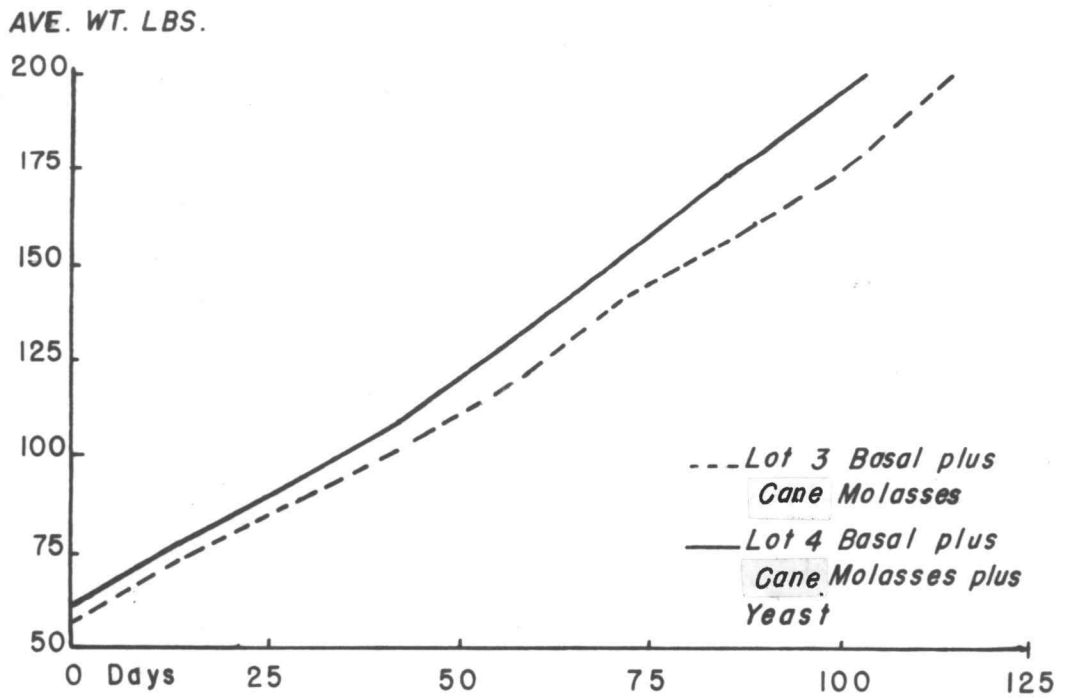


TABLE 4

RESULTS OF FEEDING TRIAL
INDIVIDUAL PIG BASIS

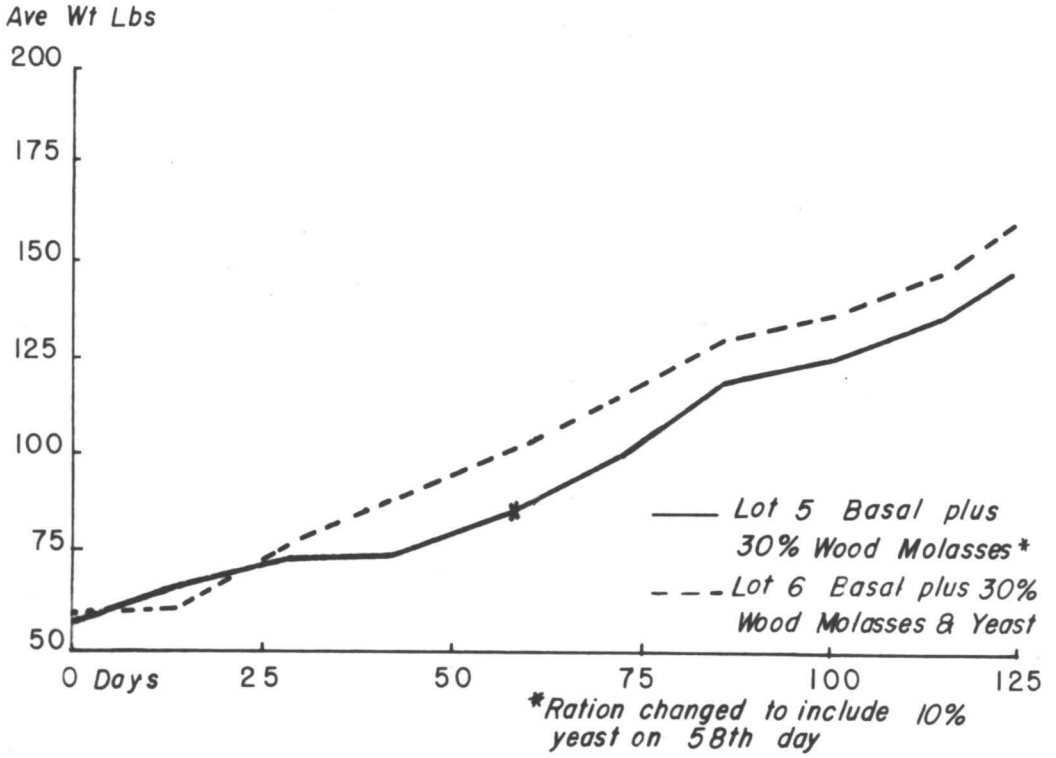
LOT	I	II	III	IV	V	VI	VII	VIII
Days on feed	101	113	114	105	124	124	124	114
Pigs per lot	3	3	3	3	3	3	3	3
Average initial weight-lbs.	63	56	57	60	57	58	59	57
Average final weight-lbs.	202	201	200	201	147	160	201	199
Average daily gain-lbs.	1.38	1.29	1.25	1.35	0.72	0.82	1.14	1.24
Av. daily feed consumed-lbs.	6.54	7.40	7.48	8.14	6.32	6.19	6.21	5.84
Feed cost per cwt. gain - $	19.95	23.10	24.13	27.53	35.67	29.84	20.73	20.42
Total feed consumed	661	836	853	855	784	768	770	666
Total dry matter cons.	594	681	705	707	650	637	663	574
Total gain-lbs.	137	146	142	142	90	102	141	142
Lbs. feed per 100 lbs. gain	477	574	599	603	872	753	545	470
Feed utilization (rank)	2nd	4th	5th	6th	8th	7th	3rd	1st
Lbs. dry matter per 100 lbs. gain	428	468	495	499	724	625	469	405
Dry matter utilization (rank)	2nd	3rd	5th	6th	8th	7th	4th	1st

were tried, and it was found that when no water was used in mixing the molasses and grain, the pigs appeared to eat better and waste less feed. The daily feed records do not show any increase in consumption, but personal observation before and after the water was excluded showed that the pigs liked the drier feed slightly better and did not root quite as much onto the floor. On the 58th day, the ration for Lot V was changed to include 10 percent dried brewers' yeast to determine if yeast in excess of 5 percent would give beneficial results. As can be seen in the chart, the gains increased up to the 85th day, when one pig went off feed and lost weight for several days. At this same date, one pig in Lot VI failed to gain for the next two weeks. When the average daily gain is calculated for Lot V before (.50 lbs.) and after (.92 lbs.) the ration was changed, and for the same periods for Lot VI (.76 lbs. before and .88 lbs. after), it may be seen that the yeast in excess of 5 percent of the ration did exert a beneficial effect in increasing the daily gains.

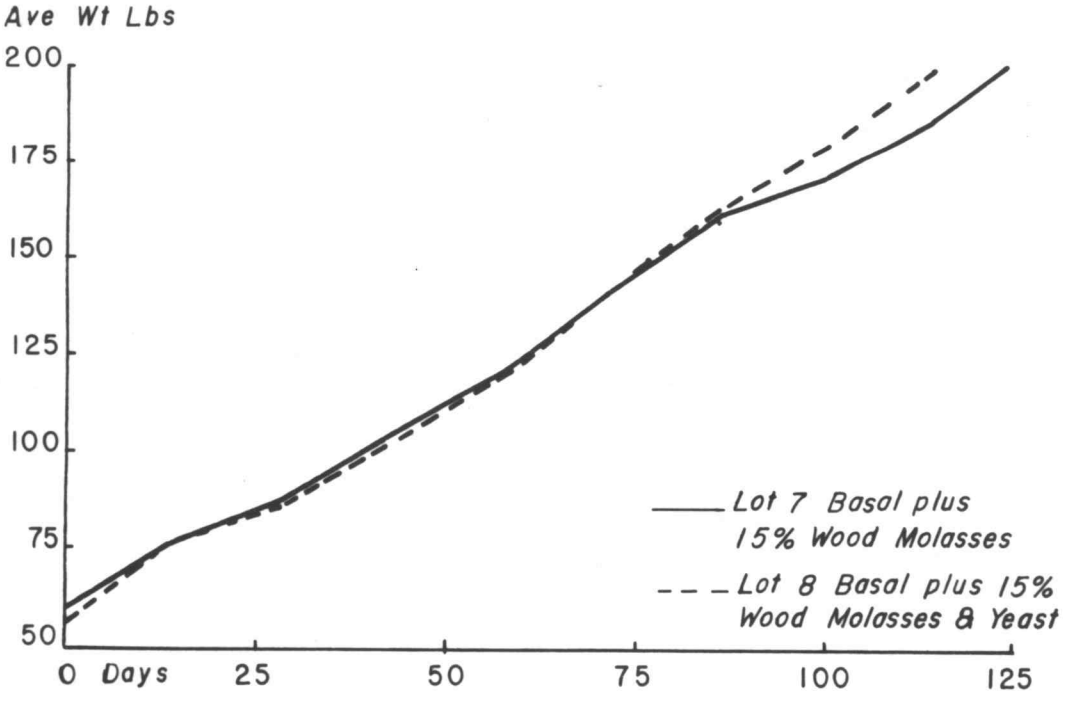
When the growth curves of Lots VII and VIII are compared on Chart 2, both lots made practically identical gains up to the 85th day when one pig in Lot VII went off feed and brought the average daily gains down. It took Lot VII 9 days longer than Lot VIII to reach finishing weight. A possible explanation for the erratic gains of these lots is that the pigs apparently reached a limit of tolerance for the molasses and went off feed for a few days until hunger overcame their dislike for the molasses. The addition of

CHART 2

GROWTH OF PIGS IN LOTS 5 & 6



GROWTH OF PIGS IN LOTS 7 & 8



yeast apparently increased the palatability, for the initial break in the growth curve of Lot VI did now show as soon as in Lot V. That the 30 percent level of wood molasses was too high is evident from the fact that even 10 percent yeast failed to stop the pigs from going off feed. Lot VII, which received no yeast, took longer to reach the breaking point than the lots on the higher levels of wood molasses and Lot VIII, which received yeast, does not show any break in the growth curve.

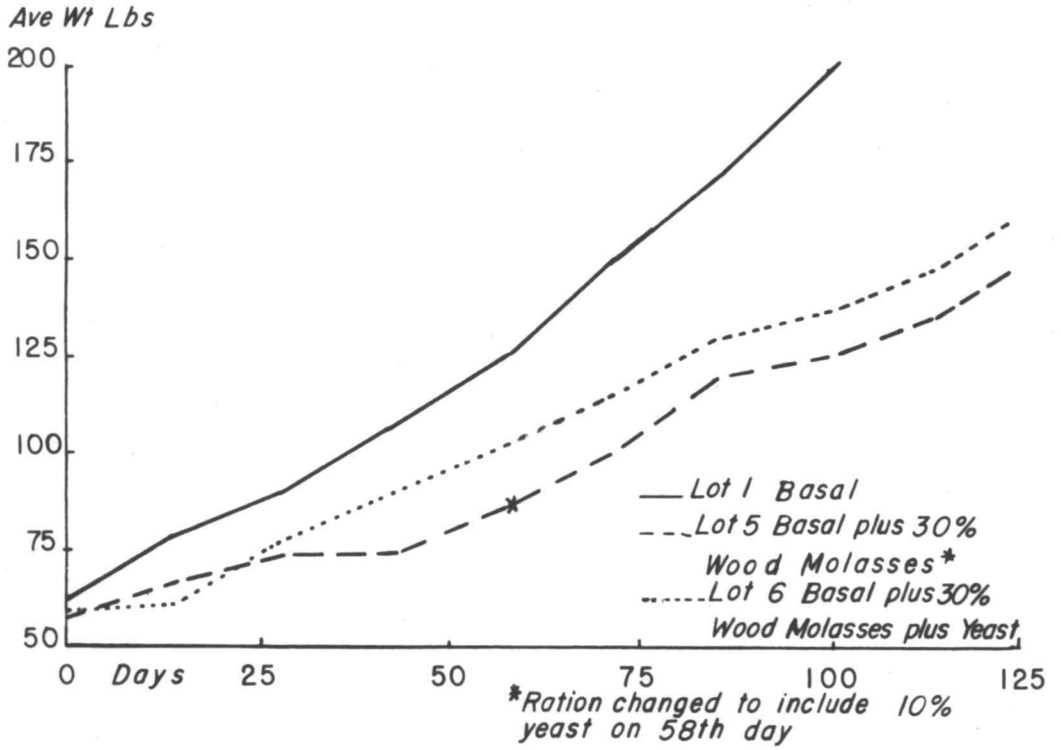
Chart 3 is included to compare the growth curves of Lots I, V, and VI, and of I, VII, and VIII, to show the differences in gains of the basal lot and the wood molasses lots. There is a wide spread between the daily gain of Lot I and of Lots V and VI, but between Lot I and Lots VII and VIII, there is only a small difference. This emphasizes the unsuitability of the 30 percent molasses rations.

Chart 4 compares the basal lot with all the molasses lots which did not receive yeast. Lot V is included even though it received yeast for part of the feeding period. It should be noted that when Lots II and III are compared, the daily gains are almost identical but the feed cost per hundred pounds of gain (Table 4) is higher for Lot III because of differences in the efficiency of feed utilization. This may be called our experimental error.

In Table 4, under "Days on Feed," it must be pointed out that all lots except V and VI were taken off the experiment when the pigs averaged 200 pounds. Lots V and VI were taken off on the 124th day when the last of the other lots finished, as it was obvious that they

CHART 3

COMPARISON OF GAINS OF LOTS 1, 5 AND 6



COMPARISON OF GAINS OF LOTS 1, 7 AND 8

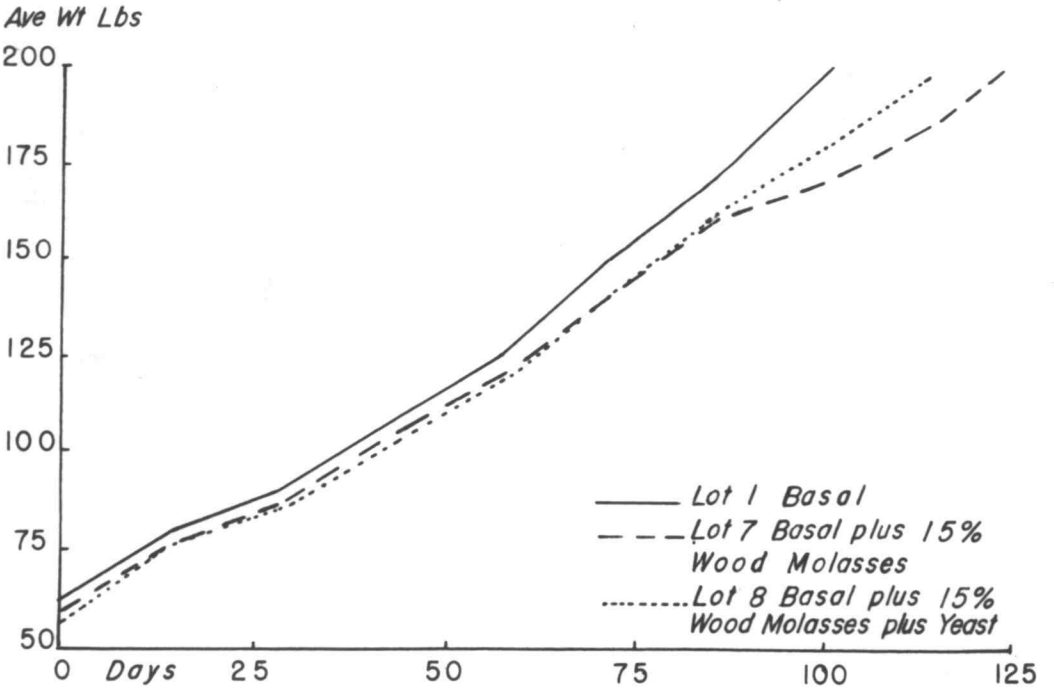
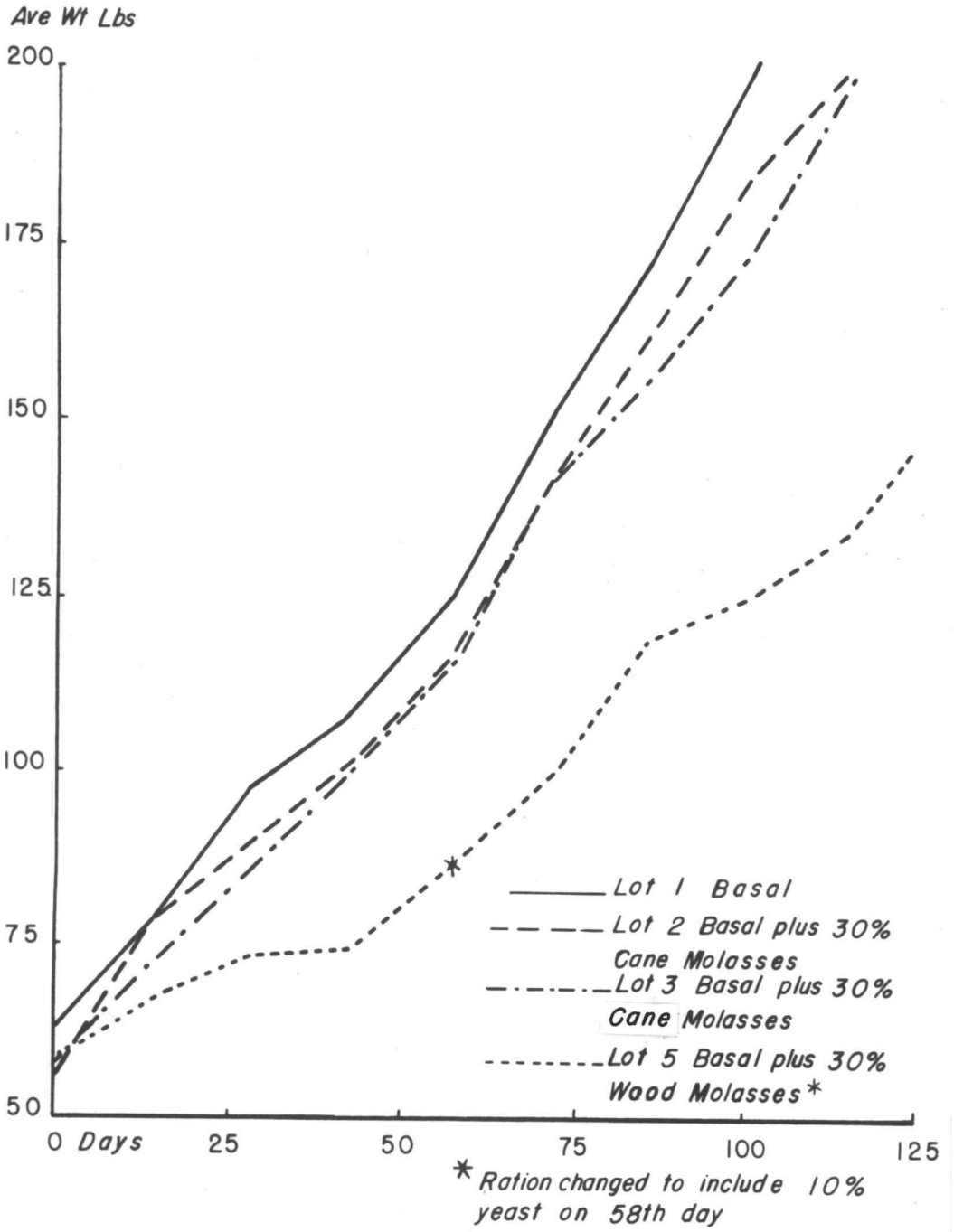


CHART 4

COMPARISON OF GAINS OF LOTS 1, 2, 3 AND 5



were doing poorly and would take a long time to reach finishing weight.

The relative efficiency of gain, when computed using total feed consumed, is very nearly the same as when computed using the total dry matter of the feeds fed. Lot II, which was in fourth place, advanced to third on the dry matter basis over Lot VII. This was due to the larger amount of moisture in the ration of Lot II.

Table 5 gives the cost of the feeds used in this experiment. The prices stated were the prices of the last orders of that item that had been purchased by the Department of Animal Husbandry. For the feeds especially purchased for this experiment, the actual cost is listed, less any freight charges. For the wood molasses, the cost was estimated, using the higher estimate given by the Forest Products Laboratory (25, p. 7-9) and adding approximately 50 percent to include cost of barrelling and handling.

TABLE 5

COST OF FEEDS FED

FEED	PRICE PER TON
Ground barley	$83.00
Tankage	120.00
Ground alfalfa	42.00
Wood molasses	30.00
Cane molasses	70.00
Dried brewers' yeast	320.00
Iodized salt	32.00
Steamed bone meal	95.00

Table 6 gives the average dressing percentages of each lot. They were calculated by dividing the dressed weight, including heads, by the sale weight. Two lots, V and VI, are considerably lower than the rest, emphasizing the fact that these pigs were not as fat as the others at the end of the experiment.

The amount of feed required per hundred pounds of gain is high in this experiment because of the gummy nature of the feed and because of the makeshift equipment used, which allowed the pigs to root a considerable amount of the feed onto the floor where it was wasted. It was observed that Lots V and VI wasted more feed than the other lots.

Because chronic diarrhea is characteristic when high levels of molasses are fed, every occurrence of diarrhea in this experiment was noted and it was found that in no case did the diarrhea become chronic. It did occur intermittently in the lots on cane and 30 percent wood molasses, but the basal lot and the lots on 15 percent wood molasses were not bothered.

TABLE 6

DRESSING PERCENTAGE BY LOTS

Lot Number	Total Sale Weight	Total Dressed Weight	Dressing Percent
I	612 lbs.	486 lbs	79.4 %
II	590	471	79.8
III	585	456	77.9
IV	585	466	79.6
V	420	310	73.8
VI	490	367	74.9
VII	575	451	78.4
VIII	600	480	80.0

Photographs of the individual pigs are presented in Figures one through eight. These pictures were all taken on the same day shortly after Lots I and IV were taken off the experiment. They show great differences in condition of hair coats of pigs in different lots. The pigs in Lots I and VIII were smooth and sleek looking, while the coats of others - particularly Lots V and VI - were very rough and shaggy. Lot V was much coarser looking than Lot VI. The hair condition of the other lots was intermediate between the extremely smooth and the extremely rough. The best doing pig in each lot usually had the smoothest hair coat, while the poorest pig was quite shaggy.

When the daily gains were compared statistically by analysis of variance (41, p. 219), a significant difference in daily rate of gain was found between lots. The daily gains of each lot were compared against each other by the method of minimum significant difference (31, p. 1). At the 5 percent level of significance, the gains of Lot V were significantly lower than all other lots except Lot VI, and the gains of Lot VI were significantly lower than all but Lots V and VII. At the 1 percent level of significance, the gains of Lot V were significantly lower than all buts lots VI and VII, and the gains of Lot VI are significantly lower than all but Lots V, VII, and VIII.

In the pork palatability tests, no apparent difference was noticed between the meat from pigs fed wood molasses and meat from the pigs in the other lots. The results of this test are presented

in Table 7. Texture, preference, aroma, and flavor of each chop were scored by six judges who differed considerably in their placings. Each judge sampled each chop and ranked it in order of fineness of texture and preference. The aroma was classified as strong or mild, normal or abnormal, and the flavor of the fat and of the lean were classified the same way. A numerical score was given each chop for each item and the scores for each lot totalled and the lots ranked in order of the scores given. Cooking loss was ranked with the least loss receiving the highest rank. Tenderness was determined by a shearing test, with the average of two or more readings listed and the rank determined from that. As there was so little difference between the wood molasses lots and the other lots, no statistical analysis was made. For all practical purposes, there was no difference in the taste of any of the chops.

It must be emphasized that this was only a preliminary trial and a small number of animals was used per lot. Therefore, no final conclusions should be made until further experimentation with larger numbers of animals warrants such conclusions.

TABLE 7

PORK PALATABILITY RESULTS

LOT NUMBER	I	II	III	IV	V	VI	VII	VIII
Texture (1, finest)	7	2	1	4	4	4	8	6
Preference (1, most preferable)	3	8	4	7	6	2	5	1
Aroma (1, mildest)	4	3	2	8	6	1	7	5
Aroma (1, most normal)	2.5	6	1	8	7	4.5	4.5	2.5
Flavor of lean (1, mildest)	5	2.5	7	7	7	1	4	2.5
Flavor of lean (1, most normal)	6.5	5	1.5	6.5	8	4	3	1.5
Flavor of fat (1, most mild)	2.5	1	2.5	8	7	5.5	5.5	4
Flavor of fat (1, most normal)	3.5	6.5	1.5	8	1.5	3.5	5.	6.5
Cooking loss (1, lowest)	6	1	3	2	8	7	4	5
Shearing test (1, most tender)	4	2	8	7	1	3	6	5
TOTAL of all tests	44	37	31.5	65.5	55.5	35.5	52	39
Wood molasses lots vs other lots (total of 4 lots)				178.0				182.0
FINAL RANK	5	3	1	8	7	2	6	4

DISCUSSION

As the results shown on the data sheet indicate, the 30 per cent level of wood molasses is too high. Several hypotheses have been advanced to explain the poor gains of Lots V and VI. They are: low palatability; dilution of essential nutrients in the basal ration by the wood molasses; toxic effects of the wood molasses; and inhibiting factor(s) present in the wood molasses which prevent utilization of some essential nutrient(s) in the basal ration.

The low palatability was evident to all who observed the pigs at feeding time. The pigs in Lots V and VI did not relish the feed, and Lots VII and VIII did not clean up their feed as fast as the lots on cane molasses. It was not possible in this experiment to determine if the other hypotheses for poor gains were true.

One possibility that should be investigated is the possible beneficial effects of adding more than 5 percent dried brewers' yeast to the 15 percent wood molasses ration. The 10 percent yeast level gave increased gains in Lot V, and perhaps it would increase the gains of a lower level molasses ration also. The present price of dried brewers' yeast is too high for this to be practical but, if present plans materialize, fodder yeast can be produced from wood waste at a price to compete with present-day protein feeds.

SUMMARY

Because of the limited number of pigs in each lot, no definite conclusions should be drawn. The following summary is set forth with the intention of serving only as a guide in planning further experiments and should not be regarded as final.

1. Poor gains and inefficient feed utilization resulted when growing pigs were fed a ration containing ground barley, tankage, ground alfalfa, iodized salt, steamed bone meal, and 30 percent by weight of Douglas-fir molasses. When dried brewers' yeast was included as 5 or 10 percent of the ration, the gains increased slightly in proportion to the amount of yeast fed.

2. When the wood molasses was fed as 15 percent of the ration, the pigs gained 1.14 pounds per head daily. The average daily gain of the basal lot was 1.38 pounds. On a ration containing 15 percent wood molasses and 5 percent dried brewers' yeast, the pigs gained more rapidly (1.24 pounds daily) than without yeast and used 104 pounds less feed each to reach the same average weight.

3. The most rapid average daily gains were made by Lot I, basal (1.39 pounds), and Lot IV, 30 percent cane molasses plus 5 percent dried brewers' yeast (1.35 pounds. Lot II and Lot III, 30 percent cane molasses, and Lot VIII, 15 percent wood molasses plus 5 percent dried brewers' yeast, were all very similar --- 1.29 pounds, 1.25 pounds, and 1.24 pounds respectively. The rest

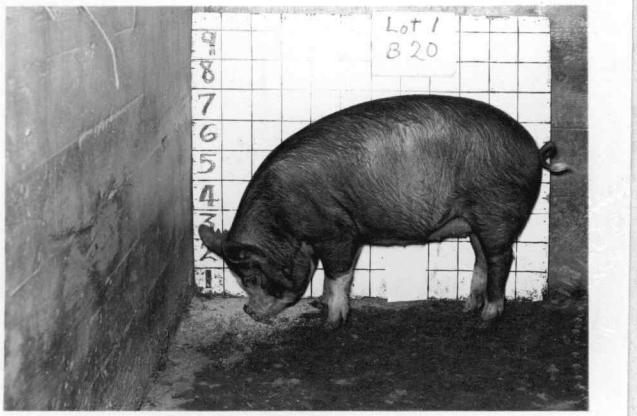
of the daily gains were as follows: Lot VII, 15 percent wood molasses, 1.14 pounds; Lot VI, 30 percent wood molasses plus 5 percent dried brewers' yeast, 0.82 pounds; and Lot V, 30 percent wood molasses, 0.72 pounds.

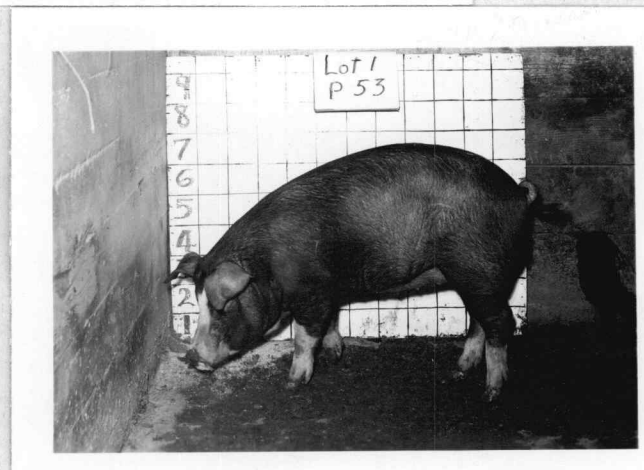
4. The most efficient gains were made by the pigs on 15 percent wood molasses plus yeast, which ranked fourth in rate of gain. The basal lot was second in efficiency of gain.

5. The possibility of using increased amounts of yeast in a ration containing 15 percent wood molasses has been discussed.

APPENDIX

Photographs Taken on 102nd Day of Experiment





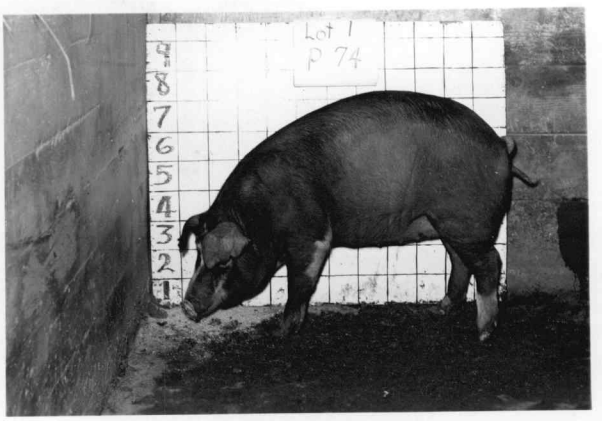


Figure 1. Lot I, Basal Ration

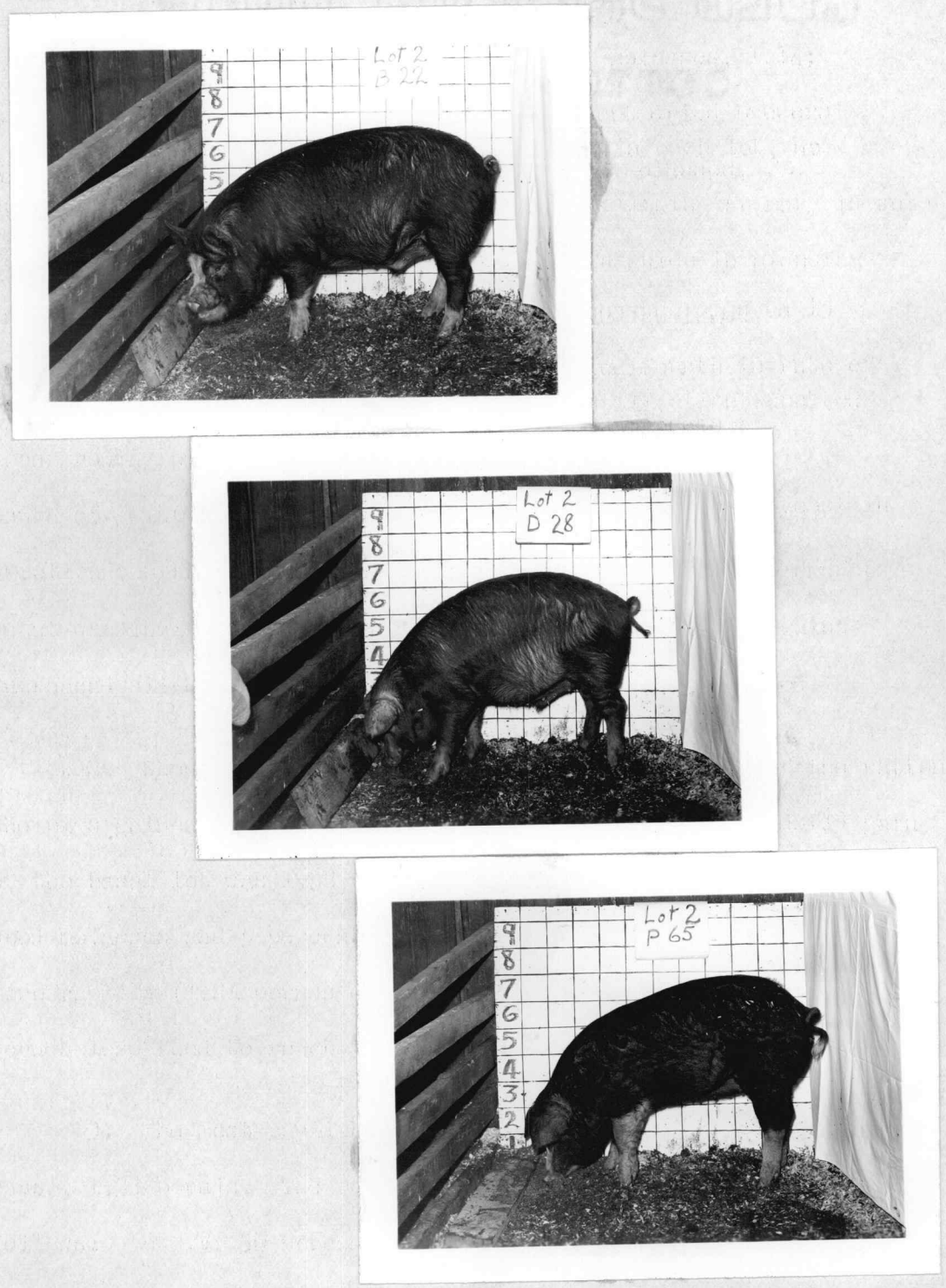


Figure 2. Lot II, Basal Plus 30 Percent Cane Molasses

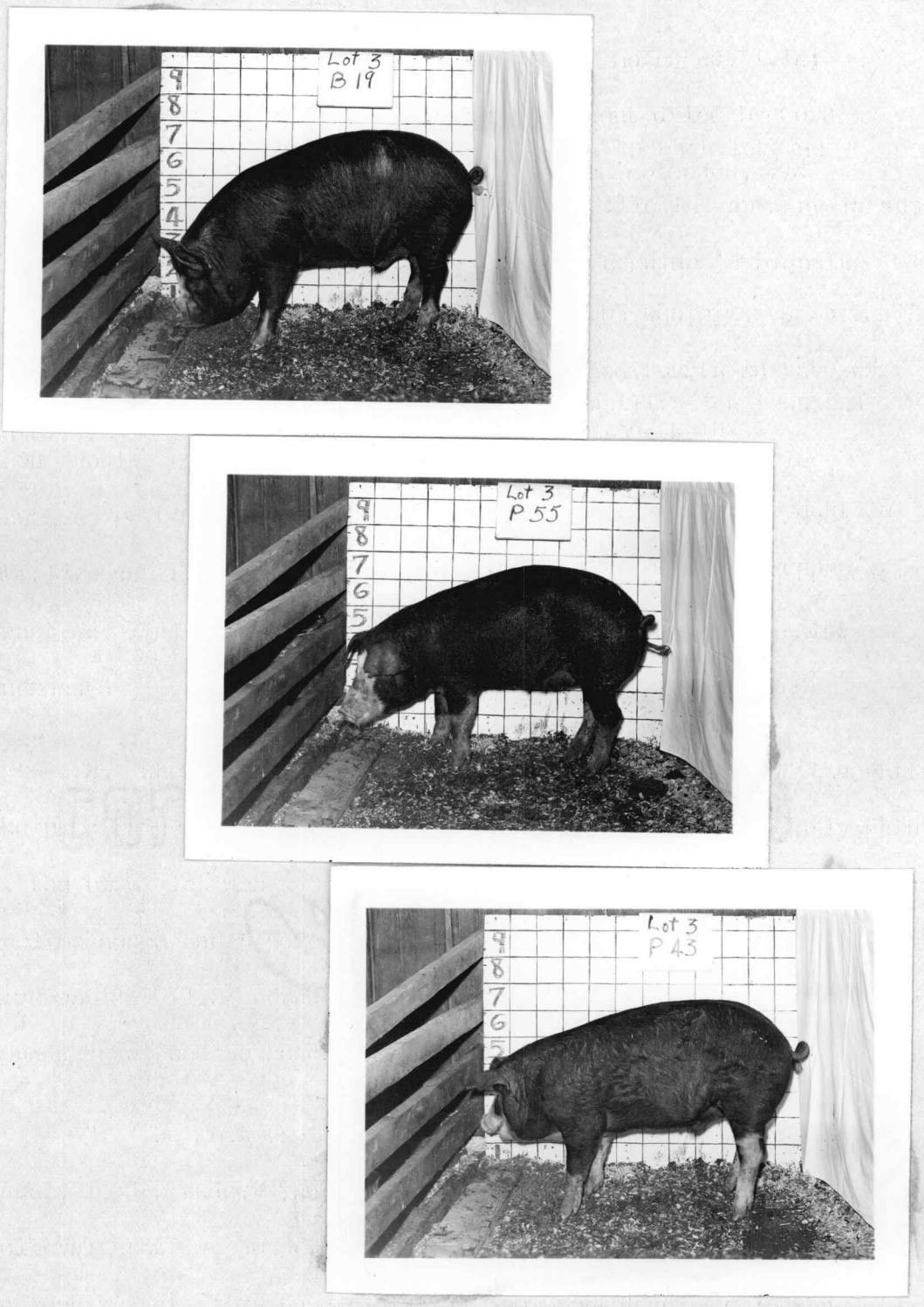


Figure 3. Lot III, Basal Plus 30 Percent Cane Molasses

Figure 4. Lot IV, Basal Plus 30 Percent Cane Molasses Plus 5 Percent Dried Brewers' Yeast

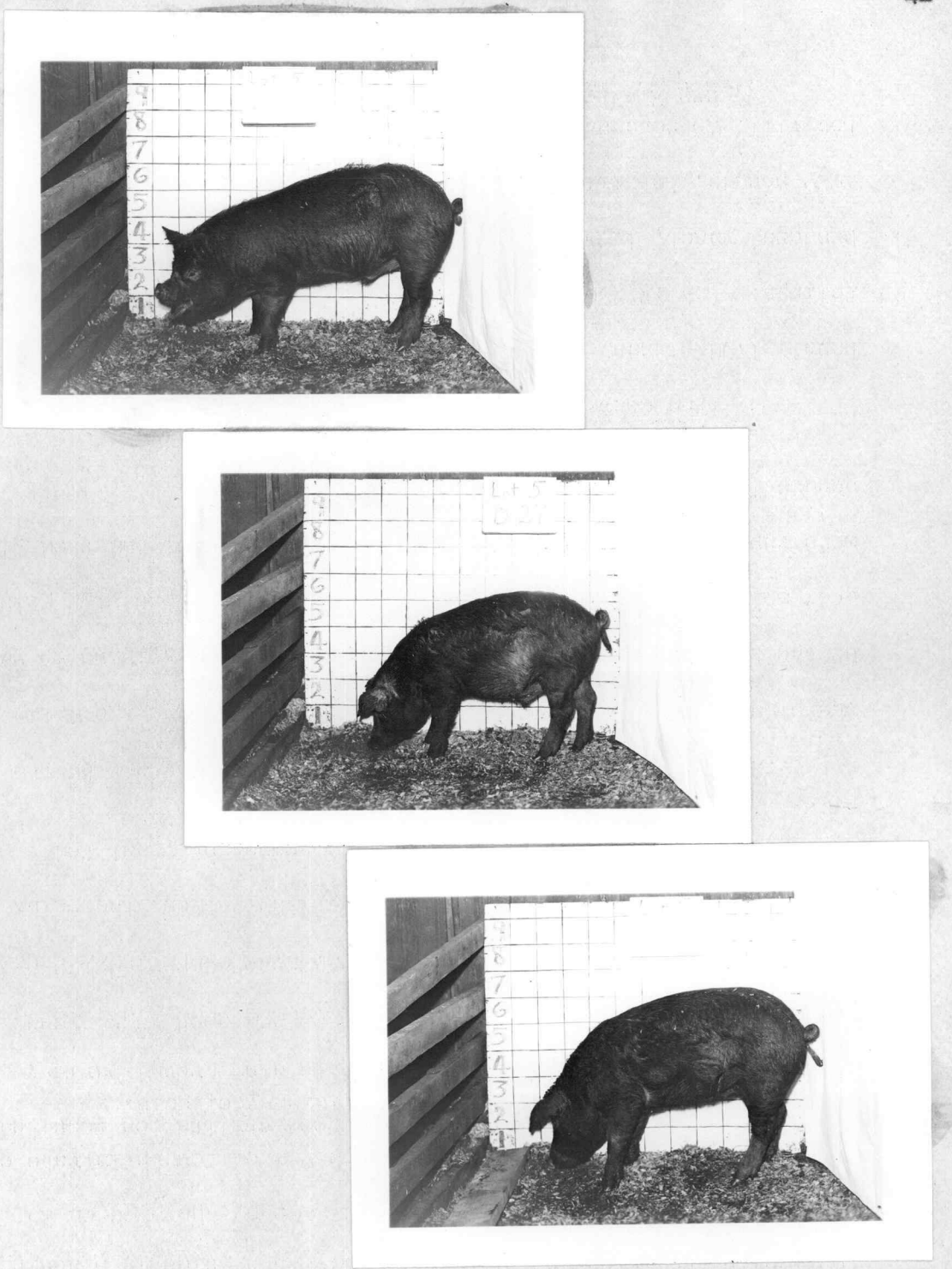


Figure 5. Lot V, Basal Plus 30 Percent Wood Molasses
Notice the Extremely Rough Hair Coats

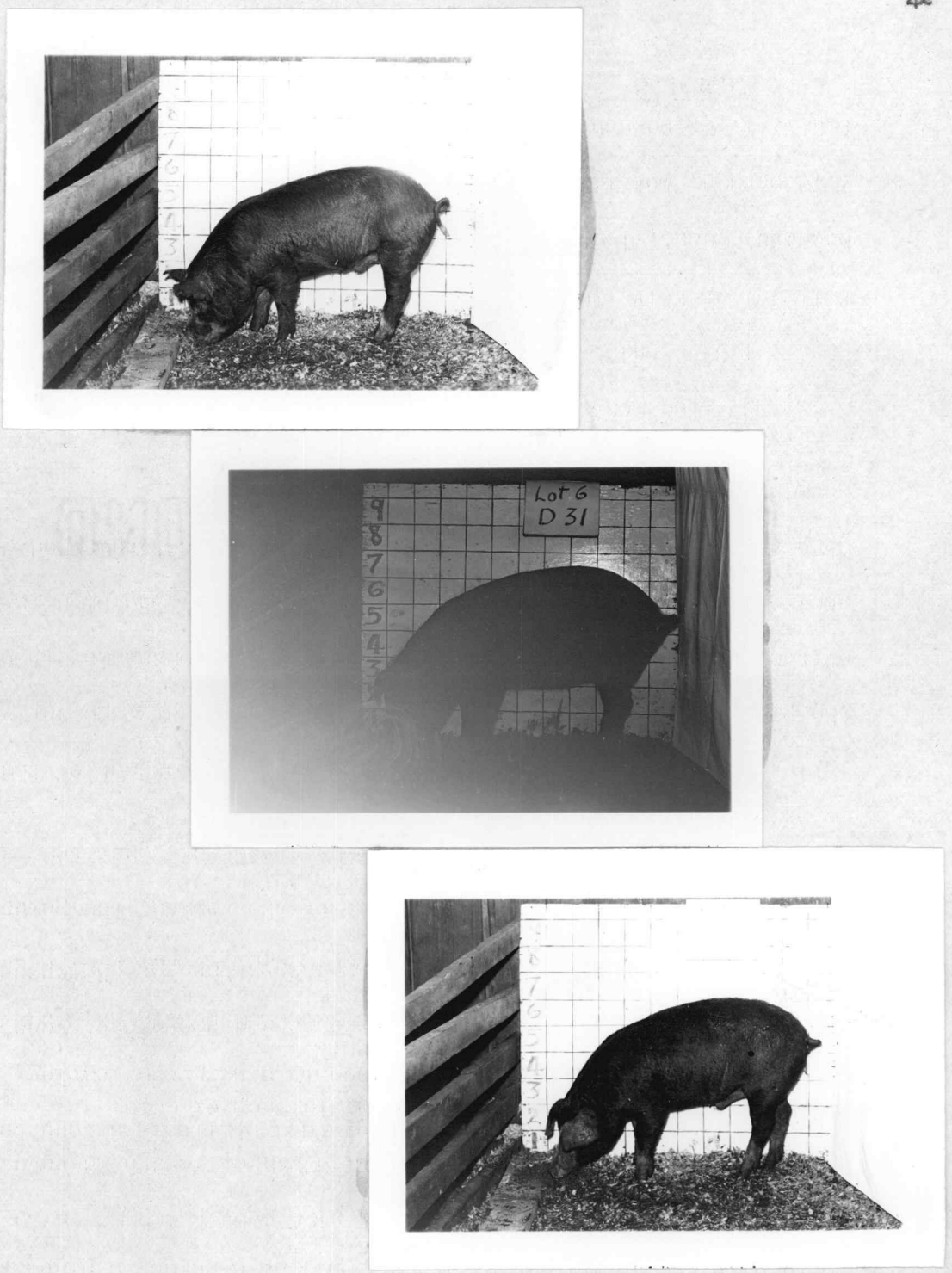


Figure 6. Lot VI, Basal Plus 30 Percent Wood Molasses Plus 5 Percent Dried Brewers' Yeast

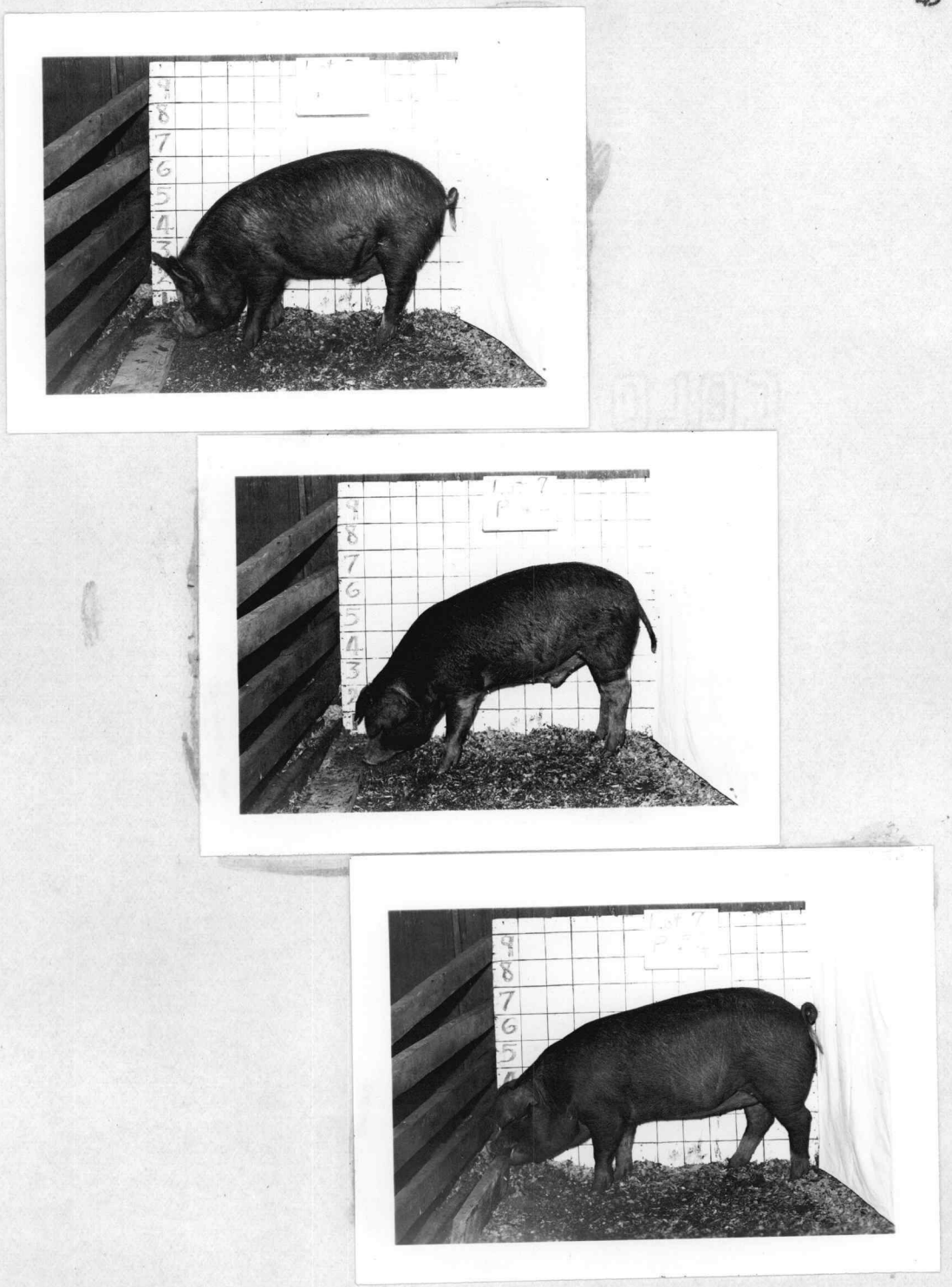


Figure 7. Lot VII, Basal Plus 15 Percent Wood Molasses

Figure 8. Lot VIII, Basal Plus 15 Percent Wood Molasses Plus 5 Percent Dried Brewers' Yeast

BIBLIOGRAPHY

1. Barnett, E. and Goodell, C. J. Grazing and feeding trials with hogs. Mississippi Agricultural Experiment Station Bulletin 210; 18-19, 1923.

2. Beaumont, J. H. Feeds for swine. Hawaii Agricultural Experiment Station Report for the Year 1940, p. 30-31.

3. Board of Directors, University of Wisconsin. Confirm finding that molasses is too expensive to use in livestock rations. Wisconsin Annual Report, 1933-1934, Bulletin 430: 119.

4. Board of Directors, University of Wisconsin. Molasses proves an expensive hog feed. Wisconsin Annual Report, 1937-1938, Bulletin 440: 15.

5. Bohstedt, G., Roche, B. H., Fargo, I. M., Rupel, I. W., Fuller, J. G., and Newman, Paul E. Molasses incorporated in grain mixtures. American Society of Animal Production Proceedings 1933, p. 52.

6. Bohstedt, G., Roche, B. H., Fargo, I. M., Rupel, I. W.,Fuller, J. G. and Newman, Paul E. Molasses incorporated in grain mixtures for livestock. Wisconsin Annual Report, 1932-1933, Bulletin 428: 16.

7. Burns, John C. Hog feeding experiments. Texas Agricultural Experiment Station Bulletin 131: 12, 1912.

8. Carroll, W. E. and Burroughs, Wise. Cane molasses for growing-fattening pigs. University of Illinois Department of Animal Husbandry, Swine Division, Mimeo H-27, 1936. 3 p.

9. Department of Animal Husbandry, Kansas State College. Substitution of blackstrap molasses for corn. Kansas Agricultural Experiment Station Circular 207, 1941. 20 p.

10. Department of Animal Husbandry, Oregon State College. The comparative efficiency of molasses and mangels as supplements to barley. Unpublished date, Experiment Number 181130, 1918.

11. Department of Animal Husbandry, Oregon State College. The effect of sugar cane syrup on the palatability of shorts. Unpublished data, Experiment Number 180820, 1918.

12. Department of Animal Industry and Range Management, Montana Agricultural Experiment Station. Observations on feeding wood sugar molasses (lodgepole and larch) to sheep. Montana Agricultural Experiment Station Mimeograph, 1947. 1 p.

13. Departments of Animal Husbandry, Dairy Husbandry and Poultry Husbandry, University of Missouri. Cane molasses (blackstrap) as a livestock feed. University of Missouri Agricultural Experiment Station Circular 184, 1935. 18p.

14. Editorial Staff, Journal of Forestry. Application made for first wood sugar plant. Journal of Forestry 42:278, 1944.

15. Ferrin, E. F. Molasses as a substitute for grains. University of Minnesota Agricultural Experiment Station Division of Animal Husbandry, Mimeograph H-69, December 23, 1946. 3p.

16. Fjeldsted, E. J. and Potter, E. L. Finishing pigs for market. Oregon Agricultural Experiment Station Bulletin 165: 13, 1919.

17. Fletcher, J. L. Assistant, A. H. Department, Mississippi State College. Personal Communication. August 2, 1948.

18. Gervacio, E. T. Further studies on molasses as hog feed, molasses versus rice bran in rations for growing and fattening pigs. Philippine Agriculture 30: 492, 1941.

19. Hackendorn, H. and Sotola, J. Hog feeding experiments. Washington Agricultural Experiment Station Bulletin 169: 22-26, 1922.

20. Harris, Elwin E. Industrial alcohol from wood waste. Southern Lumberman, 171: 244-248, 1945.

21. Harris, Elwin E. Animal feeds from wood residue. Forest Products Research Society, 1948 Reprint No. 8. 5p.

22. Harris, Elwin E. Wood-sugar molasses from wood waste. Southern Lumberman 175: 157-161, 1947.

23. Harris, Elwin E. Wood-sugar molasses from wood waste. United States Department of Agriculture Forest Service Forest Products Laboratory Report No. %1704, 1947. 10p.

24. Harris, Elwin E. and Beglinger, Edward. The Madison wood sugar process. Industrial and Engineering Chemistry 38: 890, 1946.

25. Harris, Elwin E. and Beglinger, Edward. The Madison wood-sugar process. United States Department of Agriculture, Forest Service, Forest Products Laboratory Report Number R1617, 1946. 20p.

26. Henke, L. A. Cane molasses as a supplement to fattening rations for swine. Hawaii Agricultural Experiment Station Bulletin 69, 1933. 15p.

27. Hughes, E. E., Crampton, E. W., Ellis, N. R., and Loeffel, W. J. Recommended nutrient allowances for domestic animals, Number II, recommended allowances for swine, A report of the committee on animal nutrition, prepared by the sub-committee on swine nutrition. National Research Council. 1944. 12p.

28. Jones, I. R., Professor, Dairy Husbandry, Oregon State College. Personal Communication. July 29, 1948.

29. Kurth, E. F. Professor, Forest Chemistry, Oregon State College. Communication with Dean Wm. A. Schoenfeld, October 14, 1947.

30. Lehrer, W. P., Jr., Assistant Professor of Animal Husbandry, University of Idaho. Personal correspondence with Associate Professor William C. Weir, Department of Animal Husbandry, Oregon State College. January 29, 1948.

31. Li, Jerome C. R. Department of Mathematics, Oregon State College. Personal Communication. July 28, 1948.

32. Lindsey, J. B., Holland, E. B. and Smith, P. H. Molasses and molasses feeds for farm stock. Massachusetts Agricultural Experiment Station Bulletin 118: 22-23, 1907.

33. Lockard, C. R. Chief, Forest Utilization Service, Southern Forest Experiment Station. Personal Communication, August 2, 1948.

34. McElhanney, T. A. Widening uses for wood waste. Pulp and Paper Magazine of Canada 49: 3, p. 124-8.

35. Morrison, F. B. Feeds and feeding. Ithaca, N. Y., The Morrison Publishing Company, Twentieth Edition, 1946. 1050p.

36. Northeastern Wood Utilization Council. Wood yeast for animal feed. Bulletin Number 12, Northeastern Wood Utilization Council, November 1946, 198p.

37. Oliver, A. W. and Potter, E. L. Fattening pigs for market. Oregon Agricultural College Station Bulletin 269: 19, 1930.

38. Rasmussen, Russel A., Smith, Harry H., Phillips, Ralph W. and Cunha, Tony J. Nutritional inadequacy of beet molasses rations for swine. Utah State Agricultural Experiment Station Bulletin 302, 1942. 22p.

39. Saeman, J. F., Locke, Edward G. and Dickerman, G. K. Production of wood sugar in Germany and its conversion to yeast and alcohol. Fiat Final Report No. 499, Joint Intelligence Objectives Agency, Washington, D. C. 1945. 117p.

40. Saeman, Jerome F., Locke, Edward G. and Dickerman, G. K. The production of wood sugar in Germany and its conversion to yeast and alcohol. Paper Trade Journal 123: 12, 38-46. 1946.

41. Snedecor, George W. Statistical Methods. Ames, Iowa, The Iowa State College Press, 1946. 485p.

42. Thompson, C. P. Blackstrap molasses as a substitute for corn in fattening hogs. American Society of Animal Production Proceedings 1937, p. 113-15.

43. Thompson, C. P. and Hillier, J. C. Blackstrap molasses as a partial substitute for corn and oats in fattening rations for swine. American Society of Animal Production Proceedings 1938, p. 146-149.

44. Willett, E. L., Work, S. H., Henke, L. A. and Maruyama, C. Cane molasses for pigs from weaning to a weight of seventy pounds. University of Hawaii Agricultural Experiment Station Technical Bulletin 3: 1-15, 1946.