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An Economic Evaluation of Feeding Sucrose to Beef and Swine Prior to Slaughter

Douglas C. Strong
Utah State University

AN ECONOMIC EVALUATION OF FEEDING SUCROSE TO BEEF AND SWINE PRIOR TO SLAUGHTER

by

Douglas C. Strong

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INTRODUCTION

General Problem

Animal feeding rations have long included carbohydrates as a primary constituent. Grains are included in most animal fattening rations, and the by-products of sugar beets have been used for many years in livestock feeding (Kutish 1950 b). The use of molasses in commercial feed mixes in 1899 made possible its extended use in animal feeding practices (Hall 1950).

That meat can be made more palatable by feeding specific feeds and by proper management practices prior to slaughter is a well-known fact. Feeders of animals have been able to change the flavor, texture, and color of meat, and particularly the liveweight of animals through the feed consumed. With these facts in mind, Dr. D. A. Greenwood and others[1] of the Utah Agricultural Experiment Station initiated fundamental nutritional studies in 1952 to determine the effects of feeding a sucrose supplement to farm animals a few days prior to slaughtering. The primary purpose of these studies was to determine the affect on the daily rate of gain in liveweight, dressing yield, liver weight, and the quality of meat of animals fed sucrose for varying periods of time prior to slaughter. The results of most of these initial studies have been reported (7) (13).

Sucrose and sucrose products in varying amounts (0 to 30 per cent of ration) were fed to 418 beef, 145 swine, 132 sheep, 892 chickens (broilers), 247 turkeys for varying periods of time (6 hours to 14 days)

1. E. B. Wilcox, L. E. Harris, L. Shupe, H. Steffen, J. A. Bennett, T. L. Bahler, and B. Crandall.

prior to slaughter. Under the conditions of these experiments, the following results were noted: (1) Sucrose feeding increased the daily rate of gain in liveweight, produced carcasses with slight increases in dressing percentage, and improvement of color; (2) sugar feeding at certain high levels caused diarrhea in some animals resulting in decreased gains in the feed-lot and dressing percentage; (3) the livers of the sucrose-fed animals generally were larger, contained more carbohydrate, and had a better flavor and texture when cooked than those of animals not fed sucrose; (4) quality appraisal scores by panel judges and shear force values indicated that the meat of sucrose-fed beef had a better flavor and texture when cooked, and was more tender.

Many requests have been received for reprints of these initial publications from sugar companies, meat packers, livestock producers, experiment station investigators, and others from all parts of the United States. Newspaper and radio stations have carried the results of the research to many people.

Although initial studies have indicated that feeding certain levels of sucrose will produce favorable and beneficial responses, considerable variation has been noted between individual animals, kinds of animals, length of the sucrose-feeding period, nutritive value of the ration fed, and the amount of sucrose fed per animal. The number of animals per treatment in many of the initial experiments was relatively small. The relative high cost of sucrose may prohibit its use as a livestock feed under more practical and commercial operations. For these reasons, it is felt that trends indicated from initial studies need to be substantiated with a statistically adequate number of animals under commercial conditions, and that an economic appraisal be made to

evaluate the responses in monetary terms to determine the relative economic feasibility. This information would be valuable in providing guidance for further studies and in recommending sucrose feeding as a general practice.

This paper reports the results of feeding various levels of sucrose to 1,003 fat beef cattle under practical operations of a large commercial meat-packing company at the Denver Union Stockyards in Denver, Colorado, together with pertinent information from initial studies conducted at the Utah Agricultural Experiment Station on 267 beef and 145 swine. An economic evaluation of the results of the overall sucrose-feeding program for all the studies was made to determine the relative feasibility from a practical standpoint.

Objectives

1. To determine the effect on gain in weight, dressing percentage, liver weight, and the quality and flavor of various cuts of meat by feeding sucrose to fat beef cattle prior to slaughter under large-scale commercial operations.

2. To make an economic appraisal of the results of all studies on beef and swine for purposes of determining the feasibility of feeding sucrose.

3. To appraise the quality of the carcass of a sucrose-fed animal in terms of color, texture, flavor, tenderness, total carbohydrate content and pH of the liver and muscle contrasted to the carcass of a non-sucrose-fed animal.

4. To determine the optimum combination of the amount of sucrose to feed and the length of feeding period for maximum net returns for each kind of farm animal.

5. To recommend a feeding and management practice to feeders.

REVIEW OF LITERATURE

It is a well-known fact that specific feeds used in the feeding of livestock and management practices prior to slaughter can alter the quality of the carcass. Studies by Bate-Smith (1948) indicated that the treatment a pig receives a few hours before slaughter may alter the quality of the meat produced. Madsen (1943) found that feeding sugar to swine a few hours before slaughter had a beneficial effect on bacon keeping quality and increased the liver weight significantly.

Culbertson of Iowa State College in 1950 fed can molasses to steers in a non-protein nitrogen feed and found that the growth made by the steers fed on these rations was on a par with that of steers fed a protein ration.

Gibbons and Rose (1950) reported that feeding carbohydrates in the form of sucrose for short periods before slaughtering improved the keeping quality, flavor, and texture of pork. They concluded that the keeping quality of meat was dependent upon the amount of acids in the meat. These workers also found that animals which were rested and fed had a larger content of glycogen in both the muscles and liver than if the animals were tired and hungry.

Madsen (1950) has done considerable research on the keeping quality of pork after feeding sugar-containing feedstuffs for two days before slaughtering, and he observed that bacon from swine fed regularly with sugar-containing feedstuffs kept better. He observed that liver from the animals which had no feed before slaughtering were shrunken and dark in color, while those of animals which received sugar were larger,

tight, and of a light color. The weight of the liver of the sugar-fed animals had also increased. The liver was of sweeter taste and more pleasant than that of the control animals. The bacon of the sugar-fed animals was also better in flavor and in salted bacon the keeping quality was increased from 11 to 21 days. In taste tests on the meat of the sugar-fed pigs it was found to have better flavor and a more tender consistency.

Gibbons and Rose (1950) showed that when sugar was fed there was a rapid disposition of glycogen in the muscle and liver. The cost of the sugar was partially offset by the increased weight of the liver.

The National Livestock and Meat Board (Ramsbottom and co-workers 1949) in researches on dark cutting beef found that as the sugar content of the muscle decreased, cut surface of meat became increasingly darker. They concluded that sugar content is directly related to the ultimate color of the meat. Removal of all or part of the sugar influenced meat color significantly. Their research indicated that pH value was higher in steers which cut dark, and that as the meat became darker the fat became lighter in color. Lighter colored fat results when fat deposits are being depleted. As a general rule, when muscle sugar was reduced 50 per cent, meat graded about one shade darker, and greater reduction of muscle sugar caused the meat to appear two or three shades darker.

Blosser and co-workers (1949) at State College of Washington studied the effect of feeding wood molasses to dairy heifers and concluded that adding wood molasses to the basal ration produced highly significant gains in weight over control animals. They did find some difficulties regarding palatability of the molasses.

The following general results have been obtained from initial studies at the Utah Agricultural Experiment Station:

(1) Wilcox and others (1952) found that feeding 2 or 4 pounds of sugar daily to beef increased the dressing percentage by 0.7 to 1.7 per cent, respectively. Evidence indicated that the length of the feeding period as well as the level of sugar fed was important. Liver weights were increased significantly. The flavor and texture of the livers from sugar-fed animals were preferred by 50 of the 75 people who tested them. Feeding sugar to swine increased the dressing percentage 4 to 6 per cent. Liver and heart weights were increased and the livers were preferred for their texture and flavor.

(2) Merkley (1952) found that feeding sucrose to swine resulted in marked increases in the percentage of carbohydrates in the muscles and in the liver of fresh pork. Only slight changes were noted in the pH of the fresh muscle, cured hams and bacon. Sugar-fed pork muscle was slightly more tender and had a better flavor and texture. Sucrose fed to beef before slaughter increased the carbohydrates in the liver and in some cases in the muscles. There was little variation in the color of the muscle and fat of beef. The pH of both the muscle and liver showed only a slight change.

(3) Greenwood and co-workers (1953) found that sucrose feeding increased the daily gain in weight and liver weight for all groups of beef animals with one exception. Dressing percentages were increased for steers fed sucrose for 3 days and for pigs fed 6 days. The percentage of carbohydrate in the liver and muscle was not consistently increased by sucrose feeding. Livers of high total carbohydrate content were preferred for their flavor and texture when cooked. Quality

appraisal scores by the panel of judges and shear force values were similar for all lots of beef and pork.

Economic studies to determine the feasibility of feeding refined sucrose, as such, are not available. The utilization of sugar beets and can by-products, however, is a sound financial enterprise in the feeding of livestock where these feeds are available.

METHOD OF PROCEDURE

Source of Data

The data for this report have been obtained from two principal sources, which are grouped as follows:

(1) Data obtained from secondary sources. These include pertinent data from initial studies conducted by the Utah Agricultural Experiment Station on 267 beef cattle and 145 swine. These studies are referred to in this report as the Utah studies. The results of 4 separate studies on beef and swine are included, and are numbered as experiments 1 through 4. These specific sources are acknowledged throughout this report. When the size, breed, and conformation of animals, rations fed, and the experimental procedures for each study were similar the results of several separate studies have been consolidated and summarized together to avoid unnecessary repetition. For some of the initial studies, information pertinent to an economic analysis are lacking, and for others, the methods of feeding are not practical under commercial operations so that the number of animals fed sucrose will not necessarily equal the totals listed above. A brief description of the experimental procedure, physical characteristics of the animals, and the rations fed are included for these studies.

(2) Data obtained from original sources. These data include the results of feeding varying amounts of sucrose to 1,003 fat beef animals under practical operations at the Denver Union Stockyards in cooperation with a large commercial meat-packing company. This study is referred to as the Denver study. A form data sheet was made up to record the original

data (Appendix table I). After each group of animals was slaughtered and all data recorded, these records were tabulated on summary sheets, by number of days fed sucrose, amount of sucrose fed, breed, and sex of the animals.

Statistical Analyses

A separate statistical analysis has been made to determine significant differences due to sucrose feeding for each of the experiments by the method of analysis of variance described by Yates (14). Reference is made to these studies throughout the discussion to point out significant differences. In addition to an analysis of variance computed for the Denver study, the results have also been analyzed statistically by the method of least squares (table 9 and Appendix table II). Significant differences are pointed out only at the 1 and 5 per cent probability levels.

Prices of Feed Ingredients and Carcass Values

The prices used for this study represent average 1954 prices as reported by local business sources and governmental livestock marketing reports (table 1). Monthly livestock prices were obtained for the Denver, Colorado, and the Ogden, Utah, livestock markets and a weighted liveweight price paid to producers was determined for each market. An average price for each of the markets was used to enable relative comparisons between the various experiments conducted. This price was further adjusted to represent an average for a composite U. S. carcass grade of 2.3, with 2.0 and 3.0 representing federal grades of choice and good, respectively. The prices used for determining the dressed carcass and liver values represent the wholesale price as reported by local meat-packing and wholesale marketing concerns. This price was checked and verified by governmental reports from major livestock markets.

The prices used in computing the cost of feed represent average retail prices for 1954 as reported by local retail feed companies and verified by U. S. Department of Agriculture reports for the state. The prices used could be reduced slightly if the feed ingredients were purchased and mixed in large quantities.

Description and Feeding of Beef

A brief description of experimental procedures, physical characteristics of the animals, and the type of ration fed for each experiment are included in this report. To avoid repetition, procedures common to all experiments are summarized as follows: (1) The sucrose was fed in the form of refined table sugar by placing it upon the basal ration and the animals taking it at free will; (2) fresh drinking water was available at all times during the sucrose-feeding period; (3) the liver and carcass of each animal were weighed at the time of slaughter and inspected by United States federal inspectors; (4) representative samples of liver and various cuts of meat were procured for chemical and organoleptic tests.

Utah Studies

Experiment 1. Sixty grade steers, all Herefords except for a few Shorthorns, were purchased as young feeders in Utah, Idaho, and Wyoming. They were fed a basal ration of ground alfalfa hay, ground barley, dried beet pulp, minerals, and molasses. The amount of molasses consumed daily per animal was equivalent to approximately 1 pound of sucrose. After about 90 days on this feed the steers were divided at random into 3 lots of 20 animals each. One lot, the control animals, was fed a regular fattening ration of the Western Livestock Feed Association. The other two lots of steers were divided at random

Table 1. Average prices used in determining cost of feed and the value of livestock carcasses and liver

Item	Per cwt
Meadow hay	$ 0.75
Alfalfa hay	1.25
Alfalfa meal, good	2.50
Mixed hay, good	0.90
Straw	0.75
Corn silage	0.40
Chopped peas	3.00
Peavine silage	0.25
Barley	2.70
Wheat	3.85
Oats	3.00
Corn, no.2	4.25
Wheat bran	2.75
Rolled oats (hulled)	5.00
Wheat middlings	3.00
Beet pulp, wet	.1175
Beet pulp, dried	2.52
Molasses, beet	1.60
Soybean meal (44%)	5.50
Linseed meal (29%)	5.50
Cottonseed meal (41%)	4.10
Fish meal (74%)	9.50
Tankage (50%)	4.60
Meat scraps (50%)	5.00
Skim milk, dried	14.00
Whey powder, dried	$ 6.00
Bonemeal, steamed	5.00
Limestone, ground	1.00
Salt, iodized	1.80
Brewer's yeast, dried	13.75
Distiller's solubles, dried	4.00
Aurofac (contains 1.8 gms. aureomycin, 8.18 mg. vitamin B_{12} per pound)	60.00

Sugar	Per lb.
a. Refined	.100
b. Raw	.079

Beef

	Liveweight* lb.	Dressed lb.
Choice	$ .240 - .225	$ .395
Good	.210 - .200	.375
Commercial	.178 - .172	.325

Swine

	Liveweight lb.	Dressed lb.
Choice	$ .242	$ .292
Good	.215	.274
Commercial	.183	.240

Liver

Beef	.35
Swine	.25

* First value represents average for Denver market and second value the Ogden market.

into 4 groups of 5 animals each and fed the regular fattening ration plus 2 or 4 pounds of sucrose per animal per day for 3, 6, 9, or 12 days prior to slaughter. All feed was removed from the animals for approximately 30 hours before slaughtering.

Experiment 2. One hundred grade Hereford steers of uniform size and conformation, 2 to 3 years of age, had been grain fed for about 300 days prior to purchase in Montana by Swift and Company. The animals were shipped to the Ogden, Utah, Swift and Company meat-packing plant, held overnight without feed but with access to water, divided into eight lots, weighed for initial weight, and fed either 0, 1, 2, or 3 pounds of sucrose for 3 or 6 days prior to slaughter. All lots were fed a basal ration composed of a chopped hay and grain mixture containing 12 per cent molasses. Feed was withheld from all animals for about 1 day prior to slaughter. All carcasses graded choice by commercial graders of Swift and Company and by federal inspectors.

Experiment 3. Ninety-seven grade Hereford heifers of uniform size and conformation, 2 to 3 years of age, had been grain fed for about 100 days prior to purchase in Idaho by Swift and Company. The grain mixture which had been fed was composed of equal quantities of wheat and barley plus chopped alfalfa, protein, and mineral supplements. The animals were shipped to Swift's Ogden plant, held for 36 hours without feed but with access to water, divided into nine lots, weighed, and fed either 0, 1, 2, or 3 pounds of sucrose with the basal ration for 3 or 5 days prior to slaughter. One lot of 17 beef heifers did not receive any basal ration during 2 days prior to slaughter. The carcasses graded choice and good.

Experiment 4. Ten uniform grade, grain-fed Hereford heifers were purchased from the Geneva Food and Chemical Company at Pleasant

Grove, Utah, in October, 1953. A ration of rolled barley, good alfalfa, bone meal, and salt was fed to the heifers for about 200 days. Molasses (at the rate of about 0.4 lb. per animal daily) was added to the ration after the grain level had been gradually increased to 5 pounds daily. After shipping to the Agricultural Experiment Station at Logan, Utah, the animals were fed a ration consisting of good alfalfa hay and a concentrate containing, on a percentage basis: Rolled barley, 58, rolled wheat, 15, dried molasses beet pulp, 20, cottonseed meal, 5, salt, 1, and bone meal, 1, for about one week. All feed was withheld from the heifers for 18 hours and a sample of blood was obtained from the jugular vein for blood glucose determination. The animals were fed either 0, 2, or 4 pounds of sucrose for 0, 3, or 6 days prior to slaughter.

The carcasses graded good except for one which was graded commercial.

Denver Study

One thousand and three fat beef cattle from 29 producers in the Denver marketing area were used as experimental animals. The animals were purchased from the feeders by a large commercial meat-packing company as they were shipped to the stockyards during the period from June 6 to August 20, 1954 for slaughter. Upon arrival at the stockyards the animals were selected for uniformity and divided at random into 4 groups, weighed, and placed in the regular pens provided by the Denver Union Stockyards Company. Management and feeding practices prior to feeding sucrose are not available for all the animals. The age of the animals ranged from 1½ to 2 years and they averaged 908 pounds in weight at the time of purchase from the producers. Of the total number, 520 were steers and 483 were heifers. The average weight was 1,005 pounds for the steers and 803 pounds for the heifers. Of the total number, 869 were of the Hereford

breed and 134 of the Angus breed. The number of animals by sex and breed for each treatment are given in table 2. Other physical characteristics of the animals for each treatment and feeding period are given in Appendix table III.

The animals were fed according to the treatments outlined in table 1 for 3, 4, 5, or 7 days prior to slaughtering. Animals receiving treatment 1 were handled according to current practice of the Denver Union Stockyards, which consisted of a ration of only prairie hay. They were designated as control animals. Animals on treatment 2 received the normal holding ration of a large commercial meat-packing company, consisting of the following ingredients on a percentage basis: Sun-cured ground alfalfa, 49; rolled barley, 20; cracked corn, 20; molasses, 10; and salt, 1. Baled alfalfa hay was also fed to these animals. Animals on treatment 4 received the normal holding ration of the large commercial meat-packing company plus two pounds of sucrose per day. To avoid repetition reference to the above mentioned treatments in subsequent discussions is by number only. A total of 671 animals were fed these rations for 3 days, 197 animals for 4 days, 105 animals for 5 days, and 30 animals for 7 days.

An attempt was made to control insects by good management, including the use of insecticides. Daily maximum and minimum air temperature readings were recorded.

On the morning after the sucrose-feeding period the animals were driven from the pens of the Denver Union Stockyard Company to holding pens of the packing company ($\frac{1}{4}$ to $\frac{1}{2}$ mile), weighed, inspected, and slaughtered two to three hours later.

Table 2. Number, breed, and sex of beef fed rations with and without sucrose for 3, 4, 5, or 7 days prior to slaughtering

Livestock producer number	Sex	Breed	Days fed	Treatments* 1	2	3	4	Total
1	M	Hereford	3	6	7	6	6	25
2	"	"	3	6	6	6	6	24
3	"	"	3	7	8	10	9	34
4	"	"	3	6	7	8	8	29
5	"	"	3	7	8	8	8	31
8	"	"	3	9	7	8	10	34
13	"	"	3	6	7	7	6	26
16	"	"	3	5	6	6	6	23
17	"	"	3	10	10	10	10	40
24	"	"	3	7	7	7	7	28
Subtotal				69	73	76	76	294
18	F	Hereford	3	10	10	10	10	40
21	"	"	3	7	7	7	7	28
22	"	"	3	11	12	10	9	42
23	"	"	3	7	7	7	7	28
25	"	"	3	8	8	8	8	32
26	"	"	3	7	7	6	6	26
27	"	"	3	6	6	6	6	24
28	"	"	3	7	9	10	11	37
29	"	"	3	13	12	13	12	50
Subtotal				76	78	77	76	307
15	F	Angus	3	5	8	6	6	25
19	"	"	3	6	7	7	6	26
28	"	"	3	7	5	4	3	19
Subtotal				18	20	17	15	70
Total animals fed 3 days				163	171	170	167	671
9	M	Hereford	4	13	14	12	13	52
10	"	"	4	5	6	7	6	24
14A	"	"	4	5	5	5	5	20
14B	"	"	4	6	6	7	6	25
Subtotal				29	31	31	30	121
10	F	Hereford	4	6	4	4	5	19
12	"	"	4	8	8	8	8	32
20	"	"	4	6	7	6	6	25
Subtotal				20	19	18	19	76
Total animals fed 4 days				49	50	49	49	197

Table 2. (continued)

Livestock producer number	Sex	Breed	Days fed	Treatments* 1	2	3	4	Total
7	M	Hereford	5	6	6	7	7	26
11	"	"	5	8	8	7	7	30
Subtotal				14	14	14	14	56
7	M	Angus	5	6	6	6	6	24
11	"	"	5	6	7	6	6	25
Subtotal				12	13	12	12	49
Total animals fed 5 days				26	27	26	26	105
6	F	Mixed	7	8	9	6	7	30
Total all steers				124	131	133	132	520
Total all heifers				122	126	118	117	483
GRAND TOTAL				246	257	251	249	1,003

*Treatments:

1. Received the regular feed supplied by the Denver Union Stockyards, namely, prairie or meadow hay.

2. Received the normal holding ration used by Armour and Company consisting of the following on a percentage basis: Sun-cured, ground alfalfa hay, 49; rolled barley, 20; cracked corn, 20; molasses, 10; and salt, 1. Baled hay was also fed to the animals during most of the feeding tests.

3. Received the Armour holding ration (2) plus 1 pound of sucrose per animal per day.

4. Received the Armour holding ration (2) plus 2 pounds of sucrose per animal per day.

The animals were slaughtered in separate lots in the meat-packing company plant, which was a federally inspected establishment. Government inspectors examined each carcass and provided reports on the conditions of the liver and other organs. Color readings were made on the fat and muscle of each carcass with Munsell color plates made by the Munsell Color Company, Inc., Baltimore, Maryland.

Each carcass was weighed immediately after slaughtering. It was impossible to obtain the cold carcass weights and a shrinkage of 2 per cent was allowed in computing dressing percentages. This is an average amount of shrinkage for the Armour and Company meat-packing plant at Denver, Colorado. The carcasses were allowed to cool for two to three days before grading.

Representative samples of rib roasts were purchased by the Utah Agricultural Experiment Station, placed in containers provided with solid carbon dioxide, and shipped to Logan, Utah, by air express for chemical and organoleptic tests. All tests were completed within 4 to 7 weeks.

Description and Feeding of Swine

Experiment 1. Six litter mate, grade Duroc-Jersey and six litter mate, Chesterwhite pigs were fed a basal ration consisting of the following on a percentage basis: Protein supplement, 15; ground alfalfa, 5; ground barley, 78.5; bone meal, 1.0; and salt, 0.5 until they reached a weight of about 200 pounds. The amount of feed fed corresponded to recommended nutrient requirements of the National Research Council, Recommended Nutrient Allowances for Swine. They were self-fed and water was available at all times. The Duroc-Jersey pigs were fed the basal ration plus 0, 2, or 4 pounds of sucrose daily

daily for 14 days prior to slaughter, which made two animals per treatment. The Chesterwhite pigs were fed the basal ration plus 0 or 2 pounds of sucrose daily for 3 days prior to slaughter, making three animals per treatment. Each pig was fed individually. The last feeding of sucrose was 16 hours before slaughter.

Experiment 2. Sixty-four swine consisting primarily of crosses of Duroc-Jersey and Poland China and/or Spotted Poland China were purchased on several farms in Cache Valley, Utah, at an average weight of 82 pounds. The pigs were fed the following basal ration on a percentage basis until a weight of approximately 200 pounds was reached: Alfalfa meal, 10; Aurofac, 0.5; salt, 0.5; meat scraps (50 per cent protein), 5; ground wheat, 50; ground barley, 27; and soybean oil meal, 7. The pigs were then divided into eight groups and fed either 0, 1, 2, or 3 pounds of sucrose sweepings for 3 or 12 days. During the sucrose-feeding period, the basal ration was in pellet form. Sucrose sweepings were fed in metal containers for each group but not individually to each pig.

Experiment 3. Forty grade Duroc-Jersey swine which were fed sucrose 5 or 6 days were selected at random from 10 different litters. After weaning and until the pigs weighed about 190 pounds, they were fed a ration consisting of the following constituents on a percentage basis: Ground barley, 49; soybean meal, 5; chopped peas, 7; meat meal, 2; shorts, 10; wheat bran, 5; alfalfa meal, 10; screenings, 10; bone meal, 0.4; calcite, 0.6; trace minerals, 0.5; and Aurofac, 0.5 When the pigs weighed about 190 pounds they were divided into eight groups and fed sucrose for 5 or 6 days. Sucrose sweepings were fed in separate metal troughs for each group but not individually to each pig. The pigs fed sucrose had access to self-feeders containing the basal ration. Feed was withheld from the pigs for about 20 hours prior to slaughter.

Experiment 4. Twelve swine (8 males, 4 females) used in this experiment were good grade Duroc-Jersey which were obtained from three litters of about the same age and weight. The basal ration consisted of the following on a percentage basis: Protein supplement (linseed oil meal, soybean oil meal, meat meal, fish meal, dry whey), 15; ground barley, 78.3; ground alfalfa hay, 5; iodized salt, 0.5; bone meal, 1; and Aurofac (lederle), 0.2. The ration was converted into small pellets to give uniform consumption of the nutrients and to reduce waste.

During the sucrose-feeding period the swine were housed and fed individually in metal metabolism cages equipped to permit the collection of urine and feces. The pigs were fed the basal ration for about 3 days until they had adjusted to the new quarters. Daily feed consumption records were kept. Six pigs were fed 2 pounds of sucrose daily for either 3, 6, or 14 days, 2 pigs were fed 4 pounds of sucrose for 3 days, 2 pigs were fed 1 pound of sucrose daily for 14 days, and 2 pigs were killed at the start of the experiment.

Experiment 5. Ten swine used in the physiological studies of this experiment were good grade Duroc-Jerseys which were obtained from two litters of approximately the same age and weight. At about 75 days of age the swine were randomized into two groups. Feed and fresh water were available in self-feeders and watering troughs constantly throughout the experiment. Stabilized fat was added to the basal ration of one group. The basal rations, on a percentage basis, for each group, consisted of the following ingredients:

Ingredient	Group 1	Group 2
Alfalfa meal	8	8
Ground corn	71	66
Protein supplement	2	2
Aurofac	1	1
Iodized salt	1	1
Stabilized animal fat		5
Total	100	100

The ingredients were ground and mixed but not pelleted.

After the swine had attained an average weight of about 165 pounds four from each group were selected at random and moved into individual metal metabolism cages equipped to permit the collection of urine and feces. Three from each group were selected at random for sucrose feeding, leaving one from each group to serve as control. Two pounds of sucrose per day were added to the basal ration for 6 of the pigs and they were fed for 14½ days.

The last feeding of sucrose occurred about 15 hours prior to slaughtering, although the pigs had access to fresh water and the basal ration. The carcasses were of high quality and were inspected by a trained meat inspector.

RESULTS AND DISCUSSION OF BEEF CATTLE

Daily Gain in Weight

Utah Studies. Records on gain in weight are available for experiments 2 and 3 of the Utah studies for 170 animals (table 3). Feeding 1, 2, or 3 pounds of sucrose for 3 days increased the daily gain in weight per steer by 3 to 5 pounds more than in the groups fed the basal ration. Daily gain in liveweight of the steers fed 2 and 3 pounds of sucrose for 6 days was slightly less than that shown by the animals not fed sucrose. Gains in weight by the heifers fed sucrose were also slightly greater for the 3-day feeding period than for the 5-day period when compared with the gain for the groups fed the basal ration (4 to 6 versus 3 pounds). Feeding 1 pound of sucrose per animal per day produced the largest average daily gains. The over-all gains in weight for all of the cattle are high. It is believed that a substantial part of this gain resulted from intestinal fill, since the animals were off feed for 36 hours before the initial weight was taken. However, the comparative gains among the groups are valid, as all animals were treated alike.

Denver Study. Feeding rations with and without sucrose to 1,003 fat beef cattle for 3, 4, 5, or 7 days prior to slaughter resulted in an over-all average increase of 2.0 pounds per day. The average daily increase for 246 beef fed ration 1 was 0.3 pounds; for 257 beef fed ration 2, 1.6 pounds; for 251 beef fed ration 3, 3.0 pounds, and for 249 beef fed ration 4, 3.2 pounds (table 4, and Appendix table IV). Gains were generally higher for beef fed 1 or 2 pounds of sucrose with

Table 3. Summary of the average daily gain in liveweight per animal for experiments 2 and 3 of the Utah studies on 170 beef fed various levels of sucrose for periods of 3, 5, and 6 days prior to slaughter

Number of days fed sucrose	Levels of sucrose: 0 No. of ans.	0 Average daily gain	1 No. of ans.	1 Average daily gain	2 No. of ans.	2 Average daily gain	3 No. of ans.	3 Average daily gain	Total number of animals	Weighted average daily gain
		lbs.		lbs.		lbs.		lbs.		lbs.
Steers										
3	14	6.3	12	11.5	12	9.3	12	9.2	50	9.0
6	14	6.5	12	6.9	12	4.8	12	5.2	50	5.9
Average or total	28	6.4	24	9.2	24	7.1	24	7.2	100	7.4
Heifers										
3	10	4.5	10	10.8	10	8.2	10	--	30	7.8
5	10	3.1	10	5.7	10	4.2	10	6.2	40	4.8
Average or total	20	3.8	20	8.2	20	6.2	10	6.2	70	6.1
Steers and heifers										
0	17	--	--	--	--	--	--	--	--	--
3	24	6.3	22	11.2	22	8.8	12	9.2	80	8.8
5	10	3.1	10	5.7	10	4.2	10	6.2	40	4.8
6	14	6.5	12	6.9	12	4.8	12	5.2	50	5.9
Average or total	48	5.3	44	8.8	44	6.7	34	6.9	170	7.0

Where no material appears, data was unavailable.

Table 4. Weighted* average daily gain in weight per animal for 1,003 beef fed rations with and without sucrose for periods of 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Average gain in weight
	1		2		3		4			
	No. of animals	Gain in weight	No. of animals	Gain in weight	No. of animals	Gain in weight	No. of animals	Gain in weight		
		lbs.		lbs.		lbs.		lbs.		lbs.
Beef fed 3 days										
Hereford steers	69	1.3	73	2.0	76	3.8	76	3.4	294	2.7
Hereford heifers	76	0.5	78	2.6	77	3.8	76	3.8	307	2.7
Angus heifers	18	1.0	20	2.1	17	4.0	15	4.3	70	2.8
Total or average	163	0.9	171	2.3	170	3.8	167	3.7	671	2.7
Beef fed 4 days										
Hereford steers	29	-0.8	31	2.6	31	3.3	30	6.5	121	2.9
Hereford heifers	20	-1.7	19	-1.9	18	-0.1	19	0.2	76	-0.9
Total or average	49	-1.2	50	0.9	49	2.0	49	4.1	197	1.4
Beef fed 5 days										
Hereford steers	14	-2.2	14	-2.7	14	-1.1	14	-2.1	56	-2.0
Angus steers	12	-0.3	13	0.4	12	1.5	12	0.4	49	0.5
Total or average	26	-1.3	27	-1.2	26	0.1	26	-0.9	105	-1.3
Beef fed 7 days										
Hereford and Angus heifers	8	1.2	9	2.5	6	1.5	7	2.7	30	2.0
Total or average	8	1.2	9	2.5	6	1.5	7	2.7	30	2.0
All steers	124	0.3	131	1.5	133	3.0	132	3.2	520	1.9
All heifers	122	0.3	126	1.8	118	3.1	117	3.2	483	2.1
Grand total or average	246	0.3	257	1.6	251	3.0	249	3.2	1,003	2.0

* Weighted on basis of number of beef per lot.

the normal holding ration of a large commercial meat-packing company for 3 days prior to slaughtering. Gain in weight was similar for the steers and heifers.

Losses in liveweight occurred for the heifers and steers fed ration 1 for 4 days, and for the heifers fed rations 2 and 3 for 4 days. Generally, the losses were less for animals receiving sucrose than for animals fed rations without sucrose.

A loss of weight occurred for Angus steers fed ration 1 for 5 days; however, gains were obtained from feeding rations 2, 3, and 4, with animals receiving 1 pound of sucrose producing the highest average gain. Losses occurred with all rations fed to Hereford steers for 5 days; however, the losses were least for the steers fed sucrose.

All beef fed 7 days gained weight, with animals receiving 2 pounds of sucrose gaining 1.5 pounds per day more than the animals fed ration 1, namely, prairie hay.

Considerable variation in weight occurred between groups of animals. It is noted, however, that the amount of variation is greatest for the relatively small number of animals in groups fed for 4, 5, or 7 days. This may indicate that an inadequate number of animals were used to establish positive trends. Many unknown factors may cause this variation; however, as all animals were treated alike, comparative gains between treatments should be valid.

The analyses of variance show that the differences in the gain in weights due to treatments are significant at the 1 per cent probability level for all beef fed for 3, 4, 5, or 7 days prior to slaughter. The differences were significantly different for heifers fed 3 days at the 5 per cent level of probability, and for the steers at approximately the 6 per cent level of probability (table 9).

Dressing Yields

Utah Studies. Data on dressing yields for 238 beef cattle for experiments 1, 2, and 3 included in the Utah studies are consolidated and summarized in table 5. Weighted average dressing yields were increased for all steers fed 1, 2, or 3 pounds of sucrose; however, decreases occurred for steers fed 4 pounds per day for 6 and 12 days. Feeding 2 pounds of sucrose per day produced the largest increases in dressing yield.

Statistical analysis of data for the 60 animals in experiment 1 showed that the differences in dressing percentage due to the number of feeding days and the quantity of sugar were highly significant. The feeding of sucrose to heifers did not increase dressing yields, except for the group fed 1 pound per day for 3 days. However, those animals which were not fed prior to slaughter had a lower dressing percentage than either the 3- or 5-day sucrose-fed heifers or those fed the basal ration. When averaging the steers and heifers only those animals fed 1 pound of sucrose for 3 days, 3 pounds for 6 days, and 4 pounds for 9 days showed any increase in dressing yield over animals not fed sucrose.

Denver Study. Feeding the high nutritive value feeds of rations 2, 3, or 4 increased the dressing yield by approximately 1 per cent above animals fed ration 1, namely prairie hay (table 6). Feeding 1 or 2 pounds of sucrose caused only slight increases in dressing percentage over animals fed ration 2. These differences were significant for the quadratic effect, indicating some adverse effects at the 2-pound level. In general, the highest dressing yields were obtained from animals fed 1 pound of sucrose with the normal holding ration of the meat-packing company for 3 days.

Table 5. Summary of dressing percentages for the Utah studies on 238 beef fed various levels of sucrose for periods of 3, 5, 6, 9, and 12 days prior to slaughter

Number of days fed sucrose	Levels of sucrose: 0 No. of ans.	0 Dressing per cent	1 No. of ans.	1 Dressing per cent	2 No. of ans.	2 Dressing per cent	3 No. of ans.	3 Dressing per cent	4 No. of ans.	4 Dressing per cent	Total number of animals	Average dressing per cent
Steers												
3	19	60.3	12	61.3	17	61.7	12	60.2	5	61.3	65	60.9
6	19	60.4	12	59.9	17	61.2	12	60.5	5	55.5	65	60.2
9	5	59.1	--	--	5	59.3	--	--	5	61.0	15	59.8
12	5	60.0	--	--	5	59.7	--	--	5	58.2	15	59.3
Average or total	48	60.2	24	60.6	44	61.0	24	60.4	20	59.0	160	60.4
Heifers												
0*	19	56.1	--	--	--	--	--	--	--	--	--	--
3	10	58.8	10	59.1	12	57.3	--	--	2	54.0	34	58.1
5	10	60.1	10	58.4	10	58.4	10	57.9	--	--	40	58.7
6	--	--	--	--	2	54.0	--	--	2	59.8	4	56.9
Average or total	20	59.4	20	58.8	24	57.5	10	57.9	4	56.9	78	58.3
Heifers and steers												
0*	19	56.1	--	--	--	--	--	--	--	--	--	--
3	29	59.8	22	60.3	29	59.9	12	60.2	7	59.2	99	59.9
5	10	60.1	10	58.4	10	58.4	10	57.9	--	--	40	58.7
6	19	60.4	12	59.9	19	60.4	12	60.5	7	56.7	69	60.0
9	5	59.1	--	--	5	59.3	--	--	5	61.0	15	59.8
12	15	60.0	--	--	5	59.7	--	--	5	58.2	15	59.3
Average or total	68	60.0	44	59.8	68	59.8	34	59.6	24	58.6	238	59.7

* Not included in averages

Table 6. Weighted* average dressing percentages based on liveweight before feeding sucrose for 1,003 beef fed rations with and without sucrose for 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Average dressing per cent
	1		2		3		4			
	No. of animals	Dressing per cent	No. of animals	Dressing per cent	No. of animals	Dressing per cent	No. of animals	Dressing per cent		
Beef fed 3 days										
Hereford steers	69	60.0	73	61.1	76	61.2	76	60.7	294	60.8
Hereford heifers	76	60.1	78	60.4	77	60.8	76	60.8	307	60.5
Angus heifers	18	60.1	20	61.2	17	60.7	15	61.1	70	60.8
Total or average	163	60.1	171	60.8	170	61.0	167	60.8	671	60.7
Beef fed 4 days										
Hereford steers	29	59.2	31	60.4	31	60.6	30	61.2	121	60.4
Hereford heifers	20	58.0	19	59.2	18	58.8	19	59.1	76	58.8
Total or average	49	58.7	50	59.9	49	59.9	49	60.4	197	59.8
Beef fed 5 days										
Hereford steers	14	57.8	14	59.1	14	58.8	14	59.5	56	58.8
Angus steers	12	59.2	13	60.0	12	60.1	12	60.1	49	59.9
Total or average	26	58.4	27	59.5	26	59.4	26	59.8	105	59.3
Beef fed 7 days										
Hereford and Angus heifers	8	59.3	9	62.1	6	60.1	7	61.3	30	60.8
Total or average	8	59.3	9	62.1	6	60.1	7	61.3	30	60.8
All steers	124	59.5	131	60.6	133	60.7	132	60.6	520	60.4
All heifers	122	59.7	126	60.3	118	60.4	117	60.6	483	60.3
Grand total or average	246	59.6	257	60.5	251	60.6	249	60.6	1,003	60.4

* Weighted on basis of number of animals per lot.

The steers fed for 3 days dressed slightly higher than the heifers fed for 3 days; however, differences between treatments by sex were slight and inconsistent, and not statistically significant.

The high nutritive value feeds in all instances increased the dressing percentage over the low nutritive value feed for ration 1, but the effect of adding sucrose seemed to have only negligible effect on dressing percentage.

More detailed information for each group of animals for the Denver study is presented in Appendix table V.

Weight of Livers

Utah Studies. Data on weight of livers are available for 230 beef animals included in the Utah studies, and are consolidated and summarized in table 7. This information includes the weight for normal livers only. The liver weights, with few exceptions, increased with an increase in the quantity of sucrose fed. The differences were highly significant for each separate experiment. Based on a disportionate number of records available, feeding 4 pounds of sucrose per day increased the weight of the liver over animals fed no sucrose by 2.6 pounds. In general, the weight of liver increased with an increase in the length of the sucrose-feeding period.

Denver Study. Table 8 summarizes the average liver weights for the Denver study with 1,003 animals. Feeding 1 or 2 pounds of sucrose with the normal holding ration of the commercial meat-packing company increased the average weight of liver by 1.0 and 1.1 pounds, respectively, more than for animals fed ration 1, or prairie hay. The weight of livers gradually increased with an increase in the quantity of sucrose fed. The differences between ration 1 and the higher nutritive value feeds

Table 7. Summary of liver weights for Utah studies on 230 beef fed various levels of sucrose for periods of 3, 5, 6, 9, and 12 days prior to slaughter

Number of days fed sucrose	Levels of sucrose: 0 No. of ans.	0 Average liver weight	1 No. of ans.	1 Average liver weight	2 No. of ans.	2 Average liver weight	3 No. of ans.	3 Average liver weight	4 No. of ans.	4 Average liver weight	Total of animals	Weighted liver weight
		lbs.		lbs.		lbs.		lbs.		lbs.		lbs.
Steers												
3	19	12.9	12	12.8	17	14.4	12	15.7	5	15.3	65	14.0
6	19	12.8	12	13.5	17	14.4	12	14.8	5	15.7	65	13.9
9	5	13.2	--	--	5	14.6	--	--	5	16.1	15	14.6
12	5	13.8	--	--	5	15.2	--	--	5	14.8	15	14.6
Average or total	48	13.0	24	13.2	44	14.5	24	15.2	20	15.5	160	14.1
Heifers												
0	17	12.4	--	--	--	--	--	--	--	--	17	12.4
3	10	12.8	10	12.7	10	14.2	--	--	--	--	30	13.2
5	10	12.0	10	12.8	10	13.7	10	14.2	--	--	40	13.2
Average or total	20	12.4	20	12.8	20	14.0	10	14.2	--	--	87	13.2
Heifers and steers												
0	17	12.4	--	--	--	--	--	--	--	--	17	12.4
3	29	12.9	22	12.8	27	14.3	12	15.7	5	15.3	95	13.8
5	10	12.8	10	12.8	10	13.7	10	14.2	--	--	40	13.4
6	19	12.8	12	13.5	17	14.4	12	14.8	5	15.7	65	13.9
9	5	13.2	--	--	5	14.6	--	--	5	16.1	15	14.6
12	5	13.8	--	--	5	15.2	--	--	5	14.8	15	14.6
Average or total	68	12.9	44	13.0	64	14.3	34	14.9	20	15.5	230	13.8

Table 8. Weighted* average normal liver weight per animal for 1,003 beef fed rations with and without sucrose for periods of 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments 1		2		3		4		Total no. of animals	Average liver weight
	No. of animals	Liver weights	No. of animals	Liver weights	No. of animals	Liver weights	No. of animals	Liver weights		
		lbs.		lbs.		lbs.		lbs.		lbs.
Beef fed 3 days										
Hereford steers	69	10.6	73	11.8	76	11.7	76	12.0	294	11.5
Hereford heifers	76	9.8	78	10.1	77	10.3	76	10.2	307	10.1
Angus heifers	18	9.4	20	10.2	17	10.1	15	10.0	70	9.9
Total or average	163	10.1	171	10.8	170	10.9	167	11.0	671	10.7
Beef fed 4 days										
Hereford steers	29	9.9	31	10.7	31	11.5	30	11.7	121	11.0
Hereford heifers	20	8.6	19	9.7	18	9.9	19	10.4	76	9.6
Total or average	49	9.4	50	10.3	49	10.9	49	11.2	197	10.5
Beef fed 5 days										
Hereford steers	14	9.8	14	11.6	14	11.4	14	11.0	56	11.0
Angus steers	12	9.7	13	10.8	12	11.1	12	11.1	49	10.7
Total or average	26	9.8	27	11.2	26	11.3	26	11.0	105	10.8
Beef fed 7 days										
Hereford and Angus heifers	8	8.7	9	9.5	6	10.0	7	9.8	30	9.5
Total or average	8	8.7	9	9.5	6	10.0	7	9.8	30	9.5
All steers	124	10.3	131	11.4	133	11.6	132	11.7	520	11.2
All heifers	122	9.5	126	10.0	118	10.2	117	10.2	483	10.0
Grand total or average	246	9.9	257	10.7	251	10.9	249	11.0	1,003	10.6

* Weighted on basis of number of animals per lot.

of ration 2, 3, and 4 were statistically highly significant (table 9). The differences between the normal holding ration fed with and without sucrose, however, are not significant.

Feeding rations 2, 3, or 4 to steers for 3 days, and to steers and heifers for 4 days caused highly significant increases in the weight of livers over those of animals fed ration 1. The differences in weight between the livers of steers and heifers were also significant. Average normal liver weights for each group of beef fed for 3, 4, 5, and 7 days are presented in Appendix table VI.

Per Cent of Normal Livers

Utah Studies. Available information for the Utah studies on beef show that approximately 75 to 80 per cent of the beef livers were free of abscesses or abnormalities. The distribution of abnormal livers was similar for all treatments, indicating that the addition of sucrose to diets for a few days prior to slaughter had no effect on the percentage of abnormal livers.

Denver Study. The percentage of normal livers for 1,003 beef fed 3, 4, 5, or 7 days in the Denver study averaged 82.6 per cent and ranged from 79.4 to 83.1 (table 10). The distribution of abnormal livers was similar for all rations. There were no significant differences in the percentage of normal livers due to the kind of feed fed, breed, sex, or length of the sucrose-feeding period.

Feed Consumption

Utah Studies. For the Utah studies the amount of feed consumed per animal was not determined. However, according to personnel directing the experiments, the animals, in most instances, were fed according to the recommendations of the National Research Council, Recommended

Nutrient Allowances For Beef (1). For fattening 2-year-old cattle, the amount of feed recommended is 3.0, 2.9, and 2.8 per cent of the live-weight of animals of 800, 900, and 1,000 pounds, respectively. From observation of these experiments it is estimated by professional personnel that animals fed sucrose will consume from 10 to 25 per cent more total feed than animals not fed sucrose. Thus, for purposes of this study, recommended feeding allowances for feeding beef of appropriate weights plus 15 per cent for the beef fed sucrose are used in evaluating the cost of sucrose feeding of beef cattle in experiment 1 through 4 of the Utah studies.

Denver Study. The average daily feed consumed, in all cases, was least for the beef fed the less palatable stockyard ration of prairie hay (table 11). In general, beef fed sucrose with their ration consumed more feed than those receiving the same basal ration without sucrose. This indicates that the palatability of the feed is increased by adding sucrose which causes the animals to eat more. As would be expected, steers consumed more feed than heifers; however, there was no significant difference in the amount of feed consumed between breeds. The average daily feed consumption was lower for animals fed for 3 days than for those fed for 4, 5, or 7 days. The differences between the amounts of rations 2, 3, or 4 consumed were not statistically significant; however, for these rations versus ration 1 the differences were highly significant (table 9).

It is noted that this experiment was conducted during extremely hot weather which may account for the lower feed consumption per animal during the sucrose feeding than recommended for similar size animals by the National Research Council for beef cattle.

Table 9. Summary of analyses of variance for gain in liveweight, dressing percentage, liver weights, and carbohydrates in the liver for beef cattle fed rations with and without sucrose in Denver, Colorado

Source of variation	Degrees of freedom	Mean squares for: Gain in weight	Dressing %	Weight of livers	Carbohydrates in livers
Beef fed 3 days					
Steers					
Lots	9	106.27**	9.55**	6.80**	0.65**
Treatments: (3)					
Linear	1	38.11 1/	0.34	7.49**	3.85**
Quadratic	1	2.86	3.25 2/	1.64	0.61**
Cubic	1	5.41	0.20	1.43	.05
Error	27	9.53	0.80	0.45	.09
Total	39				
Heifers					
Lots	11	53.67**	7.96**	1.39**	0.26
Treatments: (3)					
Linear	1	71.40**	.03	.84	0.74*
Quadratic	1	8.93	.19	1.14	.07
Cubic	1	0.14	.77	.02	.16
Error	33	3.01	1.87	.32	.13
Total	47				

1/ Computed F .05 = 4.00 F .05 = 4.21
2/ Computed F .05 = 4.06 F .05 = 4.21

Beef fed 4 days					
Steers					
Lots	3	130.84**	19.35**	5.65**	0.12
Treatments: (3)					
Linear	1	87.36**	0.30	5.15**	.39
Quadratic	1	4.00	1.50	0.68	.04
Cubic	1	3.70	0.14	.01	.01
Error	9	4.37	1.07	0.45	.09
Total	15				
Heifers					
Lots	2	11.59	5.96**	1.72*	--
Treatments: (3)					
Linear	1	4.27	0.43	4.51**	--
Quadratic	1	0.16	0.30	.23	--
Cubic	1	3.27	1.57	.10	--
Error	6	3.96	0.37	.32	--
Total	11				

Table 9. Continued

Source of variation	Degrees of freedom	Mean squares for: Gain in weight	Dressing percentage	Weight of livers
Beef fed 5 days				
Hereford and Angus steers				
Lots	1	0.36	15.46**	0.36
Treatments: (3)				
Linear	1	0.55	1.06	1.33
Quadratic	1	0.78	.31	1.36
Cubic	1	0.93	1.62	0.24
Error	3	1.33	0.35	0.58
Total	7			

Mean squares for gain in weight, dressing percentage, weight of liver, carbohydrate in the liver, and feed consumed for all beef cattle fed sucrose for 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Source of variation	Degrees of freedom	Gain in weight	Dressing %	Weight of livers	Carbohydrates in livers	Feed consumed
Lots	28	80.67**	10.00**	5.79**	0.48*	27.06**
Treatments: (3)						
Linear	1	135.85**	0.09	16.46**	4.94**	684.74**
Quadratic	1	19.78	7.92**	3.91**	0.53*	200.23**
Cubic	1	6.44	0.04	0.90	0.14	48.84**
Error	84	5.04	0.78	0.37	0.12	3.04
Total	115					

* Significant at $P < .05$
** Highly significant at $P < .01$

Table 10. Weighted* average percentage of normal livers for 1,003 beef fed rations with and without sucrose for 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Per cent of normal livers
	1		2		3		4			
	No. of animals	Normal livers per cent	No. of animals	Normal livers per cent	No. of animals	Normal livers per cent	No. of animals	Normal livers per cent		
Beef fed 3 days										
Hereford steers	69	84.1	73	83.0	76	89.5	76	81.6	294	84.6
Hereford heifers	76	86.0	78	80.3	77	81.2	76	80.3	307	81.9
Angus heifers	18	77.8	20	75.0	17	91.2	15	80.0	70	80.7
Total or average	163	84.3	171	80.5	170	85.9	167	80.9	671	83.0
Beef fed 4 days										
Hereford steers	29	62.1	31	71.9	31	61.3	30	66.6	121	65.5
Hereford heifers	20	90.0	19	89.5	18	77.8	19	72.2	76	84.7
Total or average	49	73.5	50	78.6	49	67.4	49	72.2	197	72.9
Beef fed 5 days										
Hereford steers	14	78.6	14	100.0	14	100.0	14	78.6	56	89.3
Angus steers	12	100.0	13	100.0	12	100.0	12	91.7	49	98.0
Total or average	26	89.5	27	100.0	26	100.0	26	84.6	105	93.4
Beef fed 7 days										
Hereford and Angus heifers	8	100.0	9	100.0	6	100.0	7	100.0	30	100.0
Total or average	8	100.0	9	100.0	6	100.0	7	100.0	30	100.0
All steers	124	80.1	131	83.9	133	85.0	132	78.8	520	81.9
All heifers	122	86.4	126	82.2	118	83.1	117	80.1	483	83.3
Grand total or average	246	83.1	257	83.1	251	84.1	249	79.4	1,003	82.6

* Average weighted on basis of number of animals per lot.

Table 11. Weighted* average pounds of feed consumed per animal for 1,003 beef fed rations with and without sucrose for 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Item	Treatments 1		2		3		4		Total number of animals	Average feed consumed
	No. of animals	Feed consumed	No. of animals	Feed consumed	No. of animals	Feed consumed	No. of animals	Feed consumed		
		lbs.		lbs.		lbs.		lbs.		lbs.
Beef fed 3 days										
Hereford steers	69	8.8	73	15.4	76	16.2	76	16.7	294	14.4
Hereford heifers	76	8.5	78	13.0	77	13.3	76	14.1	307	12.2
Angus heifers	18	10.3	20	14.0	17	12.2	15	15.5	70	12.9
Total or average	163	8.8	171	14.1	170	14.5	167	15.4	671	13.2
Beef fed 4 days										
Hereford steers	29	8.9	31	15.3	31	15.6	30	17.4	121	14.4
Hereford heifers	20	9.2	19	16.8	18	17.0	19	19.0	76	15.4
Total or average	49	9.0	50	15.2	49	16.1	49	18.0	197	14.7
Beef fed 5 days										
Hereford steers	14	10.9	14	21.5	14	21.1	14	20.3	56	18.4
Angus steers	12	10.7	13	21.3	12	21.1	12	20.3	49	18.4
Total or average	26	10.8	27	21.4	26	21.1	26	20.3	105	18.4
Beef fed 7 days										
Hereford and Angus heifers	8	10.7	9	16.8	6	19.8	7	19.7	30	16.5
Total or average	8	10.7	9	16.8	6	19.8	7	19.7	30	16.5
All steers	124	9.2	131	16.6	133	17.0	132	17.6	520	15.2
All heifers	122	9.0	126	14.0	118	14.0	117	15.4	483	13.1
Grand total or average	246	9.1	257	15.3	251	15.6	249	16.6	1,003	14.2

* Average weighted on basis of number of animals per lot.

Feed Efficiency

As a measure of the relative efficiency of the different rations fed with respect to gain in liveweight the data in table 12 were computed for the Denver study. This represents the amount of change in liveweight per day for each pound of feed consumed.

The data calculated in table 12 show that the beef fed 1 or 2 pounds of sucrose daily with the holding ration 2 gained more per pound of feed intake than the animals fed other rations. The beef fed 1 pound of sucrose daily gained slightly more per pound of feed intake than those fed 2 pounds of sucrose per day. Animals fed ration 1, namely prairie hay, gained less or lost more per pound of feed intake than animals fed the other rations. The beef fed sucrose for 3 days gained more weight per pound of feed intake than did the beef fed for longer periods. With the exception of the 7-day feeding period, more feed was required per pound of gain as the length of the feeding period increased.

Chemical and Quality Tests

Chemical and quality tests on representative samples of meat and liver for each experiment were conducted by the Department of Food and Nutrition of the Utah State Agricultural College under the direction of Dr. Ethelwyn B. Wilcox. Standard acceptable procedures were used in running all tests, including the consumer preference tests of the cooked meat and liver by panels of judges. These tests were conducted for the purpose of measuring the effect of feeding sucrose on the tenderness, color, texture, juiciness, and flavor of the meat and liver. A brief summary of the results of the tests that directly reflect the quality of the meat and liver is included in this report to enable an economic appraisal to be made.

Table 12. Comparative feed efficiency ratios between the change in liveweight and feed intake per animal for 1,003 beef fed rations with and without sucrose for 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments 1		2		3		4		Total number of animals	Average comparative ratios
	No. of animals	Comparative ratios	No. of animals	Comparative ratios	No. of animals	Comparative ratios	No. of animals	Comparative ratios		
Beef fed 3 days										
Hereford steers	69	.15	73	.13	76	.23	76	.20	294	.19
Hereford heifers	76	.06	78	.20	77	.29	76	.27	307	.22
Angus heifers	18	.10	20	.15	17	.33	15	.28	70	.22
Total or average	163	.10	171	.16	170	.26	167	.24	671	.21
Beef fed 4 days										
Hereford steers	29	-.09	31	.17	31	.21	30	.37	121	.20
Hereford heifers	20	-.18	19	-.11	18	-.01	19	.11	76	-.06
Total or average	49	-.13	50	.06	49	.12	49	.28	197	.10
Beef fed 5 days										
Hereford steers	14	-.20	14	-.18	14	-.05	14	-.10	56	-.11
Angus steers	12	-.03	13	.02	12	.07	12	.02	49	.03
Total or average	26	-.12	27	-.06	26	.00	26	-.04	105	-.07
Beef fed 7 days										
Heifers (mixed)	8	.11	9	.15	6	.08	7	.13	30	.11
Total or average	8	.11	9	.15	6	.08	7	.13	30	.11
All steers	124	.03	131	.09	133	.18	132	.18	520	.13
All heifers	122	.03	126	.13	118	.22	117	.21	483	.16
Grand total or average	246	.03	257	.11	251	.20	249	.19	1,003	.14

Carbohydrate in the Liver and Muscle. The amount of carbohydrate in the liver and muscle is a good comparative measure of their quality. Meat and liver with a high carbohydrate content are preferred for flavor and tenderness.

With the exception of the results obtained for 10 animals in experiment 4 of the Utah studies, the per cent of carbohydrate in the liver was increased for the beef fed sucrose. The amount of carbohydrate in the liver, in most instances, was increased as the level of sucrose was increased; however, the length of the feeding period did not appear to influence the amount of carbohydrate in the liver. Although in some cases the amount of carbohydrate in the meat was increased, the results were not consistent for all experiments of the Utah studies (table 13).

The average per cent of carbohydrate in the muscle and meat for 1,003 beef included in the Denver study is summarized in table 14. The per cent of carbohydrate in the liver increased as the level of sucrose increased, and in most instances, as the length of the feeding period increased. Statistical analysis of these results show that these differences were statistically significant at the 1 per cent level of probability (table 9).

A limited number of samples analyzed for per cent of carbohydrate in the muscle show results that are slight and inconsistent. This conforms with the results from the Utah studies on beef.

pH in the Liver and Muscle. Available records for results of the Utah studies indicate that the pH of both the muscle and liver were not consistently influenced by the addition of varying levels of sucrose for short feeding periods. In none of these studies were the differences significantly different. These findings are substantiated by the results from the Denver study on 1,003 beef (table 15).

Table 13. Average per cent of carbohydrate and pH in the muscles and liver of beef included in the Utah studies

Number of animals	Amount of sucrose fed	Carbohydrate as dextrose	
		muscle	liver
	lbs.	per cent	per cent
Fed sucrose 3 days			
29	0	0.183	2.50
22	1	0.187	2.91
29	2	0.200	2.68
12	3	0.130	2.89
7	4	0.182	3.02
Fed sucrose 5 days			
10	0	0.19	2.52
10	1	0.13	3.00
10	2	0.24	2.96
10	3	0.27	3.42
Fed sucrose 6 days			
19	0	0.161	2.36
12	1	0.160	2.52
19	2	0.171	2.42
12	3	0.140	2.92
7	4	0.175	2.57
Fed sucrose 9 days			
5	0	0.147	2.10
5	2	0.143	2.30
5	4	0.143	2.06
Fed sucrose 12 days			
5	0	0.172	2.36
5	2	0.182	2.44
5	4	0.189	2.26
Average of 3, 5, 6, 9, and 12 days			
68	0	0.174	2.42
44	1	0.167	2.82
68	2	0.192	2.60
34	3	0.175	3.06
24	4	0.173	2.53
238			

Table 14. Average per cent of carbohydrate in the liver and muscle of beef fed rations with and without sucrose for 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Item	Number of samples	Treatments 1	2	3	4	Average carbohydrate
		%	%	%	%	%
Liver						
Beef fed 3 days						
Hereford steers	10	2.07	2.66	2.84	2.93	2.62
Hereford and Angus heifers	11	2.05	2.35	2.31	2.45	2.29
Total or average	21	2.06	2.50	2.58	2.69	2.46
Beef fed 4 days						
Hereford steers	2	2.37	2.58	2.75	2.57	2.57
Hereford heifers	2	2.09	2.32	2.50	2.70	2.40
Total or average	4	2.23	2.45	2.62	2.64	2.48
Beef fed 5 days						
Hereford and Angus steers	2	2.43	2.76	2.82	2.62	2.66
Total or average	2	2.43	2.76	2.82	2.62	2.66
Beef fed 7 days						
Hereford heifers	1	2.34	2.46	2.92	3.92	2.91
Total or average	1	2.34	2.46	2.92	3.92	2.91
Grand total or average	28	2.12	2.51	2.60	2.72	2.49
Muscle						
Beef fed 3 days	4	.182	.199	.157	.205	.186
Total or average	4	.182	.199	.157	.205	.186

Table 15. Total pH in the liver and muscle of beef fed rations with and without sucrose for 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Item	Number of samples	Treatments 1	2	3	4	Average pH in liver
		%	%	%	%	%
Liver						
Beef fed 3 days						
Hereford steers	10	6.0	6.0	6.0	6.0	6.0
Hereford and Angus heifers	11	6.0	6.0	6.0	6.0	6.0
Total or average	21	6.0	6.0	6.0	6.0	6.0
Beef fed 4 days						
Hereford steers	2	5.8	6.0	6.0	5.9	5.9
Hereford heifers	2	5.9	5.9	5.8	5.9	5.9
Total or average	4	5.8	6.0	5.9	5.9	5.9
Beef fed 5 days						
Hereford and Angus steers	2	6.2	6.1	6.0	6.1	6.1
Total or average	2	6.2	6.1	6.0	6.1	6.1
Beef fed 7 days	1	6.2	6.0	6.0	6.0	6.0
Total or average	1	6.2	6.0	6.0	6.0	6.0
Grand total or average	28	6.0	6.0	6.0	6.0	6.0
Muscle						
Beef fed 3 days		5.3	5.3	5.2	5.4	5.3
Total or average		5.3	5.3	5.2	5.4	5.3

Color of Lean and Fat. Evidence from the Utah studies shows that the color of the fresh muscle was a somewhat brighter red in the sucrose-fed meat than in the meat from animals not fed sucrose, which indicates that the quality of meat is influenced by feeding sucrose. These results conformed to the results obtained in the Denver study (table 16). The color of the meat and fat of the beef fed the high nutritive value feed of ration 2, and this ration plus one or two pounds of sucrose per day was improved over the animals that received the regular stockyard ration of prairie hay. These differences, however, were not statistically significant.

U.S. Carcass Grades. Available information from the Utah studies indicates that sucrose feeding had no effect on the carcass grade.

Carcass grades for the Denver study were summarized by assigning numerical values to the grades on the basis of prime equal to 1, choice equal to 2, good equal to 3, and commercial equal to 4. This data is presented in table 17. The beef fed the high nutritive value feeds of rations 2, 3, and 4 graded slightly higher than the beef fed the low nutritive value feed of ration 1. The addition of sucrose to rations a few days prior to slaughter had no apparent effect on carcass grades.

Tenderness. Results from shearing force tests for tenderness of meat for all of the Utah studies showed differences that were slight and inconsistent, which indicates that the addition of sucrose for a few days prior to slaughter had little effect on the tenderness of meat. Tenderness scores by panels of judges were also similar. Approximately seventy per cent of 392 people who sampled the livers from beef in the Utah studies preferred the livers from the sucrose-fed animals for flavor and tenderness.

Table 16. Weighted* average color readings (Munsell Paddle) of lean and fat for 1,003 beef fed rations with and without sucrose for 3, 4, 5, and 7 days prior to slaughter at Denver, Colorado

Item	Treatments														
	1			2			3			4			number		
	No. of animals	Color Lean	Fat	No. of animals	Color Lean	Fat	No. of animals	Color Lean	Fat	No. of animals	Color Lean	Fat	of animals	Color Lean	Fat
Beef fed 3 days															
Hereford steers	69	2.5	2.1	73	2.1	2.1	76	2.4	2.2	76	2.2	2.0	294	2.3	2.1
Hereford heifers	76	3.0	1.9	78	3.0	1.6	77	2.8	1.6	76	3.0	1.6	307	2.9	1.7
Angus heifers	18	2.6	1.7	20	2.6	1.8	17	2.6	1.8	15	2.6	1.7	70	2.6	1.8
Total or average	163	2.7	2.0	171	2.6	1.8	170	2.6	1.9	167	2.6	1.8	671	2.6	1.8
Beef fed 4 days															
Hereford steers	29	2.8	2.2	31	2.2	2.2	31	2.5	2.1	30	2.1	2.1	121	2.4	2.2
Hereford heifers	20	3.0	1.9	19	2.5	2.2	18	2.7	2.0	19	2.4	2.0	76	2.6	2.0
Total or average	49	2.9	2.1	50	2.3	2.2	49	2.6	2.1	49	2.2	2.1	197	2.5	2.1
Beef fed 5 days															
Hereford steers	14	2.3	1.8	14	2.1	1.9	14	2.2	2.0	14	2.3	2.1	56	2.2	2.0
Angus steers	12	2.3	1.8	13	2.1	1.9	12	2.2	2.0	12	2.3	2.1	49	2.2	2.0
Total or average	26	2.3	1.8	27	2.1	1.9	26	2.2	2.0	26	2.3	2.1	105	2.2	2.0
Beef fed 7 days															
Hereford and Angus heifers	8	2.1	2.0	9	1.9	2.3	6	2.3	2.2	7	2.9	2.3	30	2.3	2.2
Total or average	8	2.1	2.0	9	1.9	2.3	6	2.3	2.2	7	2.9	2.3	30	2.3	2.2
Grand total or average	246	2.7	2.0	257	2.5	1.9	251	2.5	1.9	249	2.5	1.9	1,003	2.5	1.9

* Weighted on the basis of the number of animals per lot.

Table 17. Weighted* average U. S. carcass grades for 1,003 beef fed various levels of sucrose for 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Weighted average U. S. carcass grade
	1		2		3		4			
	No. of animals	U. S. carcass grade	No. of animals	U. S. carcass grade	No. of animals	U. S. carcass grade	No. of animals	U. S. carcass grade		
Beef fed 3 days										
Hereford steers	69	2.5	73	2.4	76	2.3	76	2.4	294	2.4
Hereford and Angus heifers	94	2.2	98	2.2	94	2.3	91	2.2	377	2.2
Total or average	163	2.3	171	2.3	170	2.3	167	2.3	671	2.3
Beef fed 4 days										
Hereford steers	29	2.4	31	2.6	31	2.5	30	2.4	121	2.5
Hereford heifers	20	2.3	19	2.2	18	2.3	19	2.4	76	2.3
Total or average	49	2.4	50	2.4	49	2.4	49	2.4	197	2.4
Beef fed 5 days										
Hereford steers	14	2.6	14	2.5	14	2.4	14	2.4	56	2.5
Angus steers	12	2.8	13	2.6	12	2.8	12	2.5	49	2.6
Total or average	26	2.7	27	2.5	26	2.6	26	2.4	105	2.5
Beef fed 7 days										
Heifers (Hereford and Angus)	8	2.4	9	2.3	6	2.3	7	2.3	30	2.3
	8	2.4	9	2.3	6	2.3	7	2.3	30	2.3
Grand total or average	246	2.4	257	2.3	251	2.4	249	2.3	1,003	2.3

* Weighted on basis of number of animals per lot.

The findings from the Denver study are in substantial agreement with those of the Utah studies (table 18). Tenderness of the prime rib roast as scored by shear force values show differences that are slight and inconsistent, which indicates that the treatments had little effect on tenderness. Quality scores by the panel of judges, in general, showed preference for the meat of animals that were fed two pounds of sucrose per day; however, for the other treatments the results were slight and inconsistent.

A group of 178 people sampled the liver of animals included in the Denver study for tenderness and flavor in a consumer acceptance test (table 19). Instructions for cooking and scoring the livers, using a scale of 1 to 5, were given. Differences between the animals receiving the normal holding ration of Armour and Company, the meat-packing company which worked on this study, and this ration plus sucrose were similar; however, these were all preferred for their tenderness and flavor to the livers from the animals fed the regular stockyard ration of prairie or meadow hay.

It is noted in appraising the quality factors that for most of the experiments, beet molasses were fed as a part of the basal ration. All animals were receiving a certain amount of sucrose in the form of molasses in addition to the refined sucrose added. Many factors influence the flavor and texture of liver, among which are age of animal, nutritional state of animal, diet fed, and presence of certain insecticides and other chemicals with a bitter or undesirable flavor.

Table 18. Quality appraisal scores by panel of judges

Days fed	Sucrose fed (lbs.)	Scores by panel of judges*					Shearing force**
		Tenderness	Texture	Flavor of lean	Flavor of fat	Juiciness	
3	0	5.5	5.3	6.0	5.6	5.2	11.3
3	1	5.3	5.2	5.8	5.9	5.2	13.4
3	2	5.8	5.4	5.9	6.3	5.3	11.8

* High score indicates most tender or best.

** Low score indicates most tender.

Table 19. Consumer acceptance test for liver

Treatment	Days fed	Sucrose fed (lbs.)	Tenderness*	Flavor of lean*
1	3	0	3.4	3.1
2	3	0	4.1	4.1
3	3	1	3.8	4.0
4	3	2	3.9	4.1

* High score indicates most tender or best.

RESULTS AND DISCUSSION OF SWINE

Daily Gain in Weight

Of the 145 swine included in this report, records on the daily gain in liveweight are available for 131 which are consolidated and summarized in table 20. Feeding sucrose increased the average daily gain in weight in all cases. Feeding 2 pounds of sucrose per day produced the largest daily gains, which amounted to 1 to 3 pounds more than the animals not fed sucrose. Swine fed for 12 or 14 days gained more than those fed shorter periods, which may be due, in part, to their becoming adjusted to new quarters and fewer disturbances occurring during the feeding period. Although not included in table 20, 2 swine were fed 4 pounds of sucrose per day for 3 days without gaining in weight. This level is believed to be too high to give satisfactory gains, since diarrhea often occurs.

Dressing Yields

Experiment 1. The dressing yields were increased in all cases due to feeding sucrose (table 21). Feeding 2 pounds of sucrose per day produced the largest increases in dressing yields which amounted to an average of 4.9 per cent higher than for the average of pigs not fed sucrose. These differences were statistically significant.

Experiments 2 and 3. Although increased dressing yields were obtained from the pigs fed 6 and 12 days, with one exception, the pigs fed sucrose for 3 days showed a loss. Feeding 2 pounds of sucrose per day produced the largest overall increase in dressing yields. The differences in dressing yields between the control group and the groups fed sucrose for 6 days are significant; differences for other periods of feeding were not significant.

Table 20. Summary of average daily gains in liveweight for 131 swine fed various levels of sucrose for varying periods of time prior to slaughter

Number of days fed sucrose	Levels of sucrose								Total number of animals	Weighted average gain in weight*
	0		1		2		3			
	Number of animals	Daily weight gain	Number of animals	Daily weight gain	Number of animals	Daily weight gain	Number of animals	Daily weight gain		
3	10	-0.5	8	1.6	10	2.0	8	1.8	36	1.2
6	10	0.5	10	0.9	12	1.5	10	1.6	42	1.1
12	8	1.5	8	1.8	8	2.5	8	2.1	32	2.0
14	8	2.1	2	0.2	11	2.4	--	--	21	2.1
Average	36	0.8	28	1.3	41	2.1	26	1.8	131	1.5

* Weighted on the basis of number of animals per lot.

Table 21. Summary of average dressing percentages* for swine fed various levels of sucrose for varying periods of time prior to slaughter

Experiment number	Number of days fed	Levels of sucrose: 0 No. of ans.	0 Dressing percentage	1 No. of ans.	1 Dressing percentage	2 No. of ans.	2 Dressing percentage	3 No. of ans.	3 Dressing percentage	4 No. of ans.	4 Dressing percentage	Total number of animals	Weighted average dressing percentage
1	3	3	73.1	--	--	3	81.0	--	--	--	--	6	77.0
	14	2	79.7	--	--	2	80.0	--	--	2	80.8	6	80.2
Average		5	75.7	--	--	5	80.6	--	--	2	80.8	12	78.6
2	3	8	76.6	8	76.0	8	75.0	8	76.3	--	--	32	76.0
and	6	10	78.2	10	80.1	10	79.9	10	79.4	--	--	40	79.4
3	12	8	76.2	8	75.8	8	77.9	8	77.2	--	--	32	76.8
Average		26	77.1	26	77.5	26	77.8	26	77.8	--	--	104	77.6
4,5	3	2	79.6	--	--	2	81.3	--	--	2	82.2	6	81.0
and	6	--	--	--	--	2	80.4	--	--	--	--	2	80.4
6	14	8	75.9	2	82.5	11	76.1	--	--	--	--	21	76.6
Average		10	76.6	2	82.5	15	77.4	--	--	2	82.2	29	77.8
Total all swine													
	3	13	76.3	8	76.0	13	77.4	8	76.3	2	82.2	44	76.8
	6	10	78.2	10	80.1	12	80.0	10	79.4	--	--	42	79.5
	12	8	76.2	8	75.8	8	77.9	8	77.2	--	--	32	76.8
	14	10	76.6	2	82.5	13	76.7	--	--	2	80.8	27	77.4
Grand average		41	76.8	28	77.9	46	78.0	26	77.8	4	81.5	145	77.7

* Based on dressing percentage after the sucrose-feeding period.

Experiments 4, 5, and 6. Sucrose feeding increased the dressing yield of all groups over those not fed sucrose. The largest increase occurred when one pound of sucrose was fed for 14 days prior to slaughter; however, the number of experimental animals receiving either 1 or 4 pounds of sucrose was relatively small.

The overall average for all swine shows that the pigs fed 2 pounds of sucrose per day with the basal ration dressed higher than the pigs not fed sucrose, and of this group the swine fed for 12 days prior to slaughter had the highest spread over those not fed sucrose.

Weight of Livers

Data on weight of livers for 145 swine used as experimental animals are consolidated and summarized in table 22. Liver weights were increased, with one exception, for all of the pigs fed sucrose. These differences were statistically significant. The size of the liver increased as the length of the feeding period increased. The largest increases in liver weights occurred with the swine fed 2 pounds of sucrose for 14 days, amounting to an overall increase of 0.4 pounds over the pigs not fed sucrose.

Per Cent of Normal Livers

Available records of the experimental animals used in these studies show that all the pig livers were normal. However, experience shows that the livers of swine are frequently abscessed or contain "flukes" which renders them unfit for use. For purposes of study, it is estimated that the percentage of normal livers in swine will average 85 per cent. This estimate is based on the informed judgment of experts in the field.

Table 22. Summary of average liver weights for swine fed various levels of sucrose for varying periods of time prior to slaughter

Experiment number	Number of days fed	Levels of sucrose										Total number of animals	Weighted average liver weight
		0		1		2		3		4			
		No. of ans.	Liver weight	No. of ans.	Liver weight	No. of ans.	Liver weight	No. of ans.	Liver weight	No. of ans.	Liver weight		
			lbs.		lbs.		lbs.		lbs.		lbs.		lbs.
1	3	2	3.0	—	—	3	3.5	—	—	—	—	6	3.2
	14	2	3.2	—	—	2	3.4	—	—	2	3.8	6	3.5
Average		5	3.1	—	—	5	3.5	—	—	2	3.8	12	3.4
2	3	8	3.3	8	3.5	8	3.8	8	3.5	—	—	32	3.5
and	6	10	3.0	10	3.4	10	3.6	10	3.5	—	—	40	3.4
3	12	8	4.2	8	4.3	8	4.3	8	4.0	—	—	32	4.2
Average		26	3.5	26	3.7	26	3.9	26	3.7	—	—	104	3.7
4,5	3	2	2.9	—	—	2	4.4	—	—	2	3.6	6	3.6
and	6	—	—	—	—	2	3.6	—	—	—	—	2	3.6
6	14	8	4.5	2	3.4	11	4.7	—	—	—	—	21	4.5
Average		10	4.2	2	3.4	15	4.5	—	—	2	3.6	29	4.3
Total all swine													
	3	13	3.2	8	3.5	13	3.8	8	3.5	2	3.6	44	3.5
	6	10	3.0	10	3.4	12	3.6	10	3.5	—	—	42	3.4
	12	8	4.2	8	4.3	8	4.3	8	4.0	—	—	32	4.2
	14	10	4.2	2	3.4	13	4.5	—	—	2	3.8	27	4.3
Grand average		41	3.6	28	3.7	46	4.0	26	3.7	4	3.7	145	3.8

Feed Consumption

Accurate records of feed consumption per pig are available for only a part of the experimental animals used in this study. Based on the records that are available, the pounds of feed consumed per day for a pig weighing between 170 and 200 pounds varied from 5 to 7 pounds per day. According to the National Research Council, the recommended nutrient allowances for swine of this same size are 6.8 to 7.5 pounds of properly balanced feed per day. Due to the lack of records on a sufficiently adequate number of animals, the amount of feed recommended by the National Research Council for swine is adopted for this study. For a pig weighing between 175 and 200 pounds this amount would be 7 pounds of feed per day.

From a relatively small number of records and observations while conducting the experiments, it has been estimated that animals fed sucrose will consume approximately 15 per cent more feed, including the sucrose, than those not fed sucrose. This is due principally to the fact that the palatability of the feed is increased and an animal will eat more to satisfy his appetite.

Chemical and Quality Tests

Carbohydrate in the Liver and Muscle. Feeding swine varying amounts of sugar 3 and 14 days before slaughter resulted in marked increases in the percentage of carbohydrate in the liver and the muscle of swine in experiment 1 (table 23). The liver and muscle of the sugar-fed animals contained over twice the amount of sugar as the control animals and the muscle contained nearly twice as much sugar. These differences were significant for the sugar content of the muscle and highly significant for the sugar content of the liver.

Findings in experiments 2 and 3 show that the per cent of carbohydrate in the liver was increased by sucrose feeding; however, the increases were not consistent. Significant differences in the liver values were observed between the control and the pigs fed 3 days and as a result of increasing the quantity of sucrose for the groups fed 6 days. With the exception of the pigs fed 2 pounds of sucrose, the 12-day feeding period did not increase the per cent of carbohydrate in the liver. Under some conditions the per cent of carbohydrate in the muscle was increased by sucrose feeding, but the results were inconsistent and statistically insignificant.

In experiment 4, the percentage of carbohydrates in the muscle and liver was increased in all lots of pigs as a result of sucrose feeding. In most of the lots the carbohydrate content of the muscle or liver was double the average value for the controls.

When the results from studies on a total of 128 swine are combined, it shows substantial increases in the percentage of carbohydrate in the liver and muscle due to sucrose feeding; with a few exceptions, the percentages of carbohydrate in the liver and muscle are consistently increased as the feeding period and the quantity of sucrose are increased.

pH in the Liver and Muscle. Available records on the pH of the liver and muscle of swine for all the studies reveal that only slight changes occurred in the pH values as a result of sucrose feeding. It is unlikely that sucrose feeding favorably influenced the pH of the liver or muscle of swine.

Color of Meat. Similar values for color of the meat were obtained for the controls and the sucrose-fed swine in most of the studies. In

some instances, sucrose feeding showed favorable influences on color of meat; however, the overall results for all studies showed results that were inconsistent and not significantly different.

Tenderness and Flavor. Shearing tests conducted on most of the studies of sucrose feeding to swine showed that the sugar-fed pork was slightly more tender than the animals not fed sucrose. However, these differences were inconsistent and were not statistically significant. Quality appraisal tests showed that sugar-fed pork roasts had slightly better flavor and texture than roasts from control animals.

In general, livers of high carbohydrate content were preferred to the livers of low carbohydrate content on the basis of tenderness and flavor.

Consumer acceptance tests were made which show that from two-thirds to three-fourths of the people preferred the livers from the sucrose-fed animals.

Table 23. Average per cent of carbohydrate and pH in the muscle and liver of swine

Experiment number	Days fed sucrose	Amount of sucrose fed	Number of animals	Carbohydrate calcd. as dextrose (%) Liver	Muscle	pH Muscle	Liver
1	0	0	5	0.86	.183	5.3	6.2
	3	2	3	2.01	.294	5.2	5.9
	14	2	2	1.49	.366	5.4	6.3
	14	4	2	1.54	.344	5.4	6.4
2	0	0	10	0.85	.206	*	*
	6	1	10	0.60	.180	*	*
	6	2	10	1.08	.199	*	*
	6	3	10	1.40	.317	*	*
3	0	0	8	0.71	.107	*	*
	3	1	8	1.21	.152	*	*
	3	2	8	1.24	.180	*	*
	3	3	8	1.19	.188	*	*
	0	0	8	0.71	.100	*	*
	12	1	8	0.64	.309	*	*
	12	2	8	0.86	.096	*	*
	12	3	8	0.61	.144	*	*
4	0	0	2	0.88	.172	5.8	6.5
	3	2	2	1.99	.290	5.6	6.4
	3	4	2	2.19	.439	5.6	6.4
	6	2	2	1.84	.414	5.5	6.4
	14	1	2	2.33	.719	5.5	6.5
	14	2	2	1.62	.345	5.5	6.3
Average for all swine by number of days fed							
	0		33	0.79	.151	5.4	
	3		31	1.40	.210	5.4	
	6		32	1.08	.243	5.5	
	12		24	0.70	.183	*	
	14		8	1.74	.444	5.4	
Average for all swine by the amount of sucrose fed							
		0	33	0.78	.151		6.3
		1	28	0.91	.247		6.5
		2	37	1.28	.214		6.2
		3	26	1.09	.224		*
		4	4	1.86	.392		6.4

* Not available

EXPENSES AND BENEFITS

Beef

Increased Expenses. Feeding a sucrose supplement to farm animals may increase the expenses above the cost of feeding a conventional ration in several ways:

(1) The cost of refined sugar as a source of sucrose is much higher than the cost of conventional livestock feeds. Although refined sugar is assumed to be the source of sucrose in this study, it may be possible to use raw sugar and other forms of sucrose which are less expensive.

(2) Evidence indicates that animals will consume more feed when sucrose is added to the ration.

(3) Some additional miscellaneous expenses may be incurred for such items as extra labor for weighing, storage, and care of the sucrose, insecticides, and equipment for control of insects and rodents, additional feeding troughs or other containers, and allowances for interest on investment, and other unforeseen contingencies.

It is difficult to determine absolute costs that will apply to all practical feeding operations due to numerous variations in feeding and management practices. It is the purpose of this study to make the cost estimates as representative as possible, which will help to indicate the relative feasibility of sucrose feeding from a practical standpoint. These results should not be construed to represent absolute costs for all conditions.

The calculated cost of each basal feeding ration used in the experimental studies on beef is summarized in Appendix table VII.

Average retail prices for 1954 have been used in estimating the cost of each feed ingredient and the sucrose. For the Utah studies, an average price of $0.027 per pound was used in computing the total cost of the basal ration consumed during the sucrose-feeding period. This represents an average price for all the rations used and is weighted according to the number of animals in each experiment. For the Denver study, the calculated cost of ration 1, namely prairie hay, and the normal holding ration of Armour and Company were computed at $0.0075 and $0.028 per pound, respectively. For animals receiving sucrose in the Utah studies, the amounts of basal ration consumed were increased by 15 per cent over those not fed sucrose. Feed consumption records for part of the Utah studies are not available; however, evidence indicates that animals fed sucrose will consume an average of 15 per cent additional feed. The cost of sucrose at $0.10 per pound was applied to the amount of sugar consumed during the sucrose-feeding periods and added to the feed costs. The total cost of the basal ration and the sucrose was increased by 5 per cent to allow for miscellaneous expenses and unforeseen contingencies. This is an arbitrarily selected value, but it is considered adequate to defray the usual additional miscellaneous expenses from sucrose feeding under practical feeding operations. A substantial increase in the contingency factor will not appreciably affect the differences between the cost of feeding sucrose over the cost of not feeding sucrose.

The calculated additional increased expenses per animal for the Utah and Denver studies are summarized in tables 24 and 25, respectively. These costs represent the additional increased expenses of feeding varying levels of sucrose to beef cattle for various periods of time

Table 24. Increased additional expenses per head from feeding varying amounts of sucrose to beef cattle in the Utah studies for varying periods of time prior to slaughter *

Number of days fed sucrose	Levels of sucrose				
	0	1	2	3	4
	Increased costs	Increased costs	Increased costs	Increased costs	Increased costs
Steers					
3	--	$ 0.61	$ 0.85	$ 1.06	$ 1.29
6	--	1.25	1.72	2.12	2.55
9	--	1.92	2.55	3.22	3.85
12	--	2.55	3.41	4.27	5.14
Heifers					
3	--	0.58	0.81	1.01	1.24
5	--	0.95	1.30	1.69	2.05
6	--	1.14	1.57	2.01	2.44
Average per heifer and steer					
3	--	0.60	0.83	1.04	1.26
5	--	1.01	1.37	1.72	2.07
6	--	1.20	1.63	2.06	2.49
9	--	1.83	2.46	3.13	3.76
12	--	2.43	3.29	4.17	5.03

* Includes the increased cost of the basal ration, the sucrose, and an allowance of 5 per cent for miscellaneous expenses and unforeseen contingencies.

Table 25. Increased additional cost of feeding rations 2, 3, or 4 and miscellaneous costs* per animal for 3, 4, 5, or 7 days prior to slaughter at Denver, Colorado

Item	Treatments 1		2		3		4		Total number of animals	Weighted increased costs per animal**
	No. of animals	Average increased costs	No. of animals	Average increased costs	No. of animals	Average increased costs	No. of animals	Average increased costs		
Beef fed 3 days										
Hereford steers	69	$ --	73	$ 1.15	76	$ 1.44	76	$ 1.72	225	$ 1.44
Hereford heifers	76	--	78	.95	77	1.20	76	1.49	231	1.21
Angus heifers	18	--	20	.99	17	1.06	15	1.58	52	1.18
Total or average	163	--	171	1.04	170	1.29	167	1.60	508	1.31
Beef fed 4 days										
Hereford steers	29	--	31	1.52	31	1.85	30	2.37	92	1.91
Hereford heifers	20	--	19	1.68	18	2.01	19	2.55	56	2.08
Total or average	49	--	50	1.58	49	1.91	49	2.44	148	1.97
Beef fed 5 days										
Hereford steers	14	--	14	2.73	14	3.05	14	3.32	42	3.03
Angus steers	12	--	13	2.71	12	3.06	12	3.33	37	3.02
Total or average	26	--	27	2.72	26	3.05	26	3.32	79	3.03
Beef fed 7 days										
Hereford and Angus heifers	8	--	9	2.86	6	4.02	7	4.53	22	3.71
Total or average	8	--	9	2.86	6	4.02	7	4.53	22	3.71
All steers	124	--	131	1.56	133	1.85	132	2.18	396	1.86
All heifers	122	--	126	1.20	118	1.45	117	1.86	361	1.50
Grand total or average	246	--	257	1.38	251	1.66	249	2.03	757	1.69

* Includes an additional 5 per cent of the total feed cost for miscellaneous items and contingencies.
** Includes animals receiving treatments 2, 3, and 4.

above the average costs per animal for beef cattle not fed sucrose. Additional detail on feed costs per animal is presented in Appendix tables VIII and IX.

The additional total expenses per animal from feeding sucrose are higher for the Utah studies than for the Denver study, which is due to the differences in the amount of feed consumed per animal. The primary importance of these data, however, is the comparisons of the additional increased expenses of the animals fed sucrose over those not fed sucrose.

Increased Benefits. The additional benefits that may accrue from sucrose feeding are classified into two sources: (1) The direct benefits that are readily susceptible to monetary measurement from a combination of the increased carcass weight, the increased weight of the liver, and the increased gain in the liveweight of animals fed sucrose over animals not fed sucrose; (2) the indirect benefits that are not readily susceptible to monetary measurement from the improved quality of the meat products, the increased sales of sucrose, and the increased quantity of meat products marketed. In this study, the direct benefits are computed from data obtained in the experimental studies to indicate the feasibility of sucrose feeding from a practical standpoint to the livestock feeder or meat-packer. The indirect benefits that would accrue to numerous beneficiaries are discussed in descriptive terms.

It is not the purpose of this study to determine a specific beneficiary of the additional increased benefits from sucrose feeding, but to calculate the total increased gain to society as a whole. Although a livestock feeder will realize the additional gain in liveweight, he may not realize the additional dressing yield and liver

weight caused by feeding sucrose. Results show that only under the most favorable conditions will the receipts from increased gain in liveweight alone pay for the additional cost of feeding sucrose. When all additional benefits from sucrose feeding are considered, however, feeding refined table sugar under certain conditions appears to be economically feasible. This condition is most likely to exist for a meat-packing company or others who can feed the sucrose, slaughter the animals, and market the carcass and liver.

Direct Benefits. The increased gross receipts per animal from feeding sucrose to beef cattle in the Utah studies are computed from the increases in gain in liveweight, dressing percentage (per cent of liveweight after the sucrose-feeding period), and the increased weight of the liver. The increase in the weight of the liver has been deducted from the increase in the liveweight of the animal to avoid duplication. For the Denver study, the increased gross receipts per animal are appraised as the increased carcass weight, and the increased weight of the liver of animals fed sucrose over those not fed sucrose. The increase in carcass weight is measured from the dressing percentage based on the liveweight of the animal before the sucrose-feeding period. The change in liveweight is then reflected in the carcass weight. The methods of handling the dressing yield differ for the two studies to avoid duplication of increased gains; however, the total increased benefits computed by either method are the same.

In the Utah studies, the beef fed the basal ration without sucrose serves as the controls, and all receipts and expenses are measured from them. In the Denver study, two comparisons have been made: (1) Between the beef fed the regular stockyard ration and the Armour ration fed with

and without sucrose, and (2) between the Armour ration fed without sucrose and the Armour ration fed with sucrose.

The prices used are $0.385, $0.35, and $0.22 per pound for computing the value of the carcass, liver, and liveweight of the animals, respectively. These prices were obtained from livestock market reports and represent average 1954 prices. These prices are applied to the weight differences between the animals not fed sucrose and those fed sucrose to obtain the additional gross receipts per animal as summarized in tables 26 and 27, and Appendix tables X and XI. The net gains or losses per animal for beef cattle fed varying levels of sucrose for various periods of time are obtained by subtracting the additional increased total cost from the additional increased gross receipts (tables 28 and 29, and Appendix table XII).

On the basis of the results of the Utah studies on beef, net gains of $6.64, $6.61, and $6.61, and $0.64 per steer were obtained for steers fed 1, 2, or 3 pounds of sucrose for 3 days, respectively, and $4.71 for the heifers fed 1 pound of sucrose for 3 days. Gains for all other beef in these studies were decreased over those not fed sucrose (table 28). The highest net gains were obtained for steers fed 2 pounds of sucrose for 3 days; however, the average for heifers and steers was higher for the groups receiving 1 pound of sucrose per animal per day. On the basis of these results, it would not be economically feasible to feed beef cattle sucrose in excess of 3 days prior to slaughter.

For the Denver study, the increased net gains for all animals fed the Armour ration, with and without sucrose, for 3 to 7 days averaged almost $2.00 per animal over the beef fed the regular stockyard ration of prairie hay (table 29). Feeding one pound of sucrose with the Armour ration (ration 3) for 3 days produced the highest net gains. In only

one instance (1 pound of sucrose for 7 days) were gains lower than for the animals fed the stockyard ration. When comparing the results between the Armour ration fed with and without sucrose, additional gains of $0.67 per animal could be obtained for the beef fed 1 pound of sucrose per day (Appendix table XII). Net gains were higher for the heifers than the steers. In most instances feeding two pounds of sucrose per animal per day did not increase the net gains over the beef fed the Armour and Company holding ration without sucrose. The highest net gains were obtained for the heifers fed 2 pounds of sucrose per day for 4 days, and the largest losses were obtained for the beef fed 1 pound of sucrose for 7 days. Feeding 1 pound of sucrose for 3 days prior to slaughter appears to be more consistent than for feeding other levels of sucrose for different periods of time.

Although similar trends are noted in each of the studies, there is considerable variation in the data, particularly for the Utah studies. The causes of the variation may be due to a combination of numerous factors. In both studies, a disportionate number of animals were used, and for some treatments the numbers were relatively small. Pertinent data were lacking in some cases, and the experiments were conducted over a long period of time under varying conditions of climate, facilities, and management. The types and nutritional levels of the basal ration fed in the studies were different, which causes variation in responses. For these and other reasons it is strongly emphasized that the results from this study should not be used as a criterion for feeding sucrose under all conditions. Less favorable price-cost relationships will alter the feasibility considerably. Feeding other basal rations may produce different results and require different amounts of sucrose. It is possible to build a ration so high in

nutritive value that no significant gain could be obtained through the addition of sugar. Feeding too much sugar may cause a laxative effect and throw animals off feed. This is especially true if a basal ration already contains molasses, as in these studies.

Most of the experiments were conducted at the stockyards when the animals were upset and nervous from being transported from their normal feed-lots. Aside from being disturbed by the new surroundings at the stockyards, a new basal ration fed may have tended to throw some of the animals off feed. All of these factors undoubtedly may add to the extreme amount of variation shown throughout the studies. It is noted, however, that all animals were treated alike after they were started on experiment, and the comparison between each treatment should be valid. Less individual animal variation would be expected if the studies could have been conducted in the feed-lots prior to shipping the animals to the stockyards.

Swine

Increased Expenses. The composition and calculated cost of each ration fed in the experimental studies on swine are presented in Appendix table VIII. A composite average cost of $0.0325 per pound was used in determining the cost of the basal ration consumed during the sucrose-feeding periods. An increase in consumption of 15 per cent of the basal ration was allowed for the swine fed sucrose over those not fed sucrose. The cost of the sucrose was added to the appropriate ration to compute total feed costs. The total cost of the basal ration and the sucrose consumed was increased by 5 per cent to allow for miscellaneous expenses and unforeseen contingencies.

The calculated total expenses, and the additional increased expenses per pig are summarized in tables 30 and 31 for each level

Table 26. Calculated increased gross gains or losses per animal from feeding various levels of sucrose for varying periods of time in the Utah studies*

Number of days fed sucrose	Levels of sucrose			
	0	1	2	3
Steers				
3	--	$ 7.25	$ 7.46	$ 1.70
6	--	-1.36	1.64	- .34
Average	--	2.94	4.55	0.68
Heifers				
3	--	5.29	-3.26	--
5	--	-3.64	-5.22	--
Average	--	0.82	-4.24	--
Average for heifers and steers**				
3	--	6.27	2.10	1.70
5	--	-3.64	-5.22	--
6	--	-1.36	1.64	-0.34

* Gains or losses for each feeding period for the 1-, 2-, and 3-pound levels of sucrose represent deviations from the 0 level and comparisons of receipts between feeding periods are not valid.

** Average for heifers and steers fed for three days but only for heifers fed for five days, and steers fed for six days.

Table 27. Gross gains per animal from beef fed rations with and without sucrose for varying periods of time prior to slaughter in Denver, Colorado

Item	Treatments 1		2		3		4		Total number of animals*	Average gross receipts
	No. of animals	Gross receipts	No. of animals	Gross receipts	No. of animals	Gross receipts	No. of animals	Gross receipts		
Beef fed 3 days										
Hereford steers	69	$ --	73	$ 4.60	76	$ 4.97	76	$ 3.12	225	$ 4.23
Hereford heifers	76	--	78	1.02	77	2.32	76	2.29	231	1.87
Angus heifers	18	--	20	1.16	17	2.06	15	3.26	52	2.06
Total or average	163	--	171	2.56	170	3.48	167	2.75	508	2.93
Beef fed 4 days										
Hereford steers	29	--	31	4.87	31	5.88	30	8.26	92	6.32
Hereford heifers	20	--	19	4.02	18	2.84	19	3.92	56	3.61
Total or average	49	--	50	4.55	49	4.76	49	6.58	148	5.29
Beef fed 5 days										
Hereford steers	14	--	14	5.55	14	4.34	14	6.93	42	5.61
Angus steers	12	--	13	3.42	12	3.89	12	3.89	37	3.72
Total or average	26	--	27	4.52	26	4.13	26	5.53	79	4.72
Beef fed 7 days										
Hereford and Angus heifers	8	--	9	8.89	6	2.84	7	6.49	22	6.48
Total or average	8	--	9	8.89	6	2.84	7	6.49	22	6.48
All steers	124	--	131	4.65	133	5.02	132	4.76	396	4.81
All heifers	122	--	126	2.06	118	2.39	117	2.93	361	2.45
Grand total or average	246	--	257	3.38	251	3.78	249	3.90	757	3.68

* Total number of animals receiving rations 2, 3, and 4.

Table 28. Additional increased net gains or losses per animal for beef cattle fed varying levels of sucrose prior to slaughter in the Utah studies*

Number of days fed sucrose	Levels of sucrose 0	1	2	3
Steers				
3	$ --	$ 6.64	$ 6.61	$ 0.64
6	--	-2.61	-0.08	-2.46
Average	--	2.02	3.26	-0.91
Heifers				
3	--	4.71	-4.07	--
5	--	-4.59	-6.52	--
Average	--	0.06	-5.30	--
Average for heifers and steers**				
3	--	5.69	1.27	0.64
5	--	-4.59	-6.52	--
6	--	-2.61	-0.08	-2.46

* The estimated values per animal for each feeding period for the 1-, 2-, and 3-pound levels of sucrose represent deviation from the 0 level and comparisons of receipts between feed periods are not valid.

** Averages for heifers and steers fed sucrose for three days, for heifers fed five days, and for steers fed for six days.

Table 29. Additional increased net gains or losses per animal from beef fed rations with and without sucrose in the Denver study

Item	Treatments 1		2		3		4		Total number of animals*	Average net receipts*
	No. of animals	Average net receipts	No. of animals	Average net receipts	No. of animals	Average net receipts	No. of animals	Average net receipts		
Beef fed 3 days										
Hereford steers	69	$ —	73	$ 3.45	76	$ 3.53	76	$ 1.40	225	$ 2.78
Hereford heifers	76	—	78	0.07	77	1.12	76	0.80	231	0.66
Angus heifers	18	—	20	0.17	17	1.00	15	1.68	52	0.88
Total or average	163	—	171	1.52	170	2.19	167	1.15	508	1.62
Beef fed 4 days										
Hereford steers	29	—	31	3.35	31	4.03	30	5.89	92	4.41
Hereford heifers	20	—	19	2.34	18	0.83	19	1.37	56	1.52
Total or average	49	—	50	2.97	49	2.85	49	4.14	148	3.32
Beef fed 5 days										
Hereford steers	14	—	14	2.82	14	1.29	14	3.61	42	2.57
Angus steers	12	—	13	0.71	12	0.83	12	0.56	37	0.70
Total or average	26	—	27	1.80	26	1.08	26	2.21	79	1.69
Beef fed 7 days										
Hereford and Angus heifers	8	—	9	6.03	6	-1.18	7	1.96	22	2.77
Total or average	8	—	9	6.03	6	-1.18	7	1.96	22	2.77
All steers	124	—	131	3.09	133	3.17	132	2.57	396	2.94
All heifers	122	—	126	0.85	118	0.94	117	1.07	361	0.95
Grand total or average	246	—	257	1.99	251	2.12	249	1.87	757	1.99

* Total number of animals receiving rations 2, 3, and 4.

Table 30. Calculated total costs of feeding varying amounts of sucrose to swine for varying periods of time prior to slaughter

Number of days fed sucrose	Levels of sucrose 0 Total costs	1 Total costs	2 Total costs	3 Total costs	Average total costs
3	$ 0.68	$ 1.04	$ 1.23	$ 1.43	$ 1.10
6	1.36	2.08	2.46	2.86	2.20
12	2.73	4.16	4.92	5.72	4.40
14	3.18	4.85	5.76	6.67	5.12
Average	1.99	3.03	3.59	4.17	3.20

Table 31. Calculated additional increased costs of feeding varying amounts of sucrose to swine for varying periods of time prior to slaughter

Number of days fed sucrose	Levels of sucrose 0 Increased costs	1 Increased costs	2 Increased costs	3 Increased costs	Average increased expenses
3	$ --	$ 0.36	$ 0.55	$ 0.75	$ 0.55
6	--	0.72	1.10	1.50	1.11
12	--	1.44	2.20	3.00	2.21
14	--	1.67	2.58	3.49	2.58
Average	--	1.05	1.61	2.18	1.61

of sucrose and feeding period. The costs represent the additional increased expenses of feeding varying levels of sucrose to swine for various periods of time above the costs per animal not fed sucrose.

Most of the additional expenses incurred from sucrose feeding are due to the cost of the sucrose. It is possible to obtain sucrose from alternative sources which are lower in price than refined table sugar.

It has been estimated by representatives of sugar companies that raw sugar can be obtained for approximately 75 per cent of the cost of refined table sugar. Other sources of sucrose that appear to be less expensive than refined table sugar are syrups from sugar cane and corn products. It would be necessary to investigate these possibilities more thoroughly before conclusive statements could be made.

Increased Benefits

Direct Benefits. The additional direct benefits computed from the experimental studies on feeding varying levels of sucrose for varying periods of time to swine are summarized in tables 32 and 33. The additional increases for the sucrose-fed animals in daily gain in liveweight, liver weight, and dressing yields (based on liveweight after the sucrose-feeding period) over the swine not fed sucrose have been used to determine the direct benefits. The additional increased weight of the liver has been deducted from the additional increase in the gain in liveweight, and adjusted 15 per cent for "flukes," which render livers unfit for use. The prices used are $0.283, $0.228, and $0.25 per pound for computing the value of the carcass, liver, and liveweight of the animal, respectively. These prices are applied to the weight differences between the animals not fed sucrose and the animals fed varying levels of sucrose for various periods of time to obtain the

Table 32. Calculated increased additional gross receipts from feeding varying amounts of sucrose to swine for various periods of time prior to slaughter

Number of days fed sucrose	Levels of sucrose 0 Gross receipts	1 Gross receipts	2 Gross receipts	3 Gross receipts	Average gross receipts
3	$ --	$ 1.28	$ 2.34	$ 1.58	$ 1.73
6	--	1.64	2.40	2.19	2.08
12	--	0.59	3.70	2.21	2.17
14	--	3.66	1.59	--	2.62
Average	--	1.79	2.51	1.99	2.15

Table 33. Calculated additional increased net gains or losses from feeding varying amounts of sucrose to swine for various periods of time prior to slaughter

Number of days fed sucrose	Levels of sucrose 0 Net receipts	1 Net receipts	2 Net receipts	3 Net receipts	Average net receipts
3	$ --	$ 0.92	$ 1.79	$ 0.83	$ 1.18
6	--	0.92	1.30	0.69	0.97
12	--	-0.85	1.50	-0.79	-0.05
14	--	1.99	-0.99	--	0.50
Average	--	0.74	0.90	0.24	0.65

additional gross gains. The net gains or losses per animal represent the weight difference between the additional gains and the additional costs of feeding sucrose over animals not fed sucrose.

On the basis of the data used in this study, the net gains from feeding varying amounts of sucrose for 3, 6, 12, and 14 days were increased by an average of $0.65 per pig. Feeding 2 pounds of sucrose with the basal ration produced the highest average net gains, which amounted to $0.90 per pig. Feeding 1 pounds of sucrose per day for 14 days resulted in higher increased gains than for the other feeding periods. A loss was obtained from feeding 1 or 3 pounds of sucrose for 12 days, and for 2 pounds for 14 days. Feeding 1, 2, or 3 pounds of sucrose for 3 days produced higher average net gains than did the other feeding periods. There is considerable variation in the results, which may be due to numerous factors, including rations of varying nutritive levels, disproportionate numbers and sexes of swine between treatments, conditions of climate, management, feeding practices, etc. The results are more useful for comparisons of relative values than for absolute values. The results from this study should not be used as a criterion for feeding sucrose to swine under all conditions.

Indirect Benefits From Sucrose Feeding

Indirect benefits that may accrue from feeding sucrose to farm animals have not been evaluated in monetary terms. It is important to recognize, however, that in addition to the direct benefits enumerated above, additional indirect benefits would accrue to other recipients from the increased weight differences and improved quality of the meat and liver. No attempt has been made to identify each recipient of the additional benefits, but only to recognize that society as a whole would gain.

It was well established from these studies that the addition of sucrose to the basal ration caused the animals to eat more. The feed was made more palatable and nutritious. It was found that less feed was required per pound of gain in liveweight when sucrose was added than when the same feed was fed without sucrose. This being true, indirect benefits to society as a whole would be realized from the increased efficiency in the utilization of the present feeding rations.

Other beneficiaries would benefit from the increased weight differences caused by feeding sucrose, including transportation services, processing concerns, and others handling the additional quantities of meat and sugar from the producer to the consumer. To the extent that a particular recipient would benefit from the indirect benefits of sucrose feeding would depend on numerous factors or assumptions which are beyond the scope of this study to evaluate.

SUMMARY

Beef Cattle

Utah Studies. In 4 separate experiments a total or 267 fat, ready-to-market beef were fed from 0 to 4 pounds of sucrose per animal per day with a basal fattening ration for 3 to 12 days prior to slaughter. The basal rations used were principally of a barley base and contained from 10 to 12 per cent molasses.

Feeding 1, 2, or 3 pounds of sucrose for 3 days increased the daily gain in liveweight per steer by 3 to 5 pounds more than the animals fed the basal ration without sucrose. Feeding 1 pound of sucrose per animal per day produced the highest average daily gains in weight. Losses in weight occurred for steers fed 2 and 3 pounds of sucrose for 6 days. Gains in weight by the heifers fed sucrose were higher for the 3-day feeding period than for the 5-day feeding period when compared with the gain for the groups fed the basal ration.

Average dressing yields were increased for all steers fed 1, 2, or 3 pounds of sucrose per day; however, losses in dressing yields occurred for steers fed 4 pounds per day for 6 and 12 days. Feeding 2 pounds of sucrose per day produced the largest increases in dressing percentage. The feeding of sucrose to heifers did not increase the dressing percentage, except for the group fed 1 pound per day for 3 days. The animals not fed prior to slaughter dressed lower than either the 3- or 5-day sucrose-fed heifers. The averages for heifers and steers fed 1, 2, or 3 pounds of sucrose per day were higher than for the control group not fed sucrose. Dressing percentage for the groups fed 1 pounds of sucrose per day for 3 days was 0.5 per cent higher than for the 3-day controls.

The liver weights, with few exceptions, were increased as the quantity of sucrose fed was increased, and as the feeding time was increased. Differences varied from 0 to as much as 2.6 pounds of gain for animals fed sucrose over those not fed sucrose. Approximately 20 per cent of the livers contained "flukes" or other abnormalities.

The amount of feed consumed per animal is increased when sucrose is added to the basal ration. This is considered due to an increase in the palatability of the basal ration causing animals to eat more.

The expenses of sucrose feeding are increased by the cost of the sucrose fed, by an increase in the amount of the basal ration consumed, and by miscellaneous expenses for the additional labor, equipment, and unforeseen contingencies over the conventional type ration. Most of the increased expenses are attributable to the cost of refined sugar as the source of sucrose.

Total direct benefits (susceptible to monetary measurement) from sucrose feeding are computed from the increases in gain in weight, dressing percentage (based on liveweight after sucrose-feeding period), and the increased weight of the liver. On the basis of the data used in this study, average increased net gains of $5.69 per animal could be obtained from feeding 1 pound of sucrose for 3 days. Feeding 2 or 3 pounds of sucrose to steers for 3 days showed net increases of $6.61 to $0.64 per animal, respectively. Feeding other levels of sucrose for varying periods of time, however, showed losses over the animals fed only the basal ration. The results of the data show wide variation which may be attributable to numerous factors, including individual animal variation, disproportionate numbers of animals for each treatment, varying nutritive levels of basal rations used, physical condition of the experimental animals, climatical conditions at the time of the study,

and many others. For these and other reasons it is felt that the values obtained have significance largely from a relative standpoint.

Denver Study. One thousand and three fat beef were fed rations with and without sucrose for 3 to 7 days prior to slaughter under actual feeding, holding, and slaughtering conditions. The beef were selected for uniformity and divided at random into 4 groups and fed either the regular stockyard ration of prairie hay, the normal holding ration of Armour and Company, or this ration plus 1 or 2 pounds of sucrose per animal per day. The Armour holding ration contained 20 per cent corn and 10 per cent molasses plus ground alfalfa, barley, and salt.

The average daily gain in liveweight for animals fed the regular stockyard ration for 3 to 7 days was 0.3 pounds; for animals fed the regular Armour ration, 1.6 pounds; for animals fed the regular Armour ration plus 1 pound of sucrose per day, 3.0 pounds; and for animals fed the regular Armour ration plus 2 pounds of sucrose per day, 3.2 pounds. Daily gains were highest for beef fed 1 or 2 pounds of sucrose for 3 days. Losses in weight occurred for beef fed the stockyard ration for 4 days, and for beef fed 1 or 2 pounds of sucrose with the Armour ration for 4 days. The losses were minimized for the animals fed sucrose. The differences in gain in weight were statistically significant. Considerable variation occurred in the data for the relatively small number of animals fed for 4, 5, or 7 days prior to slaughter.

Dressing percentages were increased by approximately 1 per cent for animals fed the Armour ration with and without sucrose over the animals fed the stockyard ration. The addition of 1 or 2 pounds of sucrose increased the dressing percentage by only 0.1 per cent over

the Armour ration without sucrose. Feeding 1 pound of sucrose for 3 days produced the highest dressing yields.

Feeding 1 or 2 pounds of sucrose per day with the Armour ration increased the average weight of liver by at least 1.0 pound more than from feeding the regular stockyard ration. The liver weights were increased as the quantity of sucrose was increased. The differences in weight of livers were statistically significant. The average weight of livers for animals fed 1 or 2 pounds of sucrose was 0.2 and 0.3 pounds, respectively, larger than for animals fed the Armour holding ration without sucrose.

The per cent of normal livers varied from 79.4 to 83.1 per cent and averaged 82.6 per cent. There was no significant difference between the per cent of abnormal livers due to the ration fed.

Animals fed the regular stockyard ration consumed less feed than animals fed the other rations. The animals fed sucrose with the Armour ration consumed slightly more feed than those fed this ration without sucrose. The animals fed for 3 days consumed less feed per day than those fed for longer periods. Daily feed consumption per animal was lower than recommended for animals of similar size which may have been due, in part, to the hot weather and disturbance of the animals during the tests.

Animals fed 1 pound of sucrose daily gained more weight relative to feed intake than did animals fed other rations.

Results of chemical tests show that the average carbohydrate content of the liver increased as the level of sucrose and the feeding period increased. These differences were statistically significant. The per cent of carbohydrate in the muscle was not consistently increased by

feeding sucrose. Sucrose feeding did not consistently influence the content of pH in the muscle or liver. The color of the meat of animals fed the Armour ration or this ration plus 1 or 2 pounds of sucrose were similar; however, these were all slightly improved over the meat of animals fed the stockyard ration of prairie hay. The U. S. carcass grades for all animals were similar.

Tenderness values scored by shear force tests were similar for all rations. Quality scores by a panel of judges showed preference for meat of animals fed 2 pounds of sucrose per day; however, results for all other rations were similar. The livers of animals fed the Armour ration with and without sucrose were preferred for tenderness and flavor over those from animals fed the stockyard ration.

Total direct benefits were computed from the increased dressing percentages (based on liveweight after the sucrose-feeding period), and the increased weight of the liver of animals fed the Armour ration with and without sucrose over the animals fed the regular stockyard ration. Average net gains of $1.99 per animal were obtained for all animals fed from 3 to 7 days over animals fed the stockyard ration. The most profitable ration fed was the Armour ration plus 1 pound of sucrose for 3 days. In most instances, it would not be profitable to feed 2 pounds of sucrose with the Armour ration; however, feeding 1 pound of sucrose per day with this ration for 3 days increased the net receipts per animal by $0.67. This is considered rather significant as the Armour holding ration was a high nutritive value ration which contained corn and molasses. Animals fed a lower nutritive value ration would be expected to respond more favorably when sucrose is added.

Swine

One hundred and forty-five swine in 6 separate experiments were fed from 0 to 4 pounds of sucrose per animal per day for 3 to 14 days prior to slaughter. The basal rations consisted primarily of barley. Feeding various levels of sucrose increased the average daily gain in weight in all cases, with the highest gains occurring for the swine fed 2 pounds of sucrose per day. Feeding 4 pounds of sucrose per day caused diarrhea resulting in decreased gains in weight.

Average dressing yields were increased from 1.0 to 4.7 per cent for all swine fed sucrose above those not fed sucrose. Swine fed 2 pounds of sucrose per day, generally, dressed higher than those fed other levels. The 12- or 14-day feeding periods produced slightly higher dressing yields than did the shorter feeding periods.

Liver weights were increased, with one exception, for all pigs fed sucrose. These differences were statistically significant. The size of the liver increased as the length of the feeding period was increased. Feeding 2 pounds of sucrose per day for 14 days increased the size of the liver by 0.4 pound over pigs not fed sucrose.

Feeding swine varying amounts of sucrose for 3 to 14 days prior to slaughter increased the carbohydrate content of the liver and muscle in most cases over those not fed sucrose. The results were not as consistent for the 3 and 4 levels of sucrose, but in most cases the per cent of carbohydrate in the liver and muscle increased as the length of the feeding period increased.

Only slight changes were observed in the pH content of the liver and muscle of swine fed sucrose. In some cases an improvement in the color of meat was evident from sucrose feeding, but the results were inconsistent.

Shearing tests for tenderness showed that the sugar-fed pork was slightly more tender than for the animals not fed sucrose in most of the studies, but some results did not substantiate this finding.

The livers of high carbohydrate content were preferred for tenderness and flavor. Approximately 70 per cent of the people tasting the cooked livers preferred those from the sucrose-fed animals.

The additional increased expenses of feeding sucrose to swine includes the cost of the sucrose, an increase of 15 per cent in the amount of basal ration consumed, and an increase in the total feed costs of 5 per cent for miscellaneous expenses and unforeseen contingencies. The largest share of the total increased cost is due to the cost of sucrose which may be reduced if sucrose could be obtained from cheaper alternative sources.

The additional total direct benefits per animal are computed from the increases in daily gains in weight, liver weight, and dressing yields (based on liveweight after the sucrose-feeding period) over animals not fed sucrose. The net increase was determined by deducting the additional increased expenses from the additional increased gross receipts. The average net gains or losses from feeding various amounts of sucrose for 3 to 14 days were increased by an average of $0.65 per pig. Feeding swine the 2-pound level of sucrose with the basal ration produced an average of $0.90 per head more than animals not fed sucrose. Decreased gains were obtained for animals fed 1 or 3 pounds of sucrose for 12 days, and for 2 pounds for 14 days. All animals fed 1, 2, or 3 pounds of sucrose for 3 or 6 days increased the net receipts per animal by at least $0.69 per head over those not fed sucrose.

CONCLUSIONS

The following outstanding conclusion are drawn from the results of this study:

1. Under certain conditions it would be profitable to feed sucrose to beef and swine for a few days prior to slaughter.

2. Additional profits are computed from the weight differences of gain in liveweight, liver weight, and dressing yield of animals fed sucrose over animals not fed sucrose.

3. Due to considerable variation in the results, it is difficult to express precise conditions for profits with confidence.

4. Certain weaknesses and uncontrolled variables inherent in the study caused much variation in the data and prevented exact measurement of profits from feeding sucrose.

   a. Feeding and management practices prior to feeding sucrose were lacking for part of the animals.
   b. Feed consumption records were not kept on part of the studies.
   c. The studies were conducted over a long period of time under different conditions of climate, facilities, basal rations, nutritional state of animals, etc., which limits comparisons among the different studies.
   d. Varying amounts of sucrose in the form of beet molasses were present in some basal rations in addition to the sugar added.

e. The sucrose was fed to animals in groups, and individual animals may not have received the amount of sucrose assumed in the study.

f. Changes in price-cost relationship will alter the feasibility considerably.

5. Evidence from limited sales showed that a premium price may be obtained for sucrose-fed meat and liver.

6. Feeding too much sucrose will cause diarrhea, throw animals off feed, and result in loss of weight.

7. The most profitable combination of the amount of sucrose and the length of feeding time for a particular livestock feeder will depend to a large extent on his own particular feeding and management practices.

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Appendix table I. Record sheet for recording original data

Date at start of feeding period _____
Date of slaughter _____

Lot _____ No. of Animals _____ Breed _____ Sex _____
Group _____ Pen No. _____ Grade _____ Age _____

OWNER: ADDRESS:

Wt. before feed.	Wt. after feed.	Animal number	Warm carcass wt.	Cold carc. wt.	Dress. %	Warm liver wt.	Cond. of liver	color l f	Carc. grade U.S.	
										Ave.

RATION: RATION:

Date	am.fed	Crts	consum.	ave/an	Date	am.fed	Crts	consum	ave/an
TOTAL					TOTAL				

RATION: RATION:

Date	am.fed	Crts	consum.	ave/an	Date	am.fed	Crts	consum	ave/an
TOTAL					TOTAL				

Temperature data: Maximum _____ Minimum _____
Name of commission firm _____
Name of buyer _____
Estimated yield _____

Appendix table II. Summary of mean squares for analysis of variance by the method of least squares

Source of variation	Degrees of freedom	Mean squares for: Daily gain in weight	Liver weight	Dressing percentage	Per cent carbohydrate in liver	Carcass grade	Color of lean	Color of fat	Per cent of normal liver
Overall effect	1	.0187407**	.0012759	.0032766**	.0015317**	.0010328	.0077789**	.0031574	.0093011**
Sex	1	.0002913	.0001104	.0000123**	.0003838*	.0001951	.0005452	.0034460*	.0000139
Breed	1	.0001349	.0000016	.0000017	.0000104	.0000002	.0000555	.0000840	.0000016
Treatments:	(3)	(.0024815)	(.0003116)	(.0000104)	(.0000188)	.0000601	.0003074	.0023445*	.0003249
Linear effect	1	.0000050	.0009217**	.0000188**	.0000253	--	--	--	--
Quadratic effect	1	.0050131	.0001136	.0000188**	.0000097	--	--	--	--
Cubic effect	1	.0040551	.0000957	.0000075*	.0000164	--	--	--	--
Days fed	2	.1761965**	.0031812**	.0000023	.0009788**	.0000060	.0001708	.0203300**	.0041648**
Feed consumed	1	.0141298**	.0001176	.0000285**	.0011068**	.0002614	.0000692	.0109815	.0002565
Liveweight	1	.008461	.0052730**	.0001405**	.0000358	.0001831	.0007272	.0127406	.0000715
Error	118	.0018695	.0000860	.0000017	.0000588	.0029031	.0001112	.0008151	.0002828
Total	128								

* Significant at P< .05

** Highly significant at P< .01

Appendix table III. Physical characteristics of beef fed varying levels of sucrose for 3 to 7 days prior to slaughter at Denver, Colorado

Livestock producer number	Treatment 1 Number of animals	Treatment 1 Average live-weight	Treatment 2 Number of animals	Treatment 2 Average live-weight	Treatment 3 Number of animals	Treatment 3 Average live-weight	Treatment 4 Number of animals	Treatment 4 Average live-weight
		lbs.		lbs.		lbs.		lbs.
Hereford steers fed 3 days								
1	6	942	7	936	6	932	6	949
2	6	974	6	901	6	942	6	999
3	7	1041	8	1012	10	1050	9	1039
4	6	1128	7	1122	8	1072	8	1056
5	7	983	8	982	8	991	8	986
8	9	1231	7	1219	8	1166	10	1249
13	6	1115	7	1074	7	1073	6	1062
16	5	982	6	1020	6	970	6	1065
17	10	842	10	804	10	844	10	828
24	7	876	7	884	7	861	7	831
Average	69	1010	73	989	76	992	76	1010
Hereford heifers fed 3 days								
18	10	827	10	836	10	784	10	800
21	7	769	7	746	7	824	7	746
22	11	811	12	818	10	788	9	804
23	7	893	7	809	7	917	7	769
25	8	818	8	818	8	826	8	806
26	7	857	7	831	6	807	6	813
27	6	803	6	733	6	780	6	730
29	13	845	12	843	13	809	12	842
28	7	858	9	815	10	829	11	754
Average	76	831	78	811	77	816	76	789
Angus heifers fed 3 days								
15	5	736	8	749	6	690	6	788
19	6	685	7	710	7	750	6	733
28	7	799	5	891	4	877	3	847
Average	18	744	20	771	17	759	15	778
Average or total for all beef fed 3 days								
	163	897	171	882	170	889	167	889
Hereford steers fed 4 days								
9	13	1125	14	1147	12	1136	13	1174
10	5	725	6	794	7	752	6	683
14a	5	948	5	914	5	899	5	901
14b	6	942	6	901	7	901	6	895
Average	29	988	31	993	31	954	30	974

Appendix table III. Continued

Livestock producer number	Treatment 1 Number of animals	Treatment 1 Average live-weight lbs.	Treatment 2 Number of animals	Treatment 2 Average live-weight lbs.	Treatment 3 Number of animals	Treatment 3 Average live-weight lbs.	Treatment 4 Number of animals	Treatment 4 Average live-weight lbs.
Hereford heifers fed 4 days								
10	6	774	4	805	4	721	5	781
12	8	822	8	899	8	811	8	832
20	6	823	7	796	6	832	6	800
Average	20	808	19	841	18	798	19	808
Average or total for all beef fed 4 days								
	49	915	50	935	49	899	49	910
Hereford steers fed 5 days								
7	6	997	6	1010	7	1014	7	993
11	8	989	8	957	7	992	7	937
Average	14	992	14	980	14	1003	14	965
Angus steers fed 5 days								
7	6	1039	6	978	6	1037	6	937
11	6	791	7	812	6	814	6	835
Average	12	915	13	889	12	926	12	886
Average or total for all beef fed 5 days								
	26	956	27	936	26	967	26	929
Mixed Hereford and Angus heifers fed 7 days								
7	8	773	9	768	6	794	7	787
Average	8	773	9	768	6	794	7	787
Average or total for all steers								
	124	994	131	979	133	979	132	1067
Average or total for all heifers								
	122	811	126	806	118	804	117	791
Average or total for all beef								
	246	903	257	894	251	897	249	937

Appendix table IV. Average daily gains in liveweight for each lot of beef included in the Denver study

Livestock producer number	Treatments 1 Daily gain	2 Daily gain	3 Daily gain	4 Daily gain
	lbs.	lbs.	lbs.	lbs.
Hereford steers fed 3 days				
1	-4.2	-2.9	-0.3	1.4
2	-9.2	-1.4	1.9	-2.5
3	0	3.1	1.0	3.1
4	-4.4	-5.0	-4.2	-0.2
5	11.9	8.3	6.5	12.3
8	6.7	5.5	11.3	1.0
13	7.2	5.7	10.9	10.8
16	2.7	5.0	-0.5	0.6
17	3.2	8.2	8.0	6.5
24	-4.8	-10.0	0.5	-1.0
Average	1.3	2.0	3.8	3.4
Hereford heifers fed 3 days				
18	7.0	9.8	11.5	12.3
21	0	1.9	-2.9	1.0
22	1.7	3.2	9.8	9.1
23	2.4	3.8	3.8	1.4
25	-2.5	2.1	3.3	0.4
26	4.8	5.7	6.6	10.6
27	1.1	5.0	4.4	4.4
28	-0.7	-4.4	-0.8	-3.6
29	-6.4	-0.7	-0.7	1.4
Average	0.5	2.6	3.8	3.8
Angus heifers fed 3 days				
15	2.7	2.9	3.9	3.9
19	1.7	3.3	6.7	6.1
28	-0.7	-0.7	-0.7	1.7
Average	1.0	2.1	4.0	4.3
Average for all beef fed 3 days				
	0.9	2.3	3.8	3.7
Hereford steers fed 4 days				
10	0	-1.9	0.8	3.1
14	-1.3	5.8	4.7	7.4
Average	-0.8	2.6	3.3	6.5

Appendix table IV. Continued

Livestock producer number	Treatments 1 Daily gain	2 Daily gain	3 Daily gain	4 Daily gain
	lbs.	lbs.	lbs.	lbs.
Hereford heifers fed 4 days				
10	0	-1.9	0.8	3.5
12	-1.0	-2.2	-0.3	-0.3
20	-4.2	-1.6	-0.4	-5.0
Average	-1.7	-1.9	-0.1	0.2
Average for all beef fed 4 days				
	-1.2	0.9	2.0	4.1
Hereford steers fed 5 days				
7	-3.7	-3.0	-2.0	-3.7
11	-1.1	-2.5	-0.2	-0.4
Average	-2.2	-2.7	-1.1	-2.1
Angus steers fed 5 days				
7	0.8	3.3	3.3	1.0
11	-1.4	-2.1	-0.3	-0.3
Average	-0.3	0.4	1.5	0.4
Average all beef fed 5 days				
	-1.3	-1.2	0.1	-0.9
Mixed (Hereford and Angus) heifers fed 7 days				
	1.2	2.5	1.5	2.7
Average	1.2	2.5	1.5	2.7
Average for all steers				
	0.3	1.5	3.0	3.2
Average for all heifers				
	0.3	1.8	3.1	3.2
Average for all beef				
	0.3	1.6	3.0	3.2

Appendix table V. Average dressing percentage for each lot of beef included in the Denver study*

Livestock producer number	Treatments 1 Dressing percentage	2 Dressing percentage	3 Dressing percentage	4 Dressing percentage
Hereford steers fed 3 days				
1	60.5	59.5	61.0	61.1
2	57.1	58.9	62.3	58.7
3	63.7	64.2	63.7	63.8
4	60.4	61.5	60.4	59.3
5	60.8	63.1	62.0	61.2
8	59.3	62.1	60.1	61.3
13	60.7	62.1	63.1	60.1
16	60.6	60.7	60.3	60.3
17	59.6	60.4	59.8	60.1
24	58.0	57.5	59.2	59.5
Average	60.0	61.1	61.2	60.7
Hereford heifers fed 3 days				
18	61.0	61.1	61.6	62.1
21	59.3	59.4	58.8	58.5
22	60.3	60.6	62.8	61.1
23	58.7	59.2	58.9	58.1
25	59.9	59.4	61.1	60.4
26	60.6	61.8	62.5	62.0
27	58.0	60.2	60.1	61.1
28	60.5	59.8	59.0	58.7
29	61.7	62.2	62.2	64.5
Average	60.1	60.4	60.8	60.8
Angus heifers fed 3 days				
15	61.5	63.2	57.9	62.6
19	57.1	58.1	62.3	57.9
28	61.7	62.3	62.2	64.5
Average	60.1	61.2	60.7	60.8
Average for all beef fed 3 days				
	60.1	60.8	61.0	60.8
Hereford steers fed 4 days				
9	59.9	61.4	61.2	61.3
10	57.2	58.3	58.7	59.3
14	59.3	60.4	61.2	62.2
Average	59.2	60.4	60.6	61.2

Appendix table V. Continued

Livestock producer number	Treatments 1 Dressing percentage	2 Dressing percentage	3 Dressing percentage	4 Dressing percentage
Hereford heifers fed 4 days				
10	57.2	58.3	58.7	59.2
12	59.4	60.7	60.0	60.0
20	56.8	57.9	57.4	57.8
Average	58.0	59.2	58.8	59.1
Average for all beef fed 4 days				
	58.7	59.9	59.9	60.4
Hereford steers fed 5 days				
7	59.4	60.8	60.1	60.6
11	56.6	57.9	57.5	58.3
Average	57.8	59.1	58.8	59.5
Angus steers fed 5 days				
7	61.7	62.5	62.6	61.8
11	56.7	57.8	57.6	58.3
Average	59.2	60.0	60.1	60.1
Average for all beef fed 5 days				
	58.4	59.5	59.4	59.8
Mixed Hereford and Angus heifers fed for 7 days				
	59.3	62.1	60.1	61.3
Average	59.3	62.1	60.1	61.3
Average for all steers				
	59.5	60.6	60.7	60.6
Average for all heifers				
	59.7	60.3	60.4	60.6
Average for all beef				
	59.6	60.5	60.6	60.6

* Averages weighted on basis of number of animals per lot. Dressing percentages based on liveweight of beef before sucrose-feeding period.

Appendix table VI. Average weight of livers for each lot of beef included in the Denver study*

Livestock producer number	Treatments 1 Liver weights	2 Liver weights	3 Liver weights	4 Liver weights
	lbs.	lbs.	lbs.	lbs.
Hereford steers fed 3 days				
1	10.4	10.8	11.0	11.1
2	10.2	11.3	11.2	12.2
3	9.9	9.9	11.9	11.4
4	11.1	14.9	13.1	12.5
5	10.9	12.1	10.8	11.7
8	13.1	13.6	13.5	14.3
13	12.5	13.2	13.7	14.6
16	10.0	11.6	10.8	12.2
17	8.6	9.7	10.0	10.3
24	10.6	11.5	11.4	10.3
Average	10.6	11.8	11.7	12.0
Hereford heifers fed 3 days				
18	10.9	12.1	10.8	11.2
21	9.2	9.3	10.2	9.9
22	9.3	9.6	10.4	10.7
23	10.7	9.5	10.8	10.0
25	8.7	10.0	9.6	9.7
26	11.3	11.4	10.3	10.2
27	8.4	9.0	9.2	9.4
28	9.3	9.8	10.1	10.6
29	9.9	10.1	10.6	9.5
Average	9.8	10.1	10.3	10.2
Angus heifers fed 3 days				
15	9.2	10.0	10.1	9.9
19	9.1	10.6	10.0	10.8
28	9.9	10.1	10.1	8.5
Average	9.4	10.2	10.1	10.0
Average for all beef fed 3 days				
	10.1	10.8	10.9	11.0
Hereford steers fed 4 days				
9	10.3	11.4	13.3	13.4
10	7.9	9.4	9.4	10.1
14	10.2	10.6	10.8	10.6
Average	9.9	10.7	11.5	11.7

Appendix table VI. Continued

Livestock producer number	Treatments 1 Liver weights	2 Liver weights	3 Liver weights	4 Liver weights
	lbs.	lbs.	lbs.	lbs.
Hereford heifers fed 4 days				
10	7.7	8.9	9.3	10.0
12	9.4	10.6	10.2	11.3
20	8.5	9.1	10.0	9.5
Average	8.6	9.7	9.9	10.4
Average for all beef fed 4 days				
	9.4	10.3	10.9	11.2
Hereford steers fed 5 days				
7	10.1	13.0	11.2	10.9
11	9.6	10.5	11.5	11.1
Average	9.8	11.6	11.4	11.0
Angus steers fed 5 days				
7	10.6	10.9	11.3	10.3
11	8.8	10.7	10.9	11.9
Average	9.7	10.8	11.1	11.1
Average for all beef fed 5 days				
	9.8	11.2	11.3	11.0
Mixed Hereford and Angus heifers fed 7 days				
	8.7	9.5	10.0	9.8
Average	8.7	9.5	10.0	9.8
Average for all steers				
	10.3	11.4	11.6	11.7
Average for all heifers				
	9.5	10.0	10.2	10.2
Average for all beef				
	9.9	10.7	10.9	11.0

* Average weighted on the number of animals per lot.

Appendix table VII. Ingredients and cost of basal rations fed to beef

Feed ingredients	Per cent of ration	Cost per pound	Cost per 100# feed
Utah studies			
Experiment I			
Ground alfalfa hay	49.0	$ .025	$ 1.225
Ground barley	30.0	.024	0.720
Dried beet pulp	10.0	.0252	0.252
Beet molasses	10.0	.016	0.160
Mineral supplement and salt	1.0	.018	0.018
Total	100.0		2.375
Experiment II			
Chopped alfalfa hay	47.0	.025	1.175
Ground barley	20.0	.024	0.480
Ground wheat	20.0	.034	0.680
Beet molasses	12.0	.016	0.192
Mineral supplement and salt	1.0	.018	0.018
Total	100.0		2.545
Experiment III			
Chopped alfalfa hay	50.0	.025	1.250
Ground barley	20.0	.024	0.480
Ground wheat	20.0	.034	0.680
Soybean meal	9.0	.055	0.495
Mineral supplement and salt	1.0	.018	0.018
Total	100.0		2.923
Experiment IV			
Alfalfa hay (good)	49.0	.0125	0.6125
Rolled barley	35.0	.024	0.840
Bone meal	5.0	.050	0.250
Beet molasses	10.0	.016	0.160
Mineral supplement and salt	1.0	.018	0.018
Total	100.0		1.680
Denver study			
Ration 1			
Prairie or meadow hay	100.0	.0075	0.75
Basal ration for rations 2, 3, and 4			
Sun-cured alfalfa hay	49.0	.0125	0.6125
Rolled barley	20.0	.0240	0.480
Cracked corn	20.0	.0425	0.850
Beet molasses	10.0	.016	0.160
Salt	1.0	.018	0.018
Total	100.0		2.1205

Appendix table VIII. Estimated amount* and cost of feed consumed per animal per day for beef included in the Utah studies

Number of days fed	Daily feed consumed	Levels of sucrose: 0 0 Total feed	0 0 Total cost	1 Total feed	1 Total cost	2 Total feed	2 Total cost	3 Total feed	3 Total cost	4 Total feed	4 Total cost
	lbs.	lbs.	dollars	lbs.	dollars	lbs.	dollars	lbs.	dollars	lbs.	dollars
Steers											
3	28	84	2.27	95	2.85	92	3.08	88	3.28	85	3.50
6	28	168	4.54	190	5.73	184	6.17	176	6.55	169	6.96
9	28	252	6.80	286	8.62	275	9.22	265	9.86	254	10.46
12	28	336	9.07	381	11.49	367	12.31	353	13.13	339	13.95
Heifers											
0											
3	24	72	1.94	81	2.49	78	2.71	74	2.90	71	3.12
5	24	120	3.24	135	4.14	129	4.48	124	4.85	118	5.19
6	24	144	3.89	162	4.97	155	5.38	148	5.80	141	6.21
Average per steer and heifer											
0											
3	26	78	2.11	88	2.68	85	2.90	81	3.09	78	3.31
5	26	130	3.51	147	4.47	141	4.81	135	5.14	129	5.48
6	26	156	4.21	176	5.35	169	5.76	162	6.17	155	6.58
9	26	234	6.32	265	8.06	254	8.66	244	9.29	233	9.89
12	26	312	8.42	353	10.73	339	11.55	325	12.38	311	13.20

* For the animals receiving sucrose, the amount of sucrose is deducted from the basal ration, which is increased by 15 per cent. The cost of the sucrose is added in at $.10 per pound.

Appendix table IX. Average cost of feed* per animal for 1,003 beef fed for 3 to 7 days prior to slaughter at Denver, Colorado

Item	Treatments 1		2		3		4		Total number of animals	Weighted average cost of feed
	No. of animals	Feed cost	No. of animals	Feed cost	No. of animals	Feed cost	No. of animals	Feed cost		
Beef fed 3 days										
Hereford steers	69	$ 0.20	73	$ 1.29	76	$ 1.57	76	$ 1.83	294	$ 1.25
Hereford heifers	76	0.19	78	1.09	77	1.33	76	1.61	307	1.06
Angus heifers	18	0.23	20	1.17	17	1.24	15	1.73	70	1.07
Total or average	163	0.20	171	1.18	170	1.43	167	1.72	671	1.14
Beef fed 4 days										
Hereford steers	29	0.27	31	1.71	31	2.03	30	2.52	121	1.65
Hereford heifers	20	0.28	19	1.88	18	2.19	19	2.70	76	1.74
Total or average	49	0.27	50	1.78	49	2.09	49	2.59	197	1.68
Beef fed 5 days										
Hereford steers	14	0.41	14	3.00	14	3.31	14	3.56	56	2.57
Angus steers	12	0.40	13	2.97	12	3.31	12	3.56	49	2.57
Total or average	26	0.40	27	2.99	26	3.31	26	3.56	105	2.57
Beef fed 7 days										
Hereford and Angus heifers	8	0.56	9	3.28	6	4.38	7	4.86	30	3.14
Total or average	8	0.56	9	3.28	6	4.38	7	4.86	30	3.14
All steers	124	0.26	131	1.74	133	2.02	132	2.33	520	1.61
All heifers	122	0.23	126	1.38	118	1.60	117	2.00	483	1.30
Grand total or average	246	0.25	257	1.56	251	1.82	249	2.17	1,003	1.46

* Based on prices presented in table 1.

Appendix table X. Average gross receipts* per animal from liver for 1,003 beef fed varying levels of sucrose for 3 to 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Average receipts from liver
	1		2		3		4			
	No. of animals	Receipts from liver	No. of animals	Receipts from liver	No. of animals	Receipts from liver	No. of animals	Receipts from liver		
Beef fed 3 days										
Hereford steers	69	$ 3.06	73	$ 3.41	76	$ 3.38	76	$ 3.47	294	$ 3.34
Hereford heifers	76	2.83	78	2.92	77	2.98	76	2.95	307	2.92
Angus heifers	18	2.72	20	2.95	17	2.92	15	2.89	70	2.87
Total or average	163	2.92	171	3.13	170	3.15	167	3.18	671	3.10
Beef fed 4 days										
Hereford steers	29	2.86	31	3.09	31	3.32	30	3.38	121	3.17
Hereford heifers	20	2.49	19	2.80	18	2.86	19	3.01	76	2.79
Total or average	49	2.71	50	2.98	49	3.15	49	3.24	197	3.02
Beef fed 5 days										
Hereford steers	14	2.83	14	3.35	14	3.30	14	3.18	56	3.16
Angus steers	12	2.80	13	3.12	12	3.21	12	3.21	49	3.09
Total or average	26	2.82	27	3.24	26	3.26	26	3.19	105	3.13
Beef fed 7 days										
Hereford and Angus heifers	8	2.52	9	2.75	6	2.89	7	2.83	30	2.74
Total or average	8	2.52	9	2.75	6	2.89	7	2.83	30	2.74
All steers	124	2.96	131	3.30	133	3.34	132	3.39	520	3.26
All heifers	122	2.74	126	2.89	118	2.95	117	2.94	483	2.88
Grand total or average	246	2.85	257	3.10	251	3.16	249	3.18	1,003	3.08

* Based on an average 1954 wholesale price of $0.35 per pound, and adjusted for average percentage of normal livers of 82.6 per cent.

Appendix table XI. Average increased dressing yield in pounds and value per animal fed sucrose over animals not fed sucrose on basis of liveweights of 1,005 pounds for steers and 803 pounds for heifers

Item	Treatments								
	2			3			4		
	No. of animals	Dressing yield		No. of animals	Dressing yield		No. of animals	Dressing yield	
		lbs.	value		lbs.	value		lbs.	value
Beef fed 3 days									
Hereford steers	73	11.0	$ 4.29	76	12.0	$ 4.68	76	7.0	$ 2.73
Hereford heifers	78	2.4	0.94	77	5.6	2.18	76	5.6	2.18
Angus heifers	20	8.8	3.43	17	4.8	1.87	15	8.0	3.12
Total or average	171	6.8	2.66	170	8.4	3.27	167	6.4	2.51
Beef fed 4 days									
Hereford steers	31	12.0	4.68	31	14.0	5.46	30	20.1	7.84
Hereford heifers	19	9.6	3.74	18	6.4	2.50	19	8.8	3.43
Total or average	50	11.0	4.32	49	11.2	4.37	49	15.7	6.13
Beef fed 5 days									
Hereford steers	14	13.0	5.07	14	10.0	3.90	14	17.1	6.67
Angus steers	13	8.0	3.12	12	9.0	3.51	12	9.0	3.51
Total or average	27	10.6	4.13	26	9.5	3.72	26	13.4	5.21
Beef fed 7 days									
Hereford and Angus heifers	9	6.4	2.50	6	3.2	1.25	7	16.1	6.28
Total or average	9	6.4	2.50	6	3.2	1.25	7	16.1	6.28
All steers	131	11.2	4.37	133	12.0	4.68	132	11.2	4.37
All heifers	126	4.8	1.87	118	5.5	2.14	117	7.1	2.77
Grand total or average	257	8.1	3.16	251	8.9	3.47	249	9.3	3.63

Appendix table XII. Differences in net receipts per animal between beef fed the Armour ration without and with sucrose

Item	Treatments						Total number of animals	Average net receipts
	2		3		4			
	Number of animals	Average net receipts	Number of animals	Average net receipts	Number of animals	Average net receipts		
Beef fed 3 days								
Hereford steers	73	$ —	76	$ 0.08	76	$ -2.05	152	$ -0.98
Hereford heifers	78	—	77	1.05	76	0.73	153	0.89
Angus heifers	20	—	17	0.83	15	1.51	32	1.15
Total or average	171	—	170	0.67	167	-0.54	337	0.07
Beef fed 4 days								
Hereford steers	31	—	31	0.68	30	2.54	61	1.59
Hereford heifers	19	—	18	-1.51	19	-0.97	37	-1.23
Total or average	50	—	49	-0.12	49	1.17	98	0.52
Beef fed 5 days								
Hereford steers	14	—	14	-1.53	14	0.79	28	-0.37
Angus steers	12	—	12	0.12	12	-0.15	24	-0.02
Total or average	26	—	26	-0.77	26	0.36	52	-0.21
Beef fed 7 days								
Hereford and Angus heifers	8	—	6	-7.21	7	-5.80	13	-6.45
Total or average	8	—	6	-7.21	7	-5.80	13	-6.45
All steers	131	—	133	0.05	132	-0.53	265	-0.24
All heifers	126	—	118	0.21	117	0.16	235	0.19
Grand total or average	257	—	251	0.12	249	-0.21	500	-0.04

Appendix table XIII. Cost of the basal feeding rations fed to swine

Experiment number	Feed ingredient	Per cent of total ration	Price per pound	Total weighted per pound
1	Protein supplement*	15.0	$ 0.063	$ 0.00945
	Ground alfalfa	5.0	0.025	0.00125
	Ground barley	78.5	0.024	0.01884
	Bone meal	1.0	0.050	0.00050
	Salt	0.5	0.018	0.00009
	Total	100.0		0.03013
2	Alfalfa meal	10.0	0.025	0.00250
	Meat scraps (50% protein)	5.0	0.050	0.00250
	Ground wheat	50.0	0.034	0.01700
	Ground barley	27.0	0.024	0.00648
	Soybean oil meal	7.0	0.055	0.00385
	Iodized salt	0.5	0.018	0.00009
	Aurofac**	0.5	0.60	0.00300
	Total	100.0		0.03542
3	Ground barley	49.0	0.024	0.01176
	Soybean oil meal	5.0	0.055	0.00275
	Chopped peas	2.0	0.055	0.00385
	Meat meal	2.0	0.050	0.00100
	Shorts	10.0	0.025	0.00250
	Wheat bran	5.0	0.0275	0.00138
	Ground alfalfa hay	10.0	0.025	0.00250
	Screenings	10.0	0.015	0.00150
	Bone meal	0.4	0.050	0.00016
	Calcite	0.6		
	Trace minerals	0.5		
	Aurofac**	0.5	0.60	0.00300
	Total	100.0		0.03040
4	Protein supplement*	15.0	0.063	0.00945
	Ground alfalfa hay	5.0	0.025	0.00125
	Ground barley	78.3	0.024	0.01879
	Iodized salt	0.5	0.018	0.00009
	Bone meal	1.0	0.050	0.00050
	Aurofac**	0.2	0.60	0.00120
	Total	100.0		0.03128

* Composed of equal proportions of linseed oil meal, soybean oil meal, meat meal, fish meal, and dry whey.

** Contains 1.8 grams of aureomycin and 1.8 milligrams of vitamin B_{12} per pound.

Appendix table XIV. Average gross receipts* per animal from total gain in weight for 1,003 beef cattle fed varying levels of sucrose for 3 to 7 days prior to slaughter at Denver, Colorado

Item	Treatments								Total number of animals	Average receipts per animal
	1		2		3		4			
	No. of animals	Receipts per animal	No. of animals	Receipts per animal	No. of animals	Receipts per animal	No. of animals	Receipts per animal		
Beef fed 3 days										
Hereford steers	69	$ 0.86	73	$ 1.32	76	$ 2.51	76	$ 2.24	294	$ 1.76
Hereford heifers	76	0.33	78	1.72	77	2.51	76	2.51	307	1.77
Angus heifers	18	0.66	20	1.39	17	2.64	15	2.84	70	1.82
Total or average	163	0.59	171	1.51	170	2.52	167	2.42	671	1.77
Beef fed 4 days										
Hereford steers	29	-0.70	31	2.29	31	2.90	30	5.72	121	2.58
Hereford heifers	20	-1.50	19	-1.67	18	-0.09	19	0.18	76	-0.79
Total or average	49	-1.11	50	-1.73	49	-0.15	49	0.45	197	-1.28
Beef fed 5 days										
Hereford steers	14	-2.42	14	-2.97	14	-1.21	14	-2.31	56	-2.23
Angus steers	12	-0.33	13	0.44	12	1.65	12	0.44	49	0.45
Total or average	26	-1.46	27	-1.33	26	0.11	26	-1.04	105	-0.94
Beef fed 7 days										
Hereford and Angus heifers	8	1.85	9	3.85	6	2.31	7	4.16	30	3.08
Total or average	8	1.85	9	3.85	6	2.31	7	4.16	30	3.08
All steers	124	0.01	131	1.00	133	2.13	132	2.38	520	1.41
All heifers	122	0.18	126	1.31	118	2.12	117	2.27	483	1.46
Grand total or average	246	0.09	257	1.15	251	2.13	249	2.33	1,003	1.43

* Based on an average 1954 liveweight price of $0.22 per pound.