CARBOHYDRATE UTILIZATION IN THE YOUNG CALF

I. Nutritive Value of Glucose, Corn Syrup and Lactose as Carbohydrate Sources in Synthetic Milk.

II. The Nutritive Value of Starch and the Effect of Lactose on the Nutritive Values of Starch and Corn Syrup in Synthetic Milk.

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by

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A THESIS

submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy Husbandry

1950

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Doctor Earl Weaver, Professor of Dairy Husbandry, for making this study possible; to Doctor C. F. Huffman, Research Professor of Dairy Husbandry, for invaluable guidance in conducting these investigations and for his advice and criticisms in the preparation of this manuscript.

Gratitude is also expressed to Doctor H. D. Webster, Instructor of Animal Pathology, for his performance of the post mortem examinations; and to Mr. C. W. Duncan, Research Associate in Agricultural Chemistry, for the chemical analyses used in this report.

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INTRODUCTION

The problem of a satisfactory milk replacement for the raising of calves is a matter of utmost economic importance to the dairyman. Many calf starters have been developed but, in general, success appears to depend upon the use of at least 300 pounds of whole milk and the inclusion of dried milk products in the starter. Synthetic milks in themselves are far from being the answer to the economic problem in that the cost of purified components is much greater than the cost of whole milk. Yet fundamental problems can be approached through this means which can not be studied with calves on natural feeds. Early attempts to raise calves on purified diets were unsuccessful and it is only recently that a synthetic diet has been formulated that is satisfactory for the nutrition of the young calf.

In this investigation an attempt was made to determine the relative efficiency of certain carbohydrates incorporated in synthetic milks for calves. Since glucose has been used successfully, this sugar was selected for use as the control. Lactose, the natural carbohydrate source of the neonatal mammal, and Karo corn syrup, frequently used in formulae for infants, were selected for comparison with glucose.

REVIEW OF LITERATURE

For a comprehensive review of the literature on the general subject of purified diets, the reader is referred to a previous publication (7). Of the references covered in that report, only those with specific applications to the problem will be reconsidered here.

An indication of the importance of carbohydrate in the nutrition of the young calf was presented by Shaw and associates (32). They found that calves four to seven days of age were able to digest only about 20 per cent of the quantity of starch consumed. At two weeks of age the amount of starch digested had doubled, and at four to five weeks calves were able to digest over 90 per cent of the ingested starch.

The source of starch is often an important factor, for Langworthy and Merrill (16) have shown that while pure raw starch from corn, wheat or rice was completely digested, the starch in graham flour was 97 per cent digestible and raw potato starch varied in digestibility from 49 to 100 per cent.

Ward *et al*. (37) fed corn sugar as an ingredient in the grain mixture of calves, and reported that calves fed the corn sugar ration ate the grain mix at an earlier age and averaged 24 pounds heavier at six months than did the controls. Sugar has since been used as the primary carbohydrate source in synthetic rations for calves (7, 13, 40). Cornell workers (13) used a milk substitute containing casein, lactalbumin, sugar, butter or lard, minerals and water in attempting to study the growth requirements of calves. Poor food consumption and periodic digestive upsets were believed responsible for the slow growth obtained when this ration was fed. Although these workers reported that the calf does not need thiamin or riboflavin, contradictory reports have been published by Johnson et al. (10, 41) and Warner and Sutton (38). Warner and Sutton destroyed the riboflavin in milk by photolysis and were able to produce deficiency symptoms in calves fed the treated milk in two to four weeks. Johnson et al. produced both riboflavin deficiency (41) and thiamine deficiency (10) by using a synthetic milk developed by these workers (40). In addition to these two vitamins, the Illinois workers have found that the calf requires biotin (42), pantothenic acid (11), and pyridoxine (12). The synthetic milk used consisted of cerelose, casein, lard, minerals, vitamins and water. Casein was brought into solution by adjusting the pH with sodium bicarbonate, the minerals and cerelose added and finally the lard homogenized into the mix.

Somewhat contradictory claims are presented in the literature in regard to the value of lactose. Robinson et al. (30) found that the feeding of lactose elevated the serum calcium and inorganic phosphorus. They suggested that lactose or the lactate ion exerted a specific action in facilitating the passage of calcium into the blood. Mills *et al*. (21) likewise have reported that lactose favors the retention of calcium. Kline *et al*. (15) fed lactose to young chicks and found that it not only favored calcium absorption but also helped maintain acidity in the digestive tract. However, lactose without vitamin D resulted in subnormal growth.

Whittier *et al*. (39) found that rats grew more rapidly when lactose was the carbohydrate than they did when sucrose was used. The feeding of excess lactose caused diarrhea for a short time, after which the feces became normal. These authors felt that the growth obtained on lactose was not due to stimulation of acidophilic organisms in the lower intestine since dextrin does not have the same influence as lactose. Outhouse *et al*. (26) reported that the ingestion of lactose caused a greater quantity of calcium, phosphorus and magnesium to be stored than was found in litter mates on starch and sucrose rations.

Mitchell and associates (22) compared several carbohydrates in feeding rats and found that, as compared to glucose, lactose caused the greatest impairment of digestibility of organic matter, fructose next and sucrose the least impairment.

Rojas *et al*. (31) studied the utilization of lactose as fed to calves in natural milk and in milk plus added lactose. It appeared that under ordinary conditions the calf made efficient utilization of lactose. However, when the lactose content of milk was doubled, diarrhea occurred and efficiency of utilization declined. Johnson (14) compared several sugars in the purified diets of pigs and obtained only fair results with lactose. Lactose-fed pigs tended to develop chronic diarrhea and grew more slowly than did pigs receiving glucose.

Handler (8) attempted to determine the cause for the poor growth of rats on diets high in lactose or galactose. Histologically, the only lesions found were those attributed to simple inanition. Although diarrhea and diuresis occurred, deaths apparently were not due to dehydration or acidosis. Serum calcium was not elevated sufficiently to have been an etiologic factor. However, blood galactose levels were very high and serum inorganic phosphorus levels rather low. The conclusion reached was that death was due to a disturbance in carbohydrate metabolism whose exact nature has not been defined clearly.

Richter (29) has reported an interrelationship between galactose and fat which may be an important link in the action of lactose. Orla-Jensen <u>et al</u>. (25) have revived the old contention that lactose acts through its effect upon the intestinal flora, a view which is also supported by Brody and Sadhu (3). The effects of lactose upon intestinal motility have been reviewed rather critically by Fischer and Sutton (6), and they need not be reconsidered here.

The economic value, first of whole milk and more recently of skim milk, has been the cause of a long series of attempts to use substitutes in place of milk for young calves. In spite of many so-called successes at formulating milk substitutes, almost all of these substitutes contain milk or a milk product. Williams and Bechdel (44) reported that calves fed on a starter containing milk powder responded much better than those receiving blood flour. McIntyre (19) advocated a starter for use with calves; this, however, contained condensed whey powder.

Hathaway et al. (9) used a mixture of dried whey, 32 parts, and blood meal, 10 parts, as a substitute for liquid skim milk in the feeding of calves. Wise (45) has used dried whey, at the rate of one-half to one pound per one hundred pounds of body weight per day, for the treatment of chronic diarrhea. He cautioned, however, that excessive amounts of whey were laxative.

Cornell workers (24) have made an extensive study of calf starters. Although they have developed many satisfactory starters, the more successful ones invariably contain a dried milk product. Even in the recent works of Williams and Knodt (43) and Wallace et al. (36), which indicate definite advances in the formulation of milk replacements, the use of both dried skim milk and dried whey are advocated.

With all of the interest which has developed in the use of milk substitutes, there is no indication as to whether the favorable responses obtained with milk products are due to the lactose content, the protein, the minerals or the vitamins.

CARBOHYDRATE UTILIZATION IN THE YOUNG CALF

I. Nutritive Value of Glucose, Corn Syrup and Lactose as Carbohydrate Sources in Synthetic Milk.

OBJECT

The object of this experiment is to determine the comparative nutritive values of glucose, corn syrup and lactose when fed as carbohydrate constituents of synthetic milks for young calves.

EXPERIMENTAL PROCEDURE

Selection of Animals

The composition of the three experimental groups is indicated in table 1. All of the 18 experimental calves were males with the exception of one female in group G. The system used in assigning calves to the groups and subgroups consisted of random allotment as the calves were born in the College experimental herd. The only prerequisite to assignment was normal health and appearance. Calves were placed on experiment 2 to 3 days after birth and retained for a 31-day feeding trial since the first month is the critical period with respect to carbohydrate utilization in the calf (32). Following the feeding trial, autopsy was performed on most of the animals although a few were returned to the College experimental herd for subsequent research.

TABLE 1

Composition of the experimental groups

Group	Sub-group	No. of calves	Breed distribution	Av. starting wt.
				(lb.)
G (glucose)	--	6	5 Holstein, 1 Ayrshire	94.3
K (corn syrup)	10	2	1 Jersey, 1 Brown Swiss	82.0
	30	2	2 Holstein	96.5
	45	2	1 Jersey 1 Brown Swiss	75.5
L (lactose)	5	2	1 Holstein, 1 Jersey	67.0
	10	2	2 Holstein	81.5
	30	2	1 Holstein, 1 Jersey	69.5

Feeding and Management

Of necessity, calves were started on the experiment in all seasons of the year. Possible differences due to prenatal nutrition were minimized since the dams were stall-fed throughout the year. Calves were permitted to remain with their dams for 12 hours following parturition. Subsequently each calf was placed in an individual pen, starved 14 to 24 hours, and started on the synthetic milk diet. Feed was given twice daily via nipple pail at a rate calculated to meet the recommended nutrient allowances of the National Research Council (17).

The constituents of each of the rations fed are listed in table 2, and the chemical analyses of these rations are presented in table 3. In addition to the components listed, each calf received (a) at the time it was placed on experiment and at weekly intervals thereafter, a capsule containing 70,000 I. U. of vitamin A (shark liver oil) and 10,000 I. U. of vitamin D (viosterol), and (b) a daily dosage of 20 mg. thiamin hydrochloride, 20 mg. riboflavin, 20 mg. calcium pantothenate, 20 mg. nicotinic acid, 20 mg. para-aminobenzoic acid, 5 mg. pyridoxine hydrochloride, 10 mg. vitamin K, 1 mg. biotin, 200 mg. inositol and 3 g. choline chloride. These water soluble vitamins were prepared in stock solution, stored in amber glass under refrigeration, and added to the synthetic milk at the time of the morning feeding.

The carbohydrate content of the rations was varied in the different groups. In the G group, which was used as the control, glucose was the carbohydrate source, various amounts of glucose were replaced with corn syrup in the K group, and various amounts of glucose were replaced with lactose in the L group, as shown in table 2.

TABLE 2

Ingredients of the rations fed

	Ration						
Group	G	K			L		
Subgroup		10	30	45	5	10	30
Glucose	60	50	30	15	55	50	30
Corn syrup	--	10	30	45	--	--	--
Lactose	--	--	--	--	5	10	30
Casein	25	25	25	25	25	25	25
Lard	10	10	10	10	10	10	10
Salts*	5	5	5	5	5	5	5

*Salt mixture composed of 10 calcium carbonate, 20 calcium phosphate (secondary), 20 magnesium phosphate (tertiary), 10 potassium phosphate (secondary), 5 sodium chloride, 5 potassium chloride, 1.98 ferric citrate, 0.04 manganese sulfate, 0.04 copper sulfate and 0.04 cobalt sulfate.

TABLE 3

Chemical analysis of the rations fed

	Ration						
Group	G	K			L		
Subgroup		10	30	45	5	10	30
Moisture (%)	7.22	8.51	11.02	13.06	6.95	6.68	5.62
Protein (%)	21.39	21.36	21.30	21.26	21.38	21.38	21.37
Ash (%)	5.64	5.73	5.92	6.06	5.64	5.64	5.65
Crude fiber (%)	0.11	0.10	0.08	0.06	0.11	0.10	0.08
Ether ext. (%)	10.34	10.31	10.21	10.15	10.34	10.34	10.34
N. F. E. (%)	55.30	53.99	51.47	49.41	55.58	55.86	56.94
Ca (%)	0.65	0.65	0.66	0.67	0.65	0.65	0.65
P (%)	0.77	0.77	0.78	0.78	0.77	0.77	0.77
Mg (%)	0.31	0.32	0.35	0.37	0.31	0.32	0.32
K (%)	0.52	0.55	0.61	0.65	0.52	0.52	0.52
Fe (%)	0.0014	0.0016	0.0020	0.0023	0.0014	0.0014	0.0014
Cu (p.p.m.)	2.1	2.1	3.9	4.8	2.2	2.2	2.4
Mn (p.p.m.)	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Co (p.p.m.)	0.115	0.117	0.121	0.124	0.116	0.118	0.124

Calf pens were bedded with wood shavings. No hay was fed and in order to minimize consumption of shavings each calf received daily one ounce of a mixture containing 10 per cent cellulose, 57 per cent glucose, 24 per cent casein, 5 per cent salts and 4 per cent diluted corn syrup. With few exceptions calves ate this dry mix readily and showed slight inclination to consume shavings.

Preparation of Feed

The synthetic milk was prepared by a modification of the procedure of Wiese *et al.* (40). Due to the limited refrigeration facilities available at the experimental barn, the synthetic milk was prepared once or twice weekly and stored as a liquid concentrate. The frequency of preparation depended upon the number of calves on trial at any particular time. The liquid concentrate was prepared as follows: Four ounces of sodium bicarbonate were dissolved in 43 pounds of water at 60° C. A heavy duty electric stirrer was used and five pounds of casein were added slowly with constant agitation. Stirring was continued 20 to 30 minutes to insure complete dissolution of the casein. Near the end of the agitation period two pounds of lard (80° C.) were thoroughly mixed with the casein solution. The casein-lard solution was homogenized at 3,000 pounds pressure. The remaining components of the ration (carbohydrate (s) and salts, table 2) were mixed dry and 12.5 pounds of this dry mix were blended with the 50 pounds of the homogenized solution.

The synthetic milk liquid concentrate, thus prepared, contained 33.3 per cent dry matter and was stored under refrigeration in this form. At feeding time one part of the concentrate was added to two parts of hot water, the vitamin solution added (mornings only), and the product fed at 85 to 95° F.

Criteria for Evaluation of Response

Evaluation of the response to the experimental rations was based upon (1) observations on the health and general appearance, (2) growth and efficiency of feed utilization, (3) blood analyses, (4) rumen population and (5) post-mortem examinations.

(1) Health and general appearance. Observations and recordings were made at least once daily with regard to general condition, appetite and general reactions of the animals, and the consistency of the feces.

(2) Growth and efficiency of feed utilization. An accurate tabulation of feed consumption and refusal was maintained. Each calf was weighed prior to the morning feeding on the day it was placed on the experiment and on the 4th, 7th, 11th, 14th, 18th, 21st, 25th, 28th and 31st days of the trial.

(3) Blood analysis. Blood samples were collected from the jugular vein of each calf at weekly intervals. Determinations of hemoglobin and hematocrit were made on whole blood. The plasma was analyzed for calcium, inorganic phosphorus, magnesium and ascorbic acid.

(4) Rumen population. Samples of the rumen contents were obtained from most of the calves at weekly intervals. A few calves objected to the passage of the stomach tube and no attempt was made to force collection from such calves. The collections were made at 4 hours after the morning feeding. The samples were preserved in an aqueous solution of formaldehyde and counts were made of iodophilic organisms and total bacteria per ml. of rumen contents.

(5) Post-mortem examinations. Animals which died during the trial or were killed at the end of the experimental period were subjected to gross post-mortem examinations. Histological sections were made of selected organs from representative animals and of any organ or tissue which appeared abnormal in the gross inspection.

RESULTS

Health and General Appearance

Within two to four days after being placed on the experiment, feces from calves of the G (glucose) and K (corn syrup) groups invariably would become quite soft and in many cases semiliquid. The K group was much more severely afflicted than was the G group. On the other hand, L calves (lactose), even at the 5 per cent level, maintained normal consistency of feces throughout the trial. The L calves in general possessed smoother hair coats and showed more alertness than animals in the other groups. Calves on corn syrup, though their weight gains compared favorably with those of calves on glucose, characteristically had much duller hair coats than the latter. All calves drank the synthetic milk readily. Bloat occurred in two glucose calves, and one calf receiving the 10 per cent level of lactose died of acute bloat of the abomasum.

Growth and Feed Utilization

The gain in body weight and the efficiency of feed utilization of each of the experimental groups and subgroups is indicated in table 4. In view of the extensive variation in the starting weight, gains are represented both as pounds and as percentage increase over the starting weight.

TABLE 4

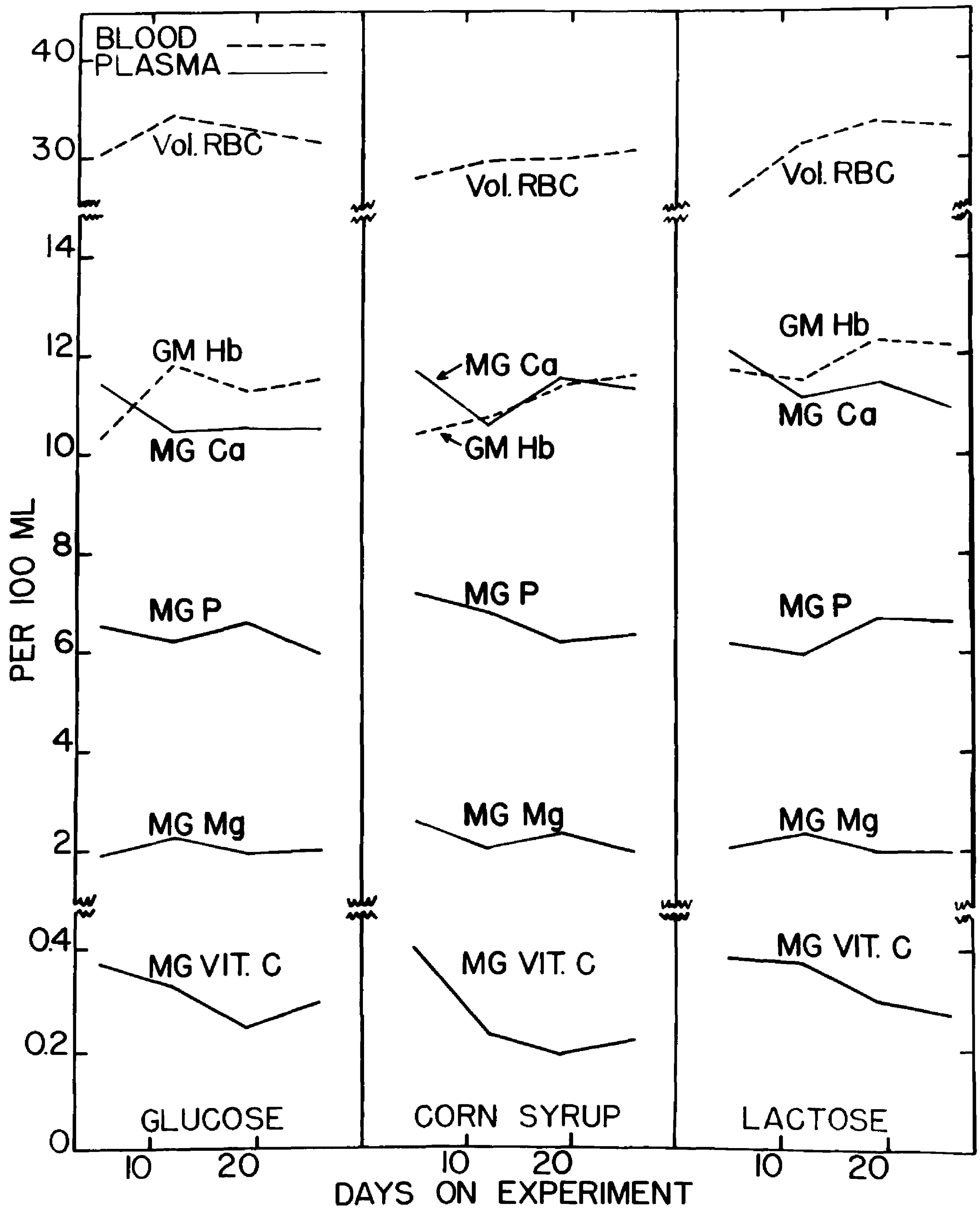
Growth and feed utilization

Group	Sub-group	Average gain (lb.)	Average gain (%)	Gain per lb. DM consumed
G	Av.	9.33 ± 1.58*	8.13	0.234 ± 0.055
K	10	15.50	18.90	0.240
	30	14.50	15.03	0.231
	45	-4.00	-5.30	-0.044
	Av.	8.66 ± 5.68	10.23	0.142 ± 0.092
L	5	16.00	23.88	0.306
	10	20.50	25.15	0.508
	30	19.50	28.06	0.338
	Av.	18.66 ± 2.73	25.92	0.384 ± 0.050

*Standard error of the mean.

Blood Analysis

The average values for hematocrit, hemoglobin and plasma calcium, inorganic phosphorus, magnesium and ascorbic acid for each group are presented graphically in figure 1. These values appear to be within the normal range for calves of this age (2, 46). There is little apparent


BLOOD
PLASMA
Vol. RBC
GM Hb
MG Ca
MG P
MG Mg
MG VIT. C
GLUCOSE
CORN SYRUP
LACTOSE
PER 100 ML
DAYS ON EXPERIMENT
0
0.2
0.4
2
4
6
8
10
12
14
30
40
10
20

difference between groups in any of the constituents, although the plasma ascorbic acid tends to be slightly lower in the corn syrup-fed calves than in the other groups.

Rumen Population

A total of 38 rumen samples were collected from the three groups. The average iodophil count (millions per ml.) was 2,800, 4,222 and 2,400 for the G, K and L groups, respectively. However, the variation obtained between calves within groups and between samples from the same calf on different dates was so great that no significance can be attached to the means. The individual counts of iodophils and total bacteria are presented in tables 20 and 21.

Post-Mortem Examination

Ten of the 18 experimental calves were subjected to post-mortem examination either during the experimental period or as in the case of one calf within 10 days after completion of the trial. Two of the lactose calves and 4 from each of the remaining groups were autopsied during this period. Congestion and consolidation of lung tissue was the most common finding, although white spotted kidneys were also prevalent. White spotted kidneys occurred irrespective of the dietary regime. Congestion and consolidation of lung tissue occurred with equal frequency in the glucose and corn syrup groups, but only one of the lactose calves had a "cold" during the experimental period, and it was successfully treated with sulfathiazole. Ulceration of the pylorus, petechial hemorrhages of the abomasum, and patchy congestion of the intestinal tract occurred frequently in the corn syrup and glucose groups, but less frequently and less severely in the lactose group. The previously mentioned lethal bloat in one lactose calf resulted in rupture of the abomasal wall.

DISCUSSION

Although growth responses were satisfactory in at least one of the groups, the reaction of calves to the synthetic milk can hardly be considered normal. The high incidence of respiratory disturbances, as evidenced by visible symptoms as well as post-mortem findings, indicate that the ability of the calves to resist infection was low. The incidence of white spotted kidneys was also high, but the etiology of this condition is vague. Moore and Hallman (23) found it associated with low vitamin A intake in young calves, while Smith (33) reported the deprivation of colostrum as a predisposing factor.

The blood data indicate that sufficient calcium, phosphorus and magnesium were absorbed to maintain the levels of these elements in the plasma. The reported rise in plasma inorganic phosphorus during the first three weeks of life (27, 46) was not apparent in these experimental animals. Likewise the normal decline in hemoglobin concentration and in hematocrit (46) was not evident in these trials. Such a decline possibly was prevented by the inclusion of iron and trace elements in the synthetic milk, although Davidson and Leitch (4) report that the reduction in hemoglobin and hematocrit following birth is independent of iron reserves and of dietary intake. This does not preclude the possibility that one or more of the trace elements included in the ration may have prevented the decline.

Corn syrup, a food substance widely used in formulae for infants, was selected as a promising carbohydrate for the neonatal calf. The results refuted pre-experimental expectations. Although growth at the 10 and 30 per cent levels compared favorably with other groups, the feces were of foul odor and of semiliquid consistency. Apparently the laxation produced by corn syrup offset any beneficial nutritive value it may have possessed. Chemical analyses (table 3) indicated that corn syrup was high in ash. It is possible that this ash contained some element(s) which caused the laxation and thus prevented the animals from utilizing properly the feed consumed.

The beneficial effect of lactose on the intestinal tract, as evidenced by the consistency of feces, was striking, and results of this benefit are reflected in the growth response and in the efficiency of feed utilization.

Much of the beneficial action of lactose may be credited to its stability and low solubility which permits it to pass unchanged into the intestine. In the intestine it promotes the growth of beneficial lactic acid-producing bacteria and inhibits scatologic putrefaction (3, 25). Although this view is not universally accepted (30, 39), it has much in its favor and must be considered until a more satisfactory explanation is advanced.

Rumen bacterial samples were collected for study as a possible index to the time at which the rumen commences to function but these samples revealed little difference among the groups. However, the intestinal flora are probably of much greater importance in controlling gastro-intestinal motility than are those of the rumen. Also, the samples were examined for characteristic rumen microorganisms, not for acid-producing bacteria. A recent review (6) adequately discusses the effect of lactose on gastro-intestinal motility and indicates that there is more evidence supporting the contention that lactose tends to cause diarrhea than there is evidence to the contrary. Within the bovine species, Wise (45) has used dried whey in treating chronic diarrhea in calves and Rojas _et al_. (31) have indicated that under normal feeding conditions lactose was utilized effectively by calves. It was only when the lactose content of milk was doubled that diarrhea and unthriftiness occurred and the efficiency of utilization was decreased markedly. The results of feeding lactose in synthetic milk are in harmony with the report of Rojas <u>et al</u>., since in all cases, the lactose content of synthetic milk was below the level contained in normal cow's milk.

Whatever the mode of action of lactose, the quantity required by the calf is small, because five per cent produced almost as satisfactory growth response as did 30 per cent. Although the difference was small, the greatest efficiency of feed utilization was obtained at the 10 per cent level of lactose. Whether the decrease in efficiency at the 30 per cent as compared to the 10 per cent level is due to too high a proportion of lactose or to biological variation is open to speculation.

SUMMARY

Eighteen neonatal calves were allotted to three experimental groups and fed rations consisting of synthetic milks which varied only in the source of carbohydrate.

The average gain in weight for the 31-day experimental period was 9.33 pounds for glucose-fed calves (G), 8.66 pounds for corn syrup-fed calves (K) and 18.66 pounds for lactose-fed calves (L). The efficiency of feed utilization, expressed as the average of gain per pound of dry matter consumed, was 0.234, 0.142 and 0.384 for the G, K and L groups, respectively. Within the subgroups, 10 and 30 per cent corn syrup produced fair results while 45 per cent was unsatisfactory. There was little difference in weight gains in response to lactose at the 5, 10 and 30 per cent levels.

Analysis of blood at weekly intervals for hematocrit, hemoglobin and plasma calcium, inorganic phosphorus, magnesium and ascorbic acid showed no apparent departure from the normal.

Examination of rumen samples for microorganisms revealed that individual differences were greater than differences between groups.

On post-mortem examination, congestion of the duodenum and rectum, abomasal petechial hemorrhages and ulceration about the pylorus were observed less frequently in the L than in G and K groups, while colds, pneumonia and white spotted kidney occurred indiscriminately in all groups.

CARBOHYDRATE UTILIZATION IN THE YOUNG CALF

II. The Nutritive Value of Starch and the Effect of Lactose on the Nutritive Values of Starch and Corn Syrup in Synthetic Milk.

OBJECT

The object of this experiment is to determine the nutritive value of starch in comparison to the carbohydrates already tested, and to determine the effect of lactose on the nutritive values of starch and corn syrup.

EXPERIMENTAL PROCEDURE

Neonatal calves were randomized to the three experimental groups listed in table 5. As in the previous investigation, calves were started on the experiment as they were born in the College experimental herd. Details regarding the selection, feeding and management of animals and the preparation of feed have been described previously (part I). The present study was initiated near the close of the forementioned investigation and, in regard to methods, was merely a continuation of it. Various amounts of carbohydrates were incorporated in the rations as shown in table 6. The KL group received glucose, corn syrup and lactose as the carbohydrate sources, the SL group received glucose, lactose and starch, and the S group received glucose and starch.

Composition and the chemical analyses of the rations fed are presented in tables 6 and 7 respectively.

TABLE 5

Composition of the experimental groups

Group	No. of calves	Breed distribution	Av. starting wt. (lb.)
KL (Corn syrup + lactose)	3	2 Holstein 1 Jersey	69.0
SL (Starch + lactose)	3	1 Holstein 1 Ayrshire 1 Jersey	77.0
S (Starch)	3	3 Holstein	95.0

TABLE 6

Ingredients of the rations fed

	Ration		
Group	KL	SL	S
Glucose	5	5	15
Corn syrup	45	--	--
Lactose	10	10	--
Starch	--	45	45
Casein	25	25	25
Lard	10	10	10
Salts*	5	5	5

*Salt mixture composed of 10 calcium carbonate, 20 calcium phosphate (secondary), 20 magnesium phosphate (tertiary), 10 potassium phosphate (secondary), 5 sodium chloride, 5 potassium chloride, 1.98 ferric citrate, 0.04 manganese sulfate, 0.04 copper sulfate and 0.04 cobalt sulfate.

TABLE 7

Chemical analysis of the rations fed

Group	Ration		
	KL	SL	S
Moisture (%)	12.52	7.36	7.90
Protein (%)	21.25	21.57	21.57
Ash (%)	6.06	5.63	5.62
Crude fiber (%)	0.05	0.07	0.08
Ether ext. (%)	10.15	10.61	10.61
N. F. E. (%)	49.97	54.76	54.22
Ca (%)	0.67	0.65	0.65
P (%)	0.78	0.78	0.78
Mg (%)	0.38	0.34	0.33
K (%)	0.65	0.52	0.52
Fe (%)	0.0023	0.0022	0.0021
Cu (p.p.m.)	4.9	2.2	2.1
Mn (p.p.m.)	0.07	0.07	0.07
Co (p.p.m.)	0.127	0.118	0.115

Criteria for the evaluation of response were altered from those of the previous investigation in that no samples of rumen contents were collected and only one post-mortem examination was conducted. The single autopsy was performed on a member of the S group to check for lesions previously produced on a starch-containing synthetic milk (7).

In search of a possible explanation for varying responses to the carbohydrates fed, a test meal containing a single carbohydrate source (e.g., glucose, lactose, starch or corn syrup) was fed to an animal and the blood sugar concentration determined at intervals over an 8-hour postprandial period. The test was repeated until a curve for each carbohydrate was obtained on three different calves. The test meal consisted of 25 per cent casein, 10 per cent lard, 5 per cent salts and 60 per cent of the carbohydrate being tested. This meal was prepared and fed in the same manner as the usual experimental ration. On the day on which the test was conducted, blood was collected prior to the morning feeding. The test meal was fed and subsequent blood samples were taken at 15 and 30 minutes, 1, 2, 4, 6 and 8 hours postprandially. All blood samples were collected by jugular venipuncture with minimal disturbance to the animal. To facilitate rapid, efficient collection of blood, the neck was clipped closely a day or two prior to collection.

Potassium oxalate was used as the anticoagulant. Filtrates were prepared within 30 minutes after the collection of blood and the amount of blood sugar was determined by the Somogyi procedure (34). Transmission was determined by a Cenco-Sheard spectrophotometer at 520 mu.

RESULTS

Health and General Appearance

The feces of calves in group S became very soft in consistency within 2 to 4 days after the animals were placed on experiment. The amount of feces voided was quite large, and the feces appeared to contain considerable undigested material. Calves of the SL group also voided excessive quantities of feces of semiliquid consistency, although in general the diarrhea in this group was not as severe as that in the S group. Diarrhea occurred infrequently in the KL group, in marked contrast to group K of the previous trial. Calves of the S group showed moderate emaciation and dehydration during the first 2 weeks of the trial whereas those of groups SL and KL were relatively thrifty throughout the trial.

Growth and Feed Utilization

Gains in body weight for the 31-day period and the efficiency of feed utilization for each group are indicated in table 8. Calves of groups KL and SL gained in weight uniformly throughout the trial, whereas, those in group S gained little or none during the first 2 weeks but they did increase in weight rapidly late in the experimental period.

TABLE 8

Growth and feed utilization

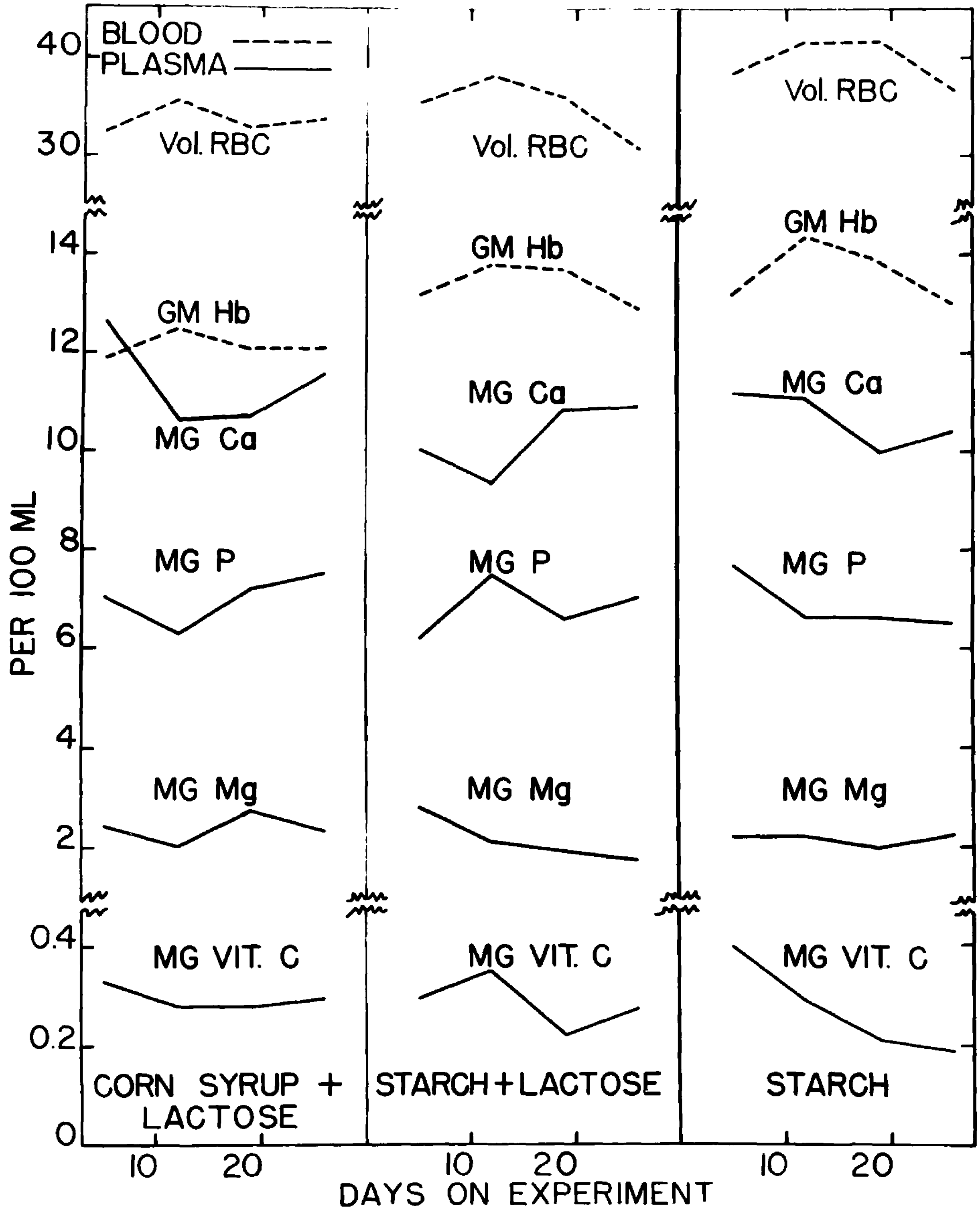
Group	Average gain		Gain per lb. DM consumed
	(lb.)	(%)	(lb.)
KL	28.33 ± 5.85*	41.06	0.487 ± 0.058
SL	24.67 ± 2.94	32.03	0.412 ± 0.072
S	14.00 ± 3.06	14.74	0.204 ± 0.046

*Standard error of the mean.

Blood Analysis

Average weekly levels of hemoglobin and cell volume (hematocrit) and each of four plasma constituents are indicated in figure 2. These average values agree reasonably well with the normal levels for calves of this age (2, 46), although the hemoglobin levels tended to be higher and the inorganic phosphorus levels somewhat lower. Variation in serum magnesium was greater than might be expected (5).

Glucose absorption curves for each of the four carbohydrates tested, plotted from serial blood sugar determinations, are shown in figure 3. Blood sugar remained quite constant after starch ingestion and registered no increase during the first 4 hours postprandially. Curves for the


BLOOD
PLASMA
Vol. RBC
GM Hb
MG Ca
MG P
MG Mg
MG VIT. C
CORN SYRUP + LACTOSE
STARCH + LACTOSE
STARCH
PER 100 ML
DAYS ON EXPERIMENT
40
30
14
12
10
8
6
4
2
0.4
0.2
0
10
20

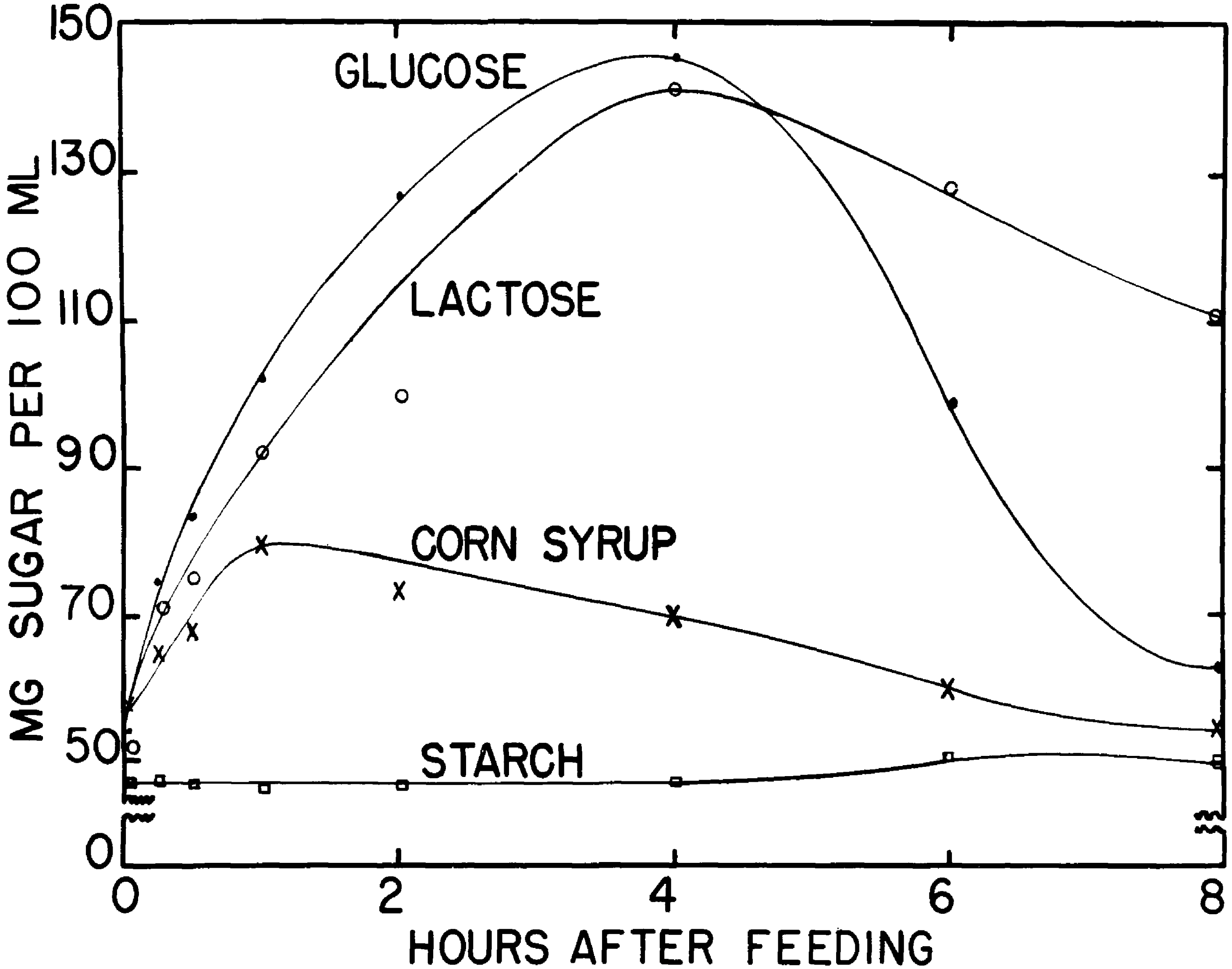


Figure 3. Blood sugar concentration curves following ingestion of a single source of carbohydrate. Each curve is the average of three tests.

other three carbohydrates rose rapidly following feeding with little difference in evidence 30 minutes after feeding. Thereafter the differences were striking. Corn syrup ingestion resulted in maximum blood sugar concentration 1 hour after feeding, whereas the glucose or lactose peak was not reached until 4 hours after feeding. The curve for glucose, however, descended much more rapidly than did that for lactose. The maximum blood sugar concentration after corn syrup ingestion was only slightly more than half the maximum concentration following the consumption of glucose or lactose.

DISCUSSION

The single post-mortem examination performed was on a member of the S group and failed to reveal many of the lesions previously reported as characteristic of calves on a high-starch synthetic milk (7). Admittedly a single observation is an inadequate basis for the drawing of conclusions. Assuming that the animal examined was representative of the group, a possible explanation for the disparity in results may be found in the fact that in the earlier study the artificial milk contained natural feedstuffs high in starch. Pure corn starch added to these natural sources produced a much higher level of starch feeding than was used in the present trial and may account for the differences noted in examining the experimental subjects.

The blood sugar level following starch ingestion showed no tendency to rise for the first 4 hours after feeding (figure 3). This might be anticipated since starch is rather slowly hydrolyzed in the digestive tract. In fact, Shaw and associates (32) reported that the calf was unable to utilize starch to an appreciable extent until nearly one month of age. The glucose absorption curves obtained on a 2-week old calf (7) substantiate this report in that there was no increase in blood sugar over the 8-hour sampling period. Since saliva of the bovine is devoid of amylolytic enzymes, and pancreatic amylases are low in this species (35), the question is raised as to whether the failure of the neonatal calf to digest starch is due to (a) the inherent weakness of pancreatic amylase, with the result that the digestion of starch must await the development of starch-splitting microorganisms in the rumen, or (b) amylolytic activity of pancreatic (and/or possibly intestinal) juice is not developed at birth and fails to become efficient until several weeks after birth.

All data used in the preparation of figure 3 are from calves 28 to 35 days of age. The rapid rise in blood sugar following lactose ingestion is difficult to explain in that lactose presumably must be hydrolyzed before appreciable absorption can take place (28, p. 103.) The continued high level of blood sugar would seem to indicate that the hydrolysis of lactose continues over a period of time. This may be considered to be advantageous in that energy is made available over an extended period and thus absorption and utilization are permitted to take place more efficiently. Blood sugar levels can be considered only as a rough index of the utilization of a carbohydrate. The concentration of blood sugar at any specified time depends upon the rate of absorption of the sugar into the blood stream and the rate at which it is removed from the blood. Removal may be accomplished through the kidneys or through utilization by the tissues, and the rate of removal, whether by excretion or utilization, varies with the sugar concerned (28, pp. 107, 133).

The alteration of response produced by adding lactose to either a corn syrup or a starch ration is remarkable indeed. With corn syrup, the addition of lactose changed the response from no gain to an average of over 28 pounds gain in 31 days (table 8). In the case of starch, lactose addition was accompanied by an increase in the rate of gain of 76 per cent (table 8). The differences are even more striking when one considers that the KL and SL groups surpassed not only the K and S groups in performance but also the L group. Such results would not appear unusual in the study of proteins, in which the biological value of one protein may be increased greatly by the addition of a second protein (1). However, carbohydrates are hydrolyzed supposedly to the constituent monosaccharides before absorption can take place

(28, p. 103) and supplementary relationships are not generally recognized in this class of compounds.

Although lactose possesses a lower specific dynamic effect than does glucose (18), and thus should be a more efficient source of energy, this slight advantage, when considered in conjunction with the relatively small amount of lactose included, certainly can not account for the differences obtained. Lactose, or specifically its constituent galactose, has been credited with increasing the utilization of fat (29). Lactose itself was reported to be antirachitic and to favor calcium metabolism in children as well as laboratory animals (15, 21, 26). By promoting an acid medium, lactose favors the absorption of both calcium and phosphorus, although Robinson et al. (30) expressed the belief that acidity was not the only factor. They suggested that lactose or the lactate ion may exert a specific action in facilitating passage of calcium into the blood. It is doubtful that either calcium or phosphorus was a limiting factor in this study because the synthetic rations were high in these elements. The improbability of such a limitation is further indicated by the fact that the blood plasma levels of these elements were not affected adversely during the experiment. It was reported in the early 1900's that lactose exerts its beneficial influence by favoring desirable bacterial forms in the intestine (20). Perhaps this might be advanced as the logical explanation of the results in this experiment.

Even so, it fails to explain the differences between the KL and SL groups of this experiment and the L groups of the previous experiment. It would appear that lactose favorably influences the utilization of certain carbohydrates as well as the utilization of fat. Regardless of the theoretical explanation, these results provide a basis for the common practice of including dry whey or non-fat dry milk solids in calf starters.

SUMMARY

Nine neonatal calves were allotted to three experimental groups and fed rations consisting of synthetic milks which varied only in the carbohydrate component.

Calves receiving corn syrup plus lactose (KL) gained an average of 28.33 pounds, those receiving starch plus lactose (SL) gained an average of 24.67 pounds while calves on starch (S) averaged only 14.00 pounds in 31 days. The efficiency of feed utilization, expressed as pounds of gain per pound of dry matter consumed, was 0.487, 0.412 and 0.204 for the KL, SL and S groups, respectively.

Serial blood samples were collected before a test meal and at 1/4, 1/2, 1, 2, 4, 6 and 8 hours after feeding and analyzed for blood sugar. The blood sugar level rose rapidly after the ingestion of glucose, lactose or corn syrup, with the maximum concentration at 4, 4 and 1 hours after feeding, respectively.

Following starch ingestion there was no change in blood sugar the first 4 hours and only a moderate increase at 6 and 8 hours.

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A P P E N D I X

TABLE 9

Allottment of individual calves to the glucose, corn syrup and lactose groups

Group	Sub Group	Calf No.	Breed	Sex
Glucose		692	Holstein	Male
		697	Holstein	Male
		705	Holstein	Female
		722	Holstein	Male
		729	Ayrshire	Male
		732	Holstein	Male
Corn Syrup	10	713	Jersey	Male
		718	Brown Swiss	Male
	30	701	Holstein	Male
		711	Holstein	Male
	45	695	Jersey	Male
		699	Brown Swiss	Male
Lactose	5	733	Holstein	Male
		702	Jersey	Male
	10	698	Holstein	Male
		712	Holstein	Male
	30	694	Holstein	Male
		696	Jersey	Male

TABLE 10

Allottment of individual calves to the corn syrup + lactose, starch + lactose and starch groups

Group	Calf No.	Breed	Sex
Corn Syrup + Lactose	714	Holstein	Male
	715	Jersey	Male
	726	Holstein	Female
Starch + Lactose	717	Ayrshire	Male
	724	Jersey	Male
	725	Holstein	Male
Starch	727	Holstein	Male
	728	Holstein	Male
	731	Holstein	Male

TABLE 11

Analized composition of ingredients used in rations

	Glucose	Starch	Lactose	Corn Syrup	Casein
Moisture (%)	7.93	9.44	2.61	20.92	9.85
Protein (%)	0.31	0.70	0.23	0	83.12
Ash (%)	0.05	0.10	0.09	0.98	2.43
Crude fiber (%)	0.12	0.05	0	0	0.16
Ether ext. (%)	0.44	1.03	0.44	0	0.31
N. F. E (%)	91.15	88.68	96.63	78.10	4.13
Ca (%)	0	0	0	0.054	0.203
P (%)	0.009	0.019	0	0.022	0.519
Mg (%)	0	0.044	0.046	0.138	0.077
K (%)	0	0	0.019	0.299	0.098

TABLE 12

Body weights in pounds of the calves in the glucose group

Days on Expt.	Calf No. 692	697	705	722	729	732
0	105	96	100	87	98	80
3	104	96	95	92	98	87
7	98	100	98	97	98	87
10	102	96	95	91	98	87
14	98	96	101	--	100	--
17	106	102	--	--	105	--
21	100	105	110	--	104	--
24	111	111	107	--	105	--
28	107	111	114	--	105	--
31	113	111	115	--	105	--

TABLE 12

Body weights in pounds of the calves in the corn syrup group

Days on Expt.	Calf No. 713	718	701	711	695	699
0	46	118	102	91	52	99
3	53	121	109	90	51	98
7	53	118	107	91	47	97
10	49	115	101	90	55	94
14	50	119	107	94	51	96
17	53	122	115	98	58	89
21	49	120	115	102	57	84
24	48	127	113	107	61	82
28	52	135	121	105	57	--
31	53	142	115	107	61	--

TABLE 14

Body weights in pounds of the calves in the lactose group

Days on Expt.	Calf No.					
	733	702	698	712	694	696
0	74	60	75	88	85	54
3	86	64	75	97	88	55
7	82	65	77	100	84	59
10	77	64	79	102	87	57
14	80	66	81	--	87	64
17	88	76	88	--	94	66
21	87	71	94	--	96	63
24	86	75	97	--	100	67
28	86	82	97	--	107	68
31	86	80	102	--	111	67

TABLE 15

Body weights in pounds of the calves in the corn syrup + lactose group

Days on Expt.	Calf No.		
	714	715	726
0	90	47	70
3	100	53	77
7	99	54	82
10	105	49	80
14	105	60	80
17	108	61	84
21	118	60	87
24	123	59	88
28	126	65	92
31	130	70	92

TABLE 16

Body weights in pounds of the calves in the starch + lactose group

Days on Expt.	Calf No. 717	724	725
0	78	52	101
3	90	55	105
7	87	60	105
10	87	63	113
14	85	62	117
17	84	69	116
21	91	72	119
24	92	70	126
28	97	74	128
31	97	80	--

TABLE 17

Body weights in pounds of the calves in the starch group

Days on Expt.	Calf No. 727	728	731
0	90	91	104
3	95	92	106
7	101	95	108
10	101	96	107
14	102	101	102
17	101	104	105
21	103	101	108
24	105	102	108
28	110	101	111
31	110	101	116

TABLE 18

Efficiency of feed utilization of individual calves in the glucose, corn syrup and lactose groups

Group and Sub Group	Calf No.	Gain lbs.	Gain %	Dry Matter Consumed	Gain per lb. DM Consumed
				lbs.	lbs.
G	692	8	7.62	70.33	.114
	697	15	15.62	62.11	.242
	705	15	15.00	68.72	.218
	722	4	4.60	16.77	.239
	729	7	7.17	62.75	.112
	732	7	8.75	14.00	.500
K 10	713	7	15.22	45.13	.155
	718	24	20.34	73.75	.325
30	701	13	12.74	70.53	.184
	711	16	17.58	57.56	.278
45	695	9	17.31	45.75	.197
	699	-17	-17.17	59.47	-.286
L 5	733	12	16.21	48.33	.248
	702	20	33.33	54.84	.365
10	698	27	36.00	61.15	.442
	712	14	15.91	24.41	.574
30	694	26	30.59	62.91	.413
	696	13	24.07	49.45	.263

TABLE 19

Efficiency of feed utilization of individual calves in the corn syrup + lactose, starch + lactose and starch groups

Group	Calf No.	Gain		Dry Matter Consumed	Gain per lb. DM Consumed
		lbs.	%		
				lbs.	lbs.
Corn syrup + Lactose	714	40	44.44	67.80	.590
	715	23	48.94	47.50	.484
	726	22	31.43	56.70	.388
Starch + Lactose	717	19	24.36	61.67	.308
	724	28	53.85	50.80	.551
	725	27	26.73	71.83	.376
Starch	727	20	22.22	67.83	.295
	728	10	10.99	66.58	.150
	731	12	11.54	71.33	.168

TABLE 20

Iodophil count of rumen contents

(millions per ml.)

	Week			
Calf No.	1	2	3	4
697	---	626.4	---	93.6
705	---	---	362.4	609.6
713	1.2	0	12.0	16.8
718	---	---	---	192.0
701	3.6	34.8	110.4	201.6
711	105.6	1178.4	2129.8	2246.4
695	14.4	57.6	837.6	1128.0
699	---	---	67.2	---
733	0	223.2	---	---
702	1.2	7.2	2.4	4.8
698	---	---	196.8	218.4
712	0	---	---	---
694	2.4	164.4	632.4	744.0
696	736.8	429.6	91.2	---
714	33.6	---	21.6	---
715	---	0	---	---
724	---	---	---	62.4
Ave.	89.9	272.2	405.8	501.6

TABLE 21

Total bacterial count of rumen contents

(millions per ml.)

Calf No.	Week 1	2	3	4
697	--	3200	--	2600
705	--	--	2900	2500
713	1900	400	2200	700
718	--	--	--	1100
701	2700	900	2000	1400
711	500	15400	8200	10700
695	1100	1100	8600	15600
699	--	--	1500	--
733	1500	3400	700	500
702	1100	1500	--	--
698	--	--	3800	600
712	2200	--	--	--
694	1300	3900	3400	3300
696	2700	7900	500	--
714	3900	--	3200	--
715	--	2900	--	--
724	--	--	--	4300
Ave.	1890	4060	3364	3936

TABLE 22

Weekly blood analysis of calf 692

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	12.90	37.0	10.7	6.16	1.82	.325
2	---	--	9.5	5.56	1.81	.297
3	10.20	29.5	10.3	6.04	2.02	.276
4	10.57	29.5	11.5	6.65	1.76	.439

TABLE 23

Weekly blood analysis of calf 697

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	7.40	22.0	12.0	5.93	2.05	.356
2	8.60	24.0	10.3	7.91	1.71	.458
3	8.90	26.5	11.3	7.81	1.73	.301
4	9.70	27.0	10.2	6.22	1.94	.239

TABLE 24

Weekly blood analysis of calf 705

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	14.55	35.5	11.5	5.90	1.80	.257
2	14.45	38.0	10.6	5.25	1.80	.139
3	13.25	37.0	10.1	5.30	1.94	.157
4	13.70	35.5	10.6	4.41	2.25	.121

TABLE 25

Weekly blood analysis of calf 722

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	7.60	---	12.7	6.41	1.59	.583

TABLE 26

Weekly blood analysis of calf 729

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	12.35	35.5	10.3	7.44	2.19	.440
2	12.00	35.0	11.5	5.06	1.91	.362
3	13.10	39.5	10.4	7.02	2.11	.239
4	12.00	34.5	9.5	6.51	2.02	.368

TABLE 27

Weekly blood analysis of calf 732

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	7.20	22.0	11.1	7.14	1.89	.279
2	12.00	40.5	10.2	7.27	3.89	.389

TABLE 28

Weekly blood analysis of calf 713

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	8.47	23.0	13.2	7.06	2.42	.289
2	9.77	28.0	12.0	6.22	1.90	.323
3	9.27	25.0	11.7	5.17	2.08	.148
4	9.83	27.0	12.1	4.92	2.46	.504

TABLE 29

Weekly blood analysis of calf 718

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	11.85	33.5	9.7	6.51	2.88	.425
2	11.07	32.0	9.2	5.79	1.92	.230
3	10.87	27.5	12.6	5.21	3.83	.206
4	10.20	24.5	11.3	7.02	1.28	.178

TABLE 30

Weekly blood analysis of calf 701

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	11.23	29.0	12.1	7.27	2.58	.259
2	12.53	33.0	10.6	5.74	2.15	.119
3	13.17	34.0	11.5	6.87	2.20	.227
4	13.47	37.0	11.5	5.93	1.92	.148

TABLE 31

Weekly blood analysis of calf 711

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	8.00	22.0	13.0	7.19	2.19	.428
2	9.47	26.0	10.4	7.27	2.05	.190
3	12.53	35.0	11.8	7.23	2.20	.256
4	13.95	36.0	11.7	7.35	2.03	.265

TABLE 32

Weekly blood analysis of calf 695

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	14.55	39.0	9.7	8.01	3.18	.422
2	12.10	35.5	10.5	6.69	1.64	.138
3	12.00	32.5	10.9	5.66	2.11	.129
4	10.70	30.0	10.5	5.48	1.87	.077

TABLE 33

Weekly blood analysis of calf 699

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	8.13	22.0	12.5	7.23	2.43	.601
2	9.40	24.5	10.6	9.13	2.58	.374
3	10.70	26.0	10.7	7.02	1.99	.167
4	11.30	28.0	10.5	7.27	2.02	.135

TABLE 34

Weekly blood analysis of calf 733

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	11.23	34.0	11.9	7.35	2.11	.545
2	12.10	36.5	11.6	7.06	3.02	.412
3	10.50	32.0	10.6	7.62	2.02	.382
4	10.57	31.5	10.3	6.54	1.87	.462

TABLE 35

Weekly blood analysis of calf 702

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	8.07	20.0	12.7	6.35	2.86	.475
2	10.50	26.5	11.9	6.95	2.99	.399
3	12.77	33.3	13.0	6.87	2.62	.232
4	14.10	38.0	11.5	5.90	1.94	.148

TABLE 36

Weekly blood analysis of calf 698

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	12.60	35.0	12.7	4.90	2.21	.344
2	11.40	32.0	11.1	1.95	1.96	.415
3	12.77	34.5	12.2	6.07	1.72	.252
4	12.00	33.0	11.3	7.67	2.11	.202

TABLE 37

Weekly blood analysis of calf 712

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	15.90	43.0	11.3	6.83	1.76	.297

TABLE 38

Weekly blood analysis of calf 694

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	13.10	34.0	12.4	6.62	1.80	.397
2	12.83	37.0	9.9	5.87	1.76	.323
3	12.45	32.0	9.8	6.19	1.48	.204
4	12.10	32.0	10.3	6.87	1.70	.227

TABLE 39

Weekly blood analysis of calf 696

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	9.03	24.0	11.9	4.83	1.62	.248
2	10.87	25.5	11.2	7.76	2.08	.312
3	12.90	36.0	11.3	6.58	2.06	.422
4	12.45	31.0	11.0	5.95	2.22	.316

TABLE 40

Weekly blood analysis of calf 714

Week on Expt.	Hemo- globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	13.00	35.5	11.9	7.06	1.69	.376
2	12.45	34.0	11.3	8.17	2.18	.297
3	11.93	30.5	10.5	7.44	2.22	.365
4	12.27	34.0	12.1	8.33	2.51	.338

TABLE 41

Weekly blood analysis of calf 715

Week on Expt.	Hemo- globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	9.03	24.0	13.2	6.51	2.97	.371
2	10.43	26.0	12.3	4.81	2.06	.365
3	9.95	24.0	11.9	7.19	3.55	.233
4	10.63	27.0	11.8	7.27	2.86	.270

TABLE 42

Weekly blood analysis of calf 726

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	13.60	37.0	11.7	7.27	2.54	.254
2	14.63	46.5	8.1	6.01	1.70	.176
3	14.55	43.5	9.7	6.95	2.31	.241
4	13.25	40.0	10.5	6.76	1.53	.272

TABLE 43

Weekly blood analysis of calf 717

Week on Expt.	Hemo-globin	Cell Volume	Plasma			
			Ca	Inorg. P	Mg	Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	15.30	42.0	8.6	5.63	3.06	.330
2	15.10	44.0	8.7	7.96	1.90	.505
3	14.20	38.0	10.9	5.32	1.62	.330
4	10.50	26.5	11.4	7.23	1.58	.367

TABLE 44

Weekly blood analysis of calf 724

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	9.77	25.5	11.4	6.58	2.91	.214
2	11.23	29.5	9.3	6.79	1.55	.193
3	11.93	32.0	11.5	7.67	2.11	.124
4	10.63	28.5	10.7	7.19	1.69	.245

TABLE 45

Weekly blood analysis of calf 725

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	14.55	39.0	9.9	6.19	2.54	.344
2	15.20	41.0	10.0	7.91	2.80	.343
3	15.00	38.0	10.0	6.76	1.94	.185
4	14.55	37.0	10.5	6.48	2.02	.202

TABLE 46

Weekly blood analysis of calf 727

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	10.93	29.0	12.3	7.49	2.29	.414
2	12.27	35.0	11.4	6.32	1.87	.193
3	12.10	34.0	11.0	6.04	1.94	.165
4	12.00	34.5	11.0	6.38	1.53	.129

TABLE 47

Weekly blood analysis of calf 728

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	14.03	44.0	10.5	7.44	2.19	.339
2	14.55	42.0	10.8	6.76	2.15	.333
3	13.70	41.0	9.7	7.14	1.80	.222
4	11.67	33.0	9.1	6.54	2.80	.207

TABLE 48

Weekly blood analysis of calf 731

Week on Expt.	Hemo-globin	Cell Volume	Plasma Ca	Plasma Inorg. P	Plasma Mg	Plasma Ascorbic acid
	gm %	%	mg %	mg %	mg %	mg %
1	14.63	42.5	10.7	8.28	2.25	.445
2	16.40	48.5	11.1	6.75	2.69	.329
3	15.90	50.0	9.3	6.58	2.40	.229
4	15.40	43.0	11.1	6.46	2.45	.226

TABLE 49

Blood sugar concentration following ingestion of a single source of carbohydrate

Carbohydrate and calf no.	Hours after feeding							
	0	1/4	1/2	1	2	4	6	8
	mg per cent							
Glucose								
711	62.8	87.0	110.6	125.3	153.6	131.8	80.4	62.0
717	52.0	54.1	73.6	78.1	84.4	92.0	72.3	54.3
733	42.0	52.7	63.6	102.6	139.3	214.0	143.0	70.1
Corn syrup								
711	54.2	70.3	86.5	100.3	101.2	69.8	72.0	--
713	66.8	81.3	66.6	78.2	68.5	92.0	64.0	72.5
714	58.0	80.0	72.1	80.4	60.0	53.1	54.7	65.7
Lactose								
724	59.7	82.0	90.9	121.2	144.2	164.6	88.7	105.8
725	49.2	--	61.5	80.0	78.0	71.1	71.0	62.3
731	42.3	60.0	73.1	74.0	74.8	186.3	225.0	161.8
Starch								
711	59.6	51.8	54.5	53.6	61.0	61.0	68.4	65.0
731	41.0	--	53.1	43.4	42.0	31.0	36.0	38.1
733	21.5	53.0	--	24.8	32.0	46.2	47.7	29.2