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THE EFFECT OF CARBOHYDRATE IN DRINKING WATER ON THE DIETARY ENERGY CONSUMED AND PERFORMANCE OF BROILER-TYPE CHICKS

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THE EFFECT OF CARBOHYDRATE IN DRINKING WATER ON THE DIETARY ENERGY CONSUMED AND PERFORMANCE OF BROILER-TYPE CHICKS

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ABSTRACT

THE EFFECT OF CARBOHYDRATE IN DRINKING WATER ON THE DIETARY ENERGY CONSUMED AND PERFORMANCE OF BROILER-TYPE CHICKS

By

Rungthip Burapharat

Two experiments were conducted to investigate the response of broiler-type chicks to sugar added in drinking water when the caloric density of their diets increased or decreased.

The first experiment was performed with three selected dietary energy levels: 2700, 3000 and 3300 kcal/kg, in combination with either none or each of three levels of glucose in drinking water: 2, 4 and 8%. The concentration of protein in all diets was kept constant at 24.1%. The results showed that feed consumed by chicks decreased as the level of either glucose in drinking water or dietary energy increased. The energy obtained from glucose solution depressed the dietary energy consumed (decrease in feed consumption) and resulted in an equal amount of total energy consumed whether chicks were given the tap water or the glucose solutions at 2, 4 or 8%. The weight gain tended to be low when chicks were given glucose in their drinking water. Chicks receiving the 8% glucose solution had significantly less gain than the control chicks. However, the feed efficiency by chicks was improved as the level of glucose in drinking water increased.

Chicks fed a high-energy diet consumed more dietary energy and had heavier weight gains than chicks fed a low-energy diet. Feed efficiency was improved progressively as the level of dietary energy increased. Dietary energy and glucose solution did not affect the liver and pancreatic weights of chicks.

The second experiment was performed with two selected dietary energy levels: 2700 and 3300 kcal/kg, in combination with either none or each of five different kinds of carbohydrates in drinking water: glucose, galactose, fructose, sucrose and lactose (all at level of 4%). The composition of the two diets were the same as in the first experiment. The results showed that the 4% galactose in drinking water induced toxicity in chicks and depressed feed consumption, dietary energy consumption and body weight gains. Chicks given the 4% lactose in their water showed the symptoms of diarrhea but their feed consumption and weight gains were not depressed. The 4% lactose treatment induced the highest consumption of feed and water. The total energy consumption was higher in chicks given the 4% sucrose or lactose than in those receiving the tap water. Chicks given the 4% sucrose solution had the highest weight gains. The 4% of either glucose or fructose did not induce any significant effect on any of the following: feed and water consumed, dietary energy consumed, total energy consumed and weight gains of chicks, when compared to the chicks receiving the tap water.

Feed efficiency was not significantly different whether chicks were given the tap water or any kind of carbohydrate solutions. However, chicks given the 4% sucrose solution tended to have the best feed efficiency.

Chicks fed the diet that contained 3300 kcal/kg consumed less diet and water than those chicks fed the diet containing 2700 kcal/kg. The total energy consumed by chicks fed these two diets was not the same. Chicks fed the diet containing 3300 kcal/kg consumed more total energy and had heavier gains and better feed efficiency than those fed the diet that contained 2700 kcal/kg. Dietary energy and the 4% of various carbohydrate solutions did not affect the liver and pancreatic weights expressed as percent of body weights, and the percent of lipids in livers of chicks.

To my parents

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INTRODUCTION

Most of the research reported in poultry nutrition would suggest that poultry eat to satisfy an inner craving for energy. The craving for energy influences feed consumption. Therefore, energy content in the diet affects feed consumption. As the energy concentration of the diet increases, the feed consumption decreases and vice versa.

That is true if all energy is obtained from the diet. However, if you put some energy in drinking water of chickens, does the energy content in drinking water affect the amount of feed and water consumed? Are chickens able to adjust their feed and water consumptions to maintain a relatively constant energy consumed? Does the energy content in drinking water improve the body weight gain and feed efficiency?

In this study, sugar was selected to be a source of energy in drinking water.

The objectives of this study were:

1. To determine the effect of adding 2, 4 and 8% of glucose in drinking water (when the dietary energy levels were 2,700, 3,000 and 3,300 kcal/kg), on feed and water consumptions, dietary energy consumed, total energy consumed, body weight gain, feed efficiency, and liver and pancreatic

weights of chicks.

2. To compare the effect of adding 4% of various carbohydrates (glucose, galactose, fructose, sucrose and lactose) in drinking water (when the dietary energy levels were 2,700 and 3,300 kcal/kg), on feed and water consumptions, dietary energy consumed, total energy consumed, body weight gain, feed efficiency, chick mortality, liver and pancreatic weights, and lipid content in livers of chicks.

LITERATURE REVIEW

Sugar was selected to be a source of energy in drinking water, since the fowl rejected water mixed with either oil or protein (Kare and Maller, 1967). The degree of acceptance of sugar (glucose, galactose, fructose, sucrose, and lactose) in drinking water by chicks has been reported by many researchers (Englemann, 1937; Jacobs and Scott, 1957; Kare *et al*., 1957; Kare and Medway, 1959). The details are given in a subsequent section of this review.

The sense of taste in the fowl

The sense of taste in the fowl has been studied because it might have some influence on the fowl's response to a sweet solution. Most of the research on taste has used the preference test to measure the sensitivity of birds to taste stimuli. Flavor is a much more effective stimulus to chicks in water than in feed (Kare *et al*., 1957). Usually, the chemical to be tested is placed in an aqueous solution and the fowl is given a choice between the mixture and pure water.

Kare and his co-workers have demonstrated behaviourally that the fowl has a sense of taste (Kare *et al.*, 1957; Kare and Medway, 1959; Kare and Fick, 1960; Fuerst and Kare, 1962; Kare and Ficken, 1963; Kare and Maller, 1967). The sensory receptors of taste are called taste buds. They are the clusters of cells lying in the cavities in the tongue's epithelium. Avian taste buds were found by Botezart (1904), Bath (1906), and Lindenmaier and Kare (1959).

The classification and taste preference in the fowl

Englemann (1934) studied chickens' choices between solutions that were acidic, salty, sweet and bitter. He found that there was a strong preference for the sugar solution. Man's taste preference for sour, salty, sweet and bitter is different from fowl's (Kare et al., 1957). For example, colocycynth pulp is bitter but acceptable to the fowl. Quinine and cocillana, also in man's bitter category, were rejected by the fowl. Honey and strawberry flavors, which are sweet and pleasant to man were almost totally rejected by the fowl, while they only moderately rejected saccharine and showed a variable degree of preference for sucrose. The one salt (sodium chloride) and the sour flavors that were tested were rejected. The chicks accepted sodium chloride solution only up to about 0.9% (Pick and Kare, 1962). However, magnesium chloride was acceptable (Englemann, 1937). In the acid category, 0.05% HCl was preferred by Bobwhites to distilled water (Brindley and Prior, 1968).

The preference of sugar solution for the fowl

The reaction of the chicken to sugar has been reported by many researchers. Trials indicated that glucose and sucrose solutions were generally slightly preferred to water. Englemann (1937) observed that sugar solutions (sucrose, fructose and maltose) were clearly preferred over water, and saccharine was least preferred, Jacobs and Scott (1957) reported that chicks preferred 12% sucrose solution, but rejected saccharine. Kare et al. (1957) also observed that chicks moderately preferred the 10% sucrose solution. However, Kare and Medway (1959) suggested that the slightly greater consumption of the sucrose solution might not indicate a true preference for sucrose, because uncontrolled variables might be involved (such as the pH of unbuffered water). Thus, the fowl was not reacting to sucrose alone. Duncan (1960) observed that birds had a slight preference for sucrose at concentrations of about 15%. Japanese quail significantly preferred a 0.30 M sucrose solution over distilled water (Harriman and Milner, 1969).

Fructose, galactose and lactose, in 5% solutions were accepted by chicks equally with distilled water (Kare and Medway, 1959). In contrast to the report of Kare and Medway (1959), Gentle (1972) reported that glucose was rejected at 5% and above. With glucose there were two tendencies; five of the birds showed a definite preference for 1%, and the other five were indifferent to all concentrations up to all 30%. Gentle (1972) also reported a preference by Brown Leghorn chickens for the 5% sucrose solution, as well as a rejection of the 30% sucrose solution.

The discrimination between carbohydrates by the fowl

Aside from taste, there are several other factors which might influence the fowl's response to sugar solution. Kare and Medway (1959) studied the fowl's reaction to different carbohydrates in solution. Some of the sugars tested were glucose, galactose, fructose, sucrose and lactose. Chicks were offered a choice of a sugar solution or distilled water.

Results indicated that the fowl can discriminate among carbohydrates. The reason for this discrimination was unknown.

The pattern of discrimination indicated that sweetness in sugar, as the human recognizes it, was not attractive to the fowl. The fowl divided its drinking from two waterers almost evenly, regardless of whether both contained water or one contained sucrose solution. This pattern of indifference was observed for glucose, the substantially less sweet lactose, and the slightly sweeter fructose as described by Cameron (1947) and Schutz and Pilgrim (1957).

Kare and Medway (1959) also reported that the level of sugar had little, if any, influence on the actual intake or selection. Despite the varying of solutions with 2.5% up to 20% glucose or sucrose, chicks accepted them equally with water. This reinforced the fact that the fowl was indifferent to glucose and sucrose. When the concentration reached 25%, moderate rejection of the sucrose solution was encountered.

The physical or chemical quality of the individual sugars (i.e., viscosity, concentration, osmotic pressure, melting point, refractive index, density, etc.) could not be used to predict reliably how a chick on an adequate diet would respond to the various sugar solutions (Kare and Medway, 1959). With 5% solutions of lactose, galactose and fructose, there was no apparent discrimination between these sugar solutions and water.

<u>The influence of calories in a sugar solution on feed consumption by the fowl</u>

Chicks tended to discriminate between natural and synthetic sweeteners. Some researchers have reported that the fowl rejected synthetic sugar such as saccharine while a sucrose solution was preferred (Englemann, 1937; Jacobs and Scott, 1957). Jacobs and Scott (1957) prepared experiments to determine whether a solution's caloric value might influence the fowl's reaction to sugar. They reported that the fowl's preference for sucrose was apparently not related to its caloric value, because after being injected with a highly concentrated dextrose solution, most of the chicks failed to reject the sucrose solution. However, Kare and Ficken (1963) indicated that fowl will respond to the calories in a sugar solution by regulating their food and fluid intake. That is, when food was limited to 75% of that consumed by the controls, the intake and selection of sucrose solution increased.

Kare and Maller (1967) observed the response of fowl (6-7 weeks old) to a sucrose solution when the caloric density of the diet was increased or decreased. The chicks were fed one of three rations: basal diet, a calorically diluted diet (contained 25% cellulose) and a calorically enriched diet (contained 25% corn oil). The two choices of fluids available were water and a 10% sucrose solution. This 10% solution was selected by the authors because it was found to produce near maximal preference and intake by chicks (Kare and Ficken, 1963). The results showed that chickens receiving a basal diet or those fed a calorically enriched diet neither selected nor rejected sucrose. However, with the calorically diluted diet the sucrose solution was selected over water (64%). The caloric intake of the fowl with the enriched diet was significantly greater ($P<.01$) than that of the control birds. There was a small numerical increase in grams of food consumed with the diluted diet by the birds receiving only water. However, this increase was not significant. The calories supplied by the drinking water did not affect weight gain.

Absorption of sugar in the fowl

Emslie and Henry (1933) studied the absorption of glucose, galactose and lactose in young chicks. The sugars were administered in 56% aqueous solutions. The absorption periods were 1.5, 3.0, 4.5 and 6 hours. The three sugars were absorbed at the following rates: glucose > galactose > lactose. There was a progressive decrease in the rate of absorption of each sugar with time. Golden and Long (1942) studied the rate of intestinal absorption of glucose in the chick. A rate of 400 mgm per hour per 100 grams of body weight was found. This rate remained constant over a 4-hour absorption period, while liver glycogen and muscle glycogen rose. This indicated that either the chick had a great ability to oxidize glucose or it was able to convert a large amount of glucose into fat.

Bogner (1957) reported that the relative absorption rates of sugar fed to chicks (2 weeks of age) were as follows: galactose > glucose > xylose > fructose. Chicks three days old and chicks two weeks old absorbed glucose at similar rates. Bogner (1961) and Bogner and Haines (1961) agreed that the absorption of glucose was not fully developed until the chick was two or three days of age.

Brown (1971) studied the absorption of sucrose by chicks. He reported that the absorptive activity for sucrose increased in the intestines of chick embryos, reaching a maximum at 19 days. This decreased at 20 days and then after hatching rose in certain parts of the intestine, i.e. the ileum and jejunum. Absorption decreased in the duodenum.

Rutter _et al_. (1953) fed chicks a diet of 30% lactose. Small amounts of lactose were found in blood carbohydrates, but there was no evidence of galactose. This suggested that chicks were not able to hydrolyze lactose to galactose and glucose. Lactase, which is present in mammals, is absent in chickens. This might explain why lactose was not hydrolyzed and was poorly absorbed in the intestinal tract.

The effect of different carbohydrates on chick growth

Monson _et al_. (1950) studied the effect of different carbohydrates (dextrin, sucrose, lactose and cerelose) on chick growth. Chicks (1 day of age) were fed a semi-purified ration containing 60% carbohydrates for four weeks. At the end of that period it was found that those chicks fed dextrin weighed 276 g, those fed cerelose 259 g, those fed sucrose 206 g, and those fed lactose 149 g. The feathering and general appearance of the birds receiving dextrin, cerelose, or sucrose were excellent. However, within a week the chicks on the lactose diets developed severe diarrhea, which lasted throughout the test period. These birds showed no decrease in feed consumption, and they consumed about twice the amount of water consumed by the other birds, indicating the extent of diarrhea.

To get a clearer understanding of the intestinal effects, Monson et al.(1950) determined the time necessary for food to pass through the chick's digestive tract. The following showed the excretion time of chickens (2 weeks of age) fed various carbohydrates: dextrin (140 minutes), sucrose (115 minutes), and lactose (77 minutes). Based on these results, the authors suggested that dextrin allows more time for synthesis to take place, since chicks fed this ration retained the food longer. This extra time may allow additional synthesis of some unknown chick growth factors.

Paul and Hans (1963) fed chicks the following diets, containing 58% carbohydrates: starch, sucrose, fructose, glucose or invert sugar (a mixture of equal parts of fructose and glucose). The results showed that the birds grew best with sucrose or starch. Their growths were poor on fructose and intermediate on glucose and invert sugar. The authors observed that the fructose diet, in comparison with both the starch and glucose diets, decreased passage time of food through the intestinal tract. They also observed that sucrose was well hydrolyzed by the chicken, even in early life, and it promoted growth comparable to that obtained with glucose or starch.

Chalupa and Fisher (1963) found that on a low-protein diet (13%) a mixture of glucose (38% of diet), starch (28%) and dextrin (5%) promoted better growth than any single carbohydrate (71% of diet). When using a single carbohydrate, they obtained better results with sucrose alone than with starch, glucose or dextrose, alone.

Galactose toxicity

The toxic effect of high galactose diets fed to chicks has been described by Dam (1944). Young chicks fed a 54.6% galactose diet developed violent convulsions and died after several days. There was a high concentration of galactose in the blood during the convulsions, but blood glucose was normal. Hepatic glycogen was almost zero, but muscle glycogen was about normal.

Rutter *et al*. (1953) found that chicks tolerated galactose up to 10% but greater amounts resulted in epileptiform convulsions and sometimes death, with a high level of galactose in the blood. These investigators injected uridine diphosphate glucose (UDPG), a coenzyme in the transformation of galactose to glucose; toxicity symptoms were not eliminated. Apparently, galactose poisoning was not merely the result of the absence of a single enzyme or co-factor in the galactose to glucose transformation. However, Hansen *et al*.(1956) reported that the avian liver content of UDPG was reduced in galactose poisoning.

Sondergaard et al.(1957) observed that chicks reared on a 50% galactose diet showed signs of ataxia, tremors, convulsions and loss of weight, and blood uric acid was found to be markedly elevated. Kidneys from galactose-poisoned chicks showed degeneration of cells in the glomeruli and tubuli. Substitution of cornstarch for galactose after 7 days of galactose feeding resulted in resumption of growth, normal behavior and normal blood uric acid in spite of the fact that the histological picture of kidneys was not normal 7 days after the diet was changed.

Rigdon et al.(1963) studied the changes in chicks fed galactose in concentrations greater than 10% and found histologic lesions in the brain, as well as some neuron degeneration. They suggested that an excessive amount of galactose in young chicks in some manner injured neurons, probably by acting through some local enzymatic system.

Kozak and Wells (1969) investigated the biochemistry of galactose toxicity in the chick brain. Galactose neurotoxicity was induced by feeding chicks a diet containing 40% (w/w) galactose for 48 hours and was accompanied by depressed levels of brain ATP, phosphocreatine and glycolytic intermediate. At the same time, increase in AMP, ADP and inorganic phosphate were found suggesting that ATP and phosphocreatine metabolize more rapidly in the galactose-poisoned chicks. The authors suggested that the lower level of brain phospholipids might be linked to the seizure and quivering syndrome of galactose toxicity. The indication here was that one of the main reasons for galactose toxicity was that this sugar interfered with the normal glycolytic and other energy-yielding processes of the cell.

Malone et al. (1971) reported that severe hyperosmolar dehydration in their chicks (1 day of age) given galactose in drinking water (10% w/v) might be responsible for the entire galactose toxicity syndrome. They found that the serum osmolalities of chicks after being given galactose for 2 days were greater than those of control chicks. Removal of galactose resulted in the return of serum osmolality to normal values in 24 hours.

Knull et al. (1972) also studied hyperosmolality, and they proposed that it was not the major factor responsible for the galactose toxicity syndrome in the chicks. They suggested that galactose affected brain energy metabolism by interfering with the supply of glucose to the brain. In their experiment, the plasma osmolality of the severely disabled chicks was greater than that of the control chicks. The injection of glucose slightly elevated the osmolality but it temporarily reversed the neurotoxicity. During the recovery phase, the brain concentrations of ATP, phosphocreatine, and glucose return to normal values.

Knull and Wells (1973) also reported that the galactose-toxicity was not due to hyperosmolality. They induced hyperosmolality in chicks by giving them galactose (40% w/w in diet), xylose (5% w/w in drinking water) or saline (0.16 M in drinking water), and compared the resultant osmolality value to that of the control group (335, 347, 352 vs. 309 milliosmoles/kg, respectively). The osmolality of the plasma from chicks fed galactose was the lowest of the three experimental groups, yet it was the only group in which neurotoxicity was observed. The chicks with galactose toxicity recovered from both physical and biochemical symptoms temporarily when they were injected with glucose. Within 20 minutes after the glucose injection, the levels of ATP, AMP, plasma glucose and brain glucose returned to the normal range. Therefore, these authors concluded that the dietary galactose induced neurotoxicity in chicks primary by inhibition of glucose transport across the blood-brain barrier.

Fructose tolerance

A diet containing high levels of fructose was tolerated well by the domestic fowl. Pearce (1970) fed pullets (aged 7-8 weeks) a 70% fructose diet. Birds accepted this diet equally as the control diet, and their weight gains were the same.

Lactose tolerance

Several investigations of lactose utilization in the fowl have been reported. Shaw (1913) observed that chickens fed milk alone died three days after hatching. An autopsy showed an intense inflammation of the gastrointestinal membranes. Hamilton and Card (1924) reported a similar irritation when mature chickens were fed lactose mixed with moist mash. Diarrhea resulted when a chicken consumed more than two grams of lactose per day. Beach and Davis (1925), Kline et al. (1932) and Ashcraft (1933) have demonstrated that lactose lowered the pH of intestinal contents.

Rutter et al. (1953) reported that chicks given a diet containing 20% lactose did not have impaired growth rate. In addition, there was no obvious change in physiological well-being. Above this level, however, feeding lactose caused growth impairment, diarrhea, and a "crooked toe" deformity, in proportion to the level fed. A quantitative examination of blood sugars revealed the presence of small amounts of lactose, but not galactose, in the blood. These observations indicated that the young chick was unable to hydrolyze lactose.

Effect of dietary sugars on hepatic lipogenesis in the fowl

Hepatic lipogenesis responded to dietary variations. Yeh and Leveille (1969) reported that hepatic lipogenesis in growing chicks was reduced at the expense of carbohydrate when the protein content of their diet was increased. Masoro et al. (1950) studied the glucose conversion to fatty acids in liver slices of rat. They concluded that the dietary carbohydrate was essential for maintenance of the capacity of hepatic tissue to convert glucose to fatty acids. Leveille et al. (1968) also reported that at least 90% of the total lipid synthesized from glucose or acetate in the fowl was of hepatic origin.

The rate of lipogenesis in chick embryos was very low (Schoenheimer and Rittenberg, 1936: Kilsheimer _et_ _al_., 1960). Goodridge (1969) studied change in the rate of hepatic lipogenesis occurring in the embryos and chicks from 16 days of incubation to 30 days after hatching. Results indicated that the development of lipogenesis occurred rapidly after newly hatched chicks were fed, involving a marked increase in the rate of fatty acid synthesis. The author suggested that the increase in lipogenesis was associated with an increase in the catabolism of glucose. The increase in the metabolism of glucose that occurred after hatching was probably due to the change from a high-fat, non-carbohydrate diet (yolk) to a high-carbohydrate, low-fat diet.

Heald (1962; 1963) and Hawkins and Heald (1966) during investigations of carbohydrate and lipid metabolism of domestic fowls, noted that the metabolism of fructose and glucose by avian liver slices was quantitatively different. Fructose stimulated the rate of respiration of liver slices more than did glucose, and also more lipid accumulated in slices incubated in the presence of fructose than in the presence of glucose. These results indicated a greater rate of lipogenesis from fructose than from glucose (Hawkins and Heald, 1966). Hepatic cholesterol concentrations in chickens were greater after feeding sucrose than after feeding glucose or starch. This suggested that the increased cholesterol synthesis was due to the fructose moiety of sucrose (Kritchevsky et al., 1959: Grant and Fahrenbach, 1959).

Pearce (1970) studied the effect of dietary fructose and glucose on hepatic lipogenesis in the fowl. Immature pullets (aged 7-8 weeks) were fasted for 48 hours and refed diets containing either 70% fructose or glucose, or a cereal-based control diet for 4 days. The results showed no significant difference in the body weights among birds fed the three diets. The liver weights (expressed as percentage of body weight) of birds fed the three different diets were as follows: 3.56 (fructose), 3.12 (glucose) and 2.73 (control). These three values were significantly different. The liver lipid content was greatest in birds fed the fructose diet (97.7 mg/g fresh liver), intermediate in birds fed the glucose diet (55.3) and lowest in the control group (47.2). The authors suggested that the increased rate of lipogenesis with fructose, as compared with glucose, might thus reflect the relative ease with which the chicken could convert fructose to acetyl CoA. The metabolism of fructose via fructose-1-phosphate would account for these differences.

MATERIALS AND METHODS

Experiment 1. The effect of glucose in drinking water on the feed energy consumed and performance of broiler-type chicks.

Broiler-type chicks (heavy cross-breed male chicks) one day-old, were purchased from Fairview Farms, Remington, Indiana. Clintose (a commercial name for glucose monohydrate obtained from Clintose Feed Manufacturers, Clintose, Iowa) was used as a glucose source and contained 9.1% moisture. This experiment was performed with three selected energy levels of diets, 2700, 3000, and 3300 kcal/kg, in combination with either none or each of three levels of glucose concentrations in drinking water, 2, 4 and 8%. The concentration of protein in all diets was kept at a constant 24.1%. There were 12 combinations and 2 replications for each treatment. The design of the experiment is shown in Table 1.

Chicks, 2 days of age, were wingbanded and individually weighed before starting the experiment. Eight chicks were randomly distributed into each of 24 cages. The chicks were raised at the Michigan State University Poultry Science Research and Teaching Center. All chicks were placed in electrically heated batteries equipped with raised wire floors. There was only one experiment in the room and the light was provided for 24 hours.

The length of the experiment was 19 days with 5 periods. Each period was 4 days, with the exception of the last

Table 1. Design of Experiment 1.

Metabolizable energy in diet (kcal/kg)	Level of glucose in drinking water (%)							
	no glucose (tap water)		2%		4%		8%	
	no. birds per group	no. groups	no. birds per group	no. groups	no. birds per group	no groups	no. birds per group	no. groups
2700	8	2	8	2	8	2	8	2
3000	8	2	8	2	8	2	8	2
3300	8	2	8	2	8	2	8	2

period which was only 3 days. Data were recorded for each period.

The chicks were fed ad libitum one of three rations shown in Table 2. The nutrient composition of rations is shown in Table 3. Drinking water was continuously available. Glucose solutions were mixed from Clintose and tap water in concentrations of 2, 4 and 8%. The water containers were too small to supply enough water for each period, so the known amount of drinking water were added daily. Evaporations of each kind of drinking water were determined from four water containers which contained the four different kinds of drinking water (0, 2, 4, and 8% glucose), and they were placed on the floor near the batteries. All water containers were cleaned at the end of each period. Feed

Table 2. Composition of 3 rations

Ingredient	Energy level in rations (kcal/kg)		
	2700	3000	3300
	ppt	ppt	ppt
Wheat midd, lings	181	---	---
Corn	412.5	546.9	491.8
Soybean meal (48% protein)	320.5	339	335
Corn gluten meal	---	19	33
Menhaden fish meal, 60% protein	25	25	25
Alfalfa meal	27	25	16
Corn oil	4.5	6.4	50
Tallow	---	4.6	14
Dicalcium phosphate	14.5	15.6	16.7
Limestone	5.6	9.4	9.4
Iodized salt	2.5	2.5	2.5
Methionine hydroxyanalog, 88% Methionine	0.98	0.6	0.6
Vitamin mix	3[a]	3[a]	3[a]
Mineral mix	3[b]	3[b]	3[b]
	1000.08	1000	1000

[a] Supplied the following per kg of diet: Vitamin A, 11000 IU; Vitamin D_3, 1100 IU; Vitamin E, 11 IU: Vitamin K, 2.2 mg; Thiamine, 2.2 mg; Riboflavin, 4.4 mg; Pantothenic acid, 14.3 mg; Niacin, 33 mg; Pyridoxine, 4.4 mg; Biotin, 0.13 mg; Choline, 1320 mg; Folacin, 1.32 mg; Vitamin B_{12}, 0.011 mg.

[b] Supplied the following per kg of diet; Manganese, 40 mg; Zinc, 20 mg; Copper, 9.9 mg; Iron, 20 mg; Magnesium, 490 mg; Selenium, 0.15 mg.

Table 3. Nutrient composition of 3 rations*

Item	Energy level in rations (kcal/kg)		
	2700	3000	3300
Metabolizable energy (kcal/kg) calculation	2703	3005	3304
Crude protein, %	24.1	24.1	24.1
Lysine, %	1.37	1.4	1.5
Methionine, %	0.47	0.47	0.47
Cystine, %	0.4	0.4	0.4
Calcium, %	1.0	1.0	1.0
Phosphorus, available, %	0.5	0.5	0.5
Linoleic acid, %	1.5	1.6	3.6

*calculated

and drinking water in the containers were collected back for measuring the feed consumption and the amount of water lost in each period. The water consumption was the difference between the water lost and water evaporated.

Chicks were weighed by group at the end of each of the first four periods. All chicks were weighed individually on day 19. Average daily gain in gm, average daily feed consumption in gm, average daily water consumption in ml, and feed to gain ratio were calculated and recorded. Average daily energy consumed in feed and water were calculated in kcal and expressed as percentage of the total daily energy consumption. The ratio of amounts of feed to water in gm/ml, and the mortality of each period were recorded. Overall results of the experiment for days 0 to 19 were also calculated.

At the end of the experiment all chicks were killed with chloroform. The pancreases and livers were removed and weighed individually. The values were calculated as percentage of body weight.

Experiment 2. The effect of various carbohydrates in drinking water on the feed energy consumed and performance of broiler-type chicks.

Broiler-type chicks (heavy cross-breed chicks), one day-old, were purchased from Fairview Farms, Remington, Indiana. Sucrose (crystals) and D-glucose (anhydrous) were obtained from Mallinckrodt Chemical Works, St. Louis, Missouri. Lactose (N.R.C. grade), D-galactose (anhydrous) and D-fructose (N.R.C. grade) were purchased from Pfanstiehl Laboratories, Inc., Waukegan, Illinois.

This experiment was performed with two selected energy levels of diets, 2700 and 3300 kcal/kg, in combination with either none or each of five different kinds of carbohydrates in drinking water, 4% glucose, 4% galactose, 4% fructose, 4% sucrose or 4% lactose. There were 12 combinations and 2 replications for each combination. The design of the experiment is shown in Table 4. The 4% of carbohydrates solution was selected because of the results from Experiment 1. Glucose at 4% in the drinking water was the second

Table 4. Design of Experiment 2.

Metabolizable energy in diet (kcal/kg	Carbohydrates in drinking water											
	tap water		4% glucose		4% galactose		4% fructose		4% sucrose		4% lactose	
	no. birds per group	no. groups	no. birds per group	no. groups	no. birds per group	no. groups	no. birds per group	no. groups	no. birds per group	no. groups	no. birds per group	no. groups
2700	8	2	8	2	8	2	8	2	8	2	8	2
3300	8	2	8	2	8	2	8	2	8	2	8	2

minimum level which started to affect the energy consumed from feed by the broiler-type chicks (see Table 8). Diets at 2700 and 3300 kcal/kg were selected because they illustrated more clearly the different effect on feed energy consumed than did the diets at 3000 to 3300 kcal/kg, or the diets at 2700 to 3000 kcal/kg.

Chicks, 2 days of age, were wingbanded, individually weighed and randomly assigned to cages with 8 birds in each group. This experiment was conducted in the experimental room of the Poultry Science building. Chicks were placed in electrically heated batteries equipped with raised wire floors. There were other experiments in the room and the light was provided for 14 hours. The length of the experiment and experimental period was the same as in Experiment 1. Data were also recorded for each period.

Feed was provided _ad libitum_. The composition of the two rations (2700 and 3300 kcal/kg) is shown in Table 2. Drinking water was continuously available. Each kind of carbohydrate: glucose, galactose, fructose, sucrose and lactose was mixed with tap water at a concentration of 4%. The known amounts of drinking water were added daily to supply enough water for each period. Evaporations of each kind of drinking water were determined from six containers which held the six different kinds of drinking water (at 4% of glucose, galactose, fructose, sucrose, lactose and tap water), and they were placed on the shelf in the experimental room. Feed and water consumptions were measured in the same way as in Experiment 1.

The collected data were the same as in Experiment 1. At the end of the experiment, all chicks were killed with chloroform. Their pancreases and livers were removed and individually weighed. The livers were stored by group in one plastic bag and kept frozen until analyzed for lipids.

Analysis procedures

The liver samples in each group were crushed and mixed together. The lipid analysis was done by group. Each group had four replications. The lipids in livers were extracted by using the method for the isolation and purification of total lipids from animal tissues (Folch *et al.*, 1957).

Accurately , 5.0 gm of a lipid sample were weighed out and placed in a Virtis homogenizer vessel. Approximately 20 ml of 2:1 chloroform-methanol solution (v/v) was added. Then the samples were homogenized for 5 min. The homogenates were filtered through glass wool into a 50 ml centrifuge tube. The filter was rinsed with 2:1 chloroform-methanol until the filtrate was clear. The filtrate was separated into two equal portions in two 50 ml centrifuge tubes. Ten ml of aqueous $CaCl_2$ 0.02% were added to each centrifuge tube, the contents stirred vigorously, and the tubes centrifuged at 2800 RPM for 5 minutes. As a result of the centrifugation, the solutions in the tubes were separated into two layers. The lipid solution (the bottom layer) from both centrifuge tubes was removed with a syringe and a blunt ended 6" stainless steel needle, and placed in a dried, weighed beaker. The beaker was placed in a hood and the chloroform evaporated under an air stream. When the sample was completely dry, the beaker was weighed. The percentage of liver lipids was determined by this formula:

$$\text{Lipid} \,/\, \frac{100 \text{ gm}}{\text{wet liver}} = \frac{\text{sample lipid weight}}{\text{sample liver weight}} \times 100$$

Statistical analysis

All data were analyzed by the f-test through the use of a Litronix 2270 calculator[1], with the exception of feed consumed, water consumed and body weight gain from Experiment 1. These data were subjected to analysis of variance by the use of a CDC 6500 computer[2] at the Michigan State University computer laboratory. Data which were expressed as percentages and proportions were transferred into a variable meeting the assumption of the analysis of variance by the use of the angular transformation[3]. The mean treatment values were compared to each other by Tukey's (1953) all pairs comparison test at x = 0.05.

[1] Litronix 2270, statistical model, Cupertino, California.

[2] Control Data Corporation, Minneapolis, Minnesota.

[3] The Angular Transformation, Table K, page 129: Statistical Tables of F. James Rohlf and Robert R. Sokal. Copyright 1969 by W.H. Freeman and Company, San Francisco.

RESULTS

On the study of the effect of interaction between the sugars in drinking water and the dietary energy on all data collected on each experimental period in both experiments, the data were tested by the use of analysis of variance. The results indicated that there were significant effects of interaction on some parameters collected from some periods in both experiments. However there was no significant effect of interaction on any data measured for the results of the 19-day trial in either experiments.

Experiment 1

Feed and water consumed: Shown in Table 5 is the average feed consumed by chicks receiving various levels of glucose in tap water from two-day old to 20 days of age (19-day trial). Feed consumption by chicks decreased as the level of either dietary energy or glucose in drinking water increased. Feed consumed was highest (646 gm) in groups of chicks given the diet that contained 2700 kcal/kg and the tap water. The lowest amount of feed consumed (455 gm) was by groups of chicks that were given the diet that contained 3300 kcal/kg and the glucose solution at 8%. Chicks receiving the glucose solutions at 2% or 4% consumed slightly less feed than those given the tap water (Table 5). Chicks given the 8% glucose solution reduced their feed consumed ($P < .05$) as compared to those given the glucose solutions at 2%, 4% or the tap water (Table 5).

Table 5. Feed consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Feed consumed (gm/bird for 19 days)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	646	570	581	533	583^{a}
3000	588	565	547	473	543^{ab}
3300	568	540	545	455	527^{b}
	(6)*	(6)	(6)	(6)	
mean	601^{a}	558^{a}	558^{a}	487^{b}	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

The reduction in feed consumption by chicks given the high level of glucose in drinking water or dietary energy occurred as early as the first period of the trial (Appendix Table 2 and 3). This indicated that the solutions of glucose up to 8% and dietary energy (2700, 3000 and 3300 kcal/kg) were able to influence the feed consumed by chicks at a very early age. The daily feed consumption for chicks during each experimental period is shown in Appendix Table 1.

In most periods, the amount of water consumed by chicks tended to be the same at any level of glucose treatment (0, 2, 4 or 8%), as shown in Appendix Table 5. However, during the 19-day trial, chicks given the glucose at 4% or 8% in their water consumed moderately less water than those given the tap water (Table 6). Significantly less water was consumed ($P < .05$) by chicks given the 2% glucose solution when compared to the amount consumed by chicks receiving the tap water (1364 vs. 1481 ml, Table 6). Water consumed by chicks fed the diet that contained 2700 kcal/kg was not significantly different in amount from that consumed by those fed the diet containing 3300 kcal/kg in most periods (Appendix Table 6). Chicks fed the diet that contained 3000 kcal/kg consumed less water than those fed the other two diets (Table 6). The detail of data on water consumed by chicks during each period is shown in Appendix Table 4.

Ratio of feed to water consumption by chicks for the 19-day trial is shown in Table 7. Chicks receiving the 8% glucose solution had a lower ratio of feed to water consumed ($P < .05$) than those given the glucose solutions at 2%, 4% or the tap water (.34 vs .41, .41 or .39, respecitvely). The results referred to the decrease ($P < .05$) in feed consumptions for chicks given the glucose solution at 8% (Table 5) while their water consumptions were not significantly different from chicks receiving the glucose solutions at 2%, 4% or the tap water (Table 6). There was no significant differences in the ratio of feed to water consumptions among chicks given the tap water or the glucose solutions at 2% or 4% in most periods (Appendix Table 8) and for the 19-day trial (Table 7). The ratio of feed to water consumption for chicks fed the diet containing 3300 kcal/kg was lower ($P < .05$) than for those chicks fed the diets that

Table 6. Water consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Water consumed (ml/bird for 19 days)				
	Level of glucose in drinking water no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	1507	1384	1491	1473	1464^{a}
3000	1444	1299	1328	1336	1352^{b}
3300	1491	1409	1432	1446	1445^{ab}
	(6)*	(6)	(6)	(6)	
mean	1481^{a}	1364^{b}	1417^{ab}	1418^{ab}	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

contained 2700 or 3000 kcal/kg in most periods (Appendix Table 9) and for the 19-day trial (Table 7). This result was due to the reduction in feed consumed by chicks fed the high energy diet (3300 kcal/kg) while their water consumptions were not significantly different from those chicks fed the low energy diets (2700 and 3000 kcal/kg).

Chicks that consumed the 2% glucose solution drank less water ($P < .05$) during the 19-day trial than those given the tap water. However, the ratio of feed to water consumed by these two treatments was the same (.41 vs. .41, Table 7).

Although the chicks that were fed the diet that contained 3000 kcal/kg consumed less water ($P < .05$) than those fed

Table 7. Ratio of feed to water consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Ratio of feed and water consumed (gm/ml/bird for 19 days)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	.42	.40	.39	.36	$.40^a$
3000	.41	.43	.41	.35	$.40^a$
3300	.37	.36	.38	.31	$.36^b$
	(6)*	(6)	(6)	(6)	
mean	$.41^a$	$.41^a$	$.39^a$	$.34^b$	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

the diet that contained 2700 kcal/kg the ratio of feed and water was the same (.40 vs. .40, Table 7). This was due to less diet being consumed by chicks fed the diet that contained 3300 kcal/kg than by those fed the diet that contained 2700 kcal/kg.

Dietary energy consumed: During the 19-day trial, the chicks receiving each successively higher level of glucose in their water had a lower consumption in dietary energy as shown in Table 8. The dietary energy consumed by chicks given either tap water or the glucose solutions at 2, 4 or 8% were 1795, 1671, 1669 and 1453 kcal, respectively. This was a result of the decrease in feed consumption when

Table 8. Dietary energy consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed (kcal/bird for 19 days)				
	Level of glucose in drinking water no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	1746	1540	1568	1439	1573[a]
3000	1763	1691	1640	1419	1628[a]
3300	1876	1782	1799	1502	1740[b]
	(6)*	(6)	(6)	(6)	
mean	1795[a]	1671[b]	1669[b]	1453[c]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a, b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

chicks were given the glucose solutions (Table 5). This indicated that the glucose added in drinking water depressed the dietary energy consumed by chicks. The reduction in dietary energy consumed by chicks given the glucose solutions was shown in all five periods (Appendix Table 11).

Chicks consumed less diet when the energy level in their diets increased (Table 5). However, the dietary energy consumed by chicks fed the diet that contained 3300 kcal/kg was higher ($P < .05$) than for those fed the diets that contained 2700 or 3000 kcal/kg (1740 vs. 1573 or 1628 kcal, respectively, Table 8). In most periods, the chicks receiving the diets with the highest energy level showed an increase in dietary energy intake (Appendix Table 12). The detail of data on dietary energy consumed by chicks for each period is shown in Appendix Table 10.

"Water-energy consumed or energy consumed from glucose in drinking water: According to Anderson *et al.* (1958), the metabolizable energy (ME) of glucose at dry weight was 3.64 kcal/gm. In this experiment, clintose was used as a source for glucose and it contained 9.1% moisture. Therefore, when calculating the availability of the ME of clintose, a mean figure of 3.28 kcal ME/gm was used in all calculations of energy consumed from glucose in drinking water.

The water consumed by chicks tended to be the same amount whether chicks were given the glucose solutions or the tap water (Table 6). Thus the chicks that were given each successively higher level of glucose had a significantly higher ($P < .05$) amount of "water-energy" consumed as shown in Table 9. Similar results were obtained in most periods (Appendix Table 14).

"Water-energy" consumed by chicks for the 19-day trial was lowest ($P < .05$) in chicks fed the diet with 3000 kcal/kg as compared to those fed the diets containing 2700 or 3300 kcal/kg (Table 9). Similar results were shown in most periods (Appendix Table 15). This was due to a significantly lower water consumption by chicks fed the diet with 3000 kcal/kg (Table 6).

Table 9. "Water-energy" consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed (kcal/bird for 19 days)				
	Level of glucose in drinking water no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	-	91	198	391	227[a]
3000	-	86	176	354	205[b]
3300	-	93	189	383	222[a]
	(6)*	(6)	(6)	(6)	
mean	-	90[a]	188[b]	376[c]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a, b, means carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Total energy consumed from feed and glucose in drinking water: There was no significant difference in the total energy consumed by chicks given any of the glucose treatments (0% up to 8%) as shown in Table 10 and Appendix Table 17.

Total energy consumed was higher (P< .05) in chicks fed the diet that contained 3300 kcal/kg than for those fed the diets that contained 2700 kcal/kg. This is shown in Table 10 (1906 vs. 1739 kcal) and Appendix Table 18 (periods 2, 4 and 5). This was a result of insufficient reduction in feed and water consumption of the chicks fed this diet (3300 kcal/kg) to equal the energy consumed by the

Table 10. Total energy consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Total energy consumed (kcal/bird for 19 days)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	1746	1631	1765	1815	1739[a]
3000	1763	1775	1816	1773	1782[a]
3300	1876	1875	1988	1885	1906[b]
	(6)*	(6)	(6)	(6)	
mean	1795[a]	1760[a]	1856[a]	1824[a]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

chicks fed the lower energy rations (2700 and 3000 kcal/kg). There was a small numerical increase in total energy consumed by chicks fed the diet that contained 3000 kcal/kg when compared to those fed the diet that contained 2700 kcal/kg (1782 vs. 1739 kcal). However, this increase was not significant. The extra in the amount of total energy consumed by chicks fed the high energy diet was from the diet alone. This was due to the decrease in "water-energy" consumptions when chicks were fed the high energy diet while their dietary energy intake increased.

Dietary energy consumed and "water-energy" consumed expressed as percent of total energy consumed: Percent of dietary energy consumed by chicks for 19-day trial decreased ($P < .05$) as the level of glucose in drinking water increased as shown in Table 11 (94.9 vs. 89.7 vs. 79.5% for the glucose solutions at 2% vs. 4% vs. 8%). Similar results were produced in all five periods (Appendix Table 20). This result referred to the decrease in dietary energy consumed by chicks when the concentration of glucose in drinking water increased.

Chicks fed the diet that contained 2700 kcal/kg had the lowest percent of dietary energy consumed ($P < .05$) when compared to those fed the diets containing 3000 or 3300 kcal/kg as shown in Table 11.

The percent "water-energy" consumed by chicks increased as the level of glucose in drinking water increased as shown in Table 12 (5.1 vs. 10.3 vs. 20.5% for the glucose solutions at 2% vs. 4% vs. 8%). The percent of "water-energy" consumed by chicks fed the diet that contained 2700 kcal/kg was higher ($P < .05$) than for those receiving the diets that contained 3000 or 3300 kcal/kg as shown in Table 12 (12.7 vs. 11.6 or 11.6%, respectively).

This indicated that the glucose added in drinking water or the low energy level in diet depressed the percent of dietary energy consumption by chicks and increased the percent of "water-energy" consumed.

<u>Body weight gain and feed efficiency</u>: Body weight gain of chicks for the 19-day trial is shown in Table 13. Chicks that were given glucose in their water had a reduced weight gain when compared to those receiving the tap water.

Table 11. Dietary energy consumed as percent of total energy consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed as percent of total energy consumed (%)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	100	94.4	88.8	78.8	87.3^{a}
3000	100	95.3	89.8	80.1	88.4^{b}
3300	100	95.0	90.5	79.7	88.4^{b}
	(6)*	(6)	(6)	(6)	
mean	100	94.9^{a}	89.7^{b}	79.5^{c}	

Table 12. "Water-energy" consumed as percent of total energy consumed by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed as percent of total energy consumed (%)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	-	5.6	11.2	21.2	12.7^{a}
3000	-	4.7	10.2	19.9	11.6^{b}
3300	-	5.0	9.5	20.3	11.6^{b}
	(6)*	(6)	(6)	(6)	
mean	-	5.1^{a}	10.3^{b}	20.5^{c}	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Table 13. Body weight gain of broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Body weight gain (gm/bird for 19 days)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	381	362	380	350	368^a
3000	371	370	377	358	369^a
3300	428	389	418	367	401^b
	(6)*	(6)	(6)	(6)	
mean	393^a	374^{ab}	392^a	358^b	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Chicks given the 8% glucose solution gained less ($P < .05$) than those given the tap water (358 vs. 393 gm. Table 13).

Chicks gained faster with the higher energy diet when compared to those fed the lower energy diet (Table 13). Body weight gains were higher ($P < .05$) in chicks fed the diet containing 3300 kcal/kg than for those chicks fed the diets that contained 2700 or 3000 kcal/kg (401 vs. 368 or 369 gm, respectively).

During the 19-day trial, the chicks gained fastest when they were given the diet that contained 3300 kcal/kg and the tap water (428 gm, Table 13). The lowest weight gain was obtained when chicks were given the diet that contained 2700 kcal/kg and the 8% glucose solution

(350 gm, Table 13).

When the concentration of glucose in drinking water increased, the feed consumed by chicks declined (Table 5) and the weight gains of chicks also declined but to a lesser extent (Table 13). That is the reason why the feed/gain was thus less for chicks given each successively higher level of glucose in drinking water (Table 14). Feed efficiency by chicks for the 19-day trial were as follows: 1.53 (tap water), 1.49 (2% glucose), 1.42 (4% glucose) and 1.36 (8% glucose). The significant difference ($P < .05$) in feed efficiency was obtained among chicks given the tap water and the glucose solution at 4% and 8%. These similar results were shown in most periods (Appendix Table 29).

When the caloric density in the ration increased, the feed consumed by chicks decreased (Table 5) but the chicks gained faster. Meanwhile, the efficiency of feed conversion was improved in chicks receiving each successively higher level of dietary energy as shown in Table 14. Feed efficiency by chicks fed the diet that contained 2700, 3000 and 3300 kcal/kg for 19-day trial were 1.58, 1.47 and 1.31. When compared to each other, these three values showed a significant difference (Table 14).

The best feed efficiency was found in chicks receiving the diet that contained 3300 kcal/kg and the glucose solution at 8% and the worst value was found in chicks given the diet that contained 2700 kcal/kg and the tap water as shown in Table 14 (1.22 vs 1.67).

Table 14. Feed efficiency by broiler-type chicks during 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Feed efficiency (gm feed/gm bird for 19 days)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	1.67	1.51	1.48	1.52	1.58[a]
3000	1.54	1.49	1.39	1.32	1.47[b]
3300	1.29	1.38	1.27	1.22	1.31[c]
	(6)*	(6)	(6)	(6)	
mean	1.53[a]	1.49[ab]	1.42[b]	1.36[b]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Liver weight and pancreatic weight: There were no significant differences due to the feeding of any level of glucose in drinking water (0% up to 8%) or dietary energy, on the liver weights, the percent liver weight as body weight, the pancreatic weights or the percent pancreatic weight of body weight of chicks sacrificed at the end of 19-day trial as shown in Tables 15, 16, 17 and 18, respectively.

Mortality: Three chicks died in the first period for reasons which appeared to be unrelated to the experimental treatment. All three chicks were from different treatment groups.

Table 15. Liver weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Liver weight (gm/bird)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	18.7	17.0	17.6	17.7	17.7[a]
3000	15.4	16.1	17.6	16.1	16.3[a]
3300	17.4	16.2	17.6	16.3	16.9[a]
	(6)*	(6)	(6)	(6)	
mean	17.1[a]	16.4[a]	17.6[a]	16.7[a]	

Table 16. Liver weight as percent of body weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Liver weight as percent of body weight (%)				
	Level of glucose in drinking water				
	no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	4.4	4.2	4.1	4.5	4.3[a]
3000	3.6	3.9	4.2	4.0	3.9[a]
3300	3.9	3.8	3.8	4.0	3.8[a]
	(6)*	(6)	(6)	(6)	
mean	3.9[a]	4.0[a]	4.0[a]	4.2[a]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Table 17. Pancreatic weight of broiler type chicks sacrified at the end of 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Pancreatic weight (gm/bird)				
	Level of glucose in drinking water no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	2.2	1.7	2.2	1.7	2.0[a]
3000	1.7	1.7	2.0	1.7	1.8[a]
3300	2.2	2.0	1.8	1.8	1.9[a]
	(6)*	(6)	(6)	(6)	
mean	2.0[a]	1.8[a]	2.0[a]	1.7[a]	

Table 18. Pancreatic weight as percent of body weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Pancreatic weight as percent of body weight (%)				
	Level of glucose in drinking water no glucose	2%	4%	8%	mean
	(2)*	(2)	(2)	(2)	(8)*
2700	.52	.42	.52	.44	.48[a]
3000	.41	.41	.47	.42	.43[a]
3300	.46	.46	.40	.44	.44[a]
	(6)*	(6)	(6)	(6)	
mean	.47[a]	.43[a]	.46[a]	.44[a]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Experiment 2

Feed and water consumed: Feed consumed by chicks for the 19-day trial is shown in Table 19. The amount of feed consumed by chicks given the tap water or the 4% of various carbohydrates was as follows: lactose (468), sucrose (440), tap water (422), glucose (421), fructose (380) and galactose (343 gm). Chicks given the 4% galactose decreased their feed intake ($P < .05$) when compared to those receiving the 4% of lactose or sucrose or the tap water. Feed consumed by chicks given the 4% lactose was highest in most periods (Appendix Table 34), but the significant difference was not shown when compared to the control chicks that were given the tap water.

Chicks fed the diet that contained 2700 kcal/kg consumed more diet ($P < .05$) than those fed the diet that contained 3300 kcal/kg as shown in Table 19 (428 vs. 396 gm). The similar results were shown in all five periods (Appendix Table 35).

Water consumed by chicks for 19-day trial is shown in Table 20. The water consumptions by chicks given the 4% of either glucose, galactose, fructose or sucrose in drinking water were not significantly different from the water consumed by chicks given the tap water (1368, 1313, 1139 or 1337 vs. 1096 ml, respectively). The chicks given the 4% lactose solution had a higher water consumption ($P < .05$) than those receiving the tap water (1562 vs. 1096 ml. for the 19-day trial, Table 20). These similar results

Table 19. Feed consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Feed consumed (gm/bird for 19 days)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	455	475	333	379	443	484	428[a]
3300	389	366	352	381	436	452	396[b]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	422[ac]	421[ac]	343[b]	380[bc]	440[ac]	468[a]	

Table 20. Water consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Water consumed (ml/bird for 19 days)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	1182	1432	1392	1176	1438	1645	1378[a]
3300	1009	1304	1233	1102	1236	1479	1227[b]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	1096[a]	1368[ab]	1313[ab]	1139[a]	1337[ab]	1562[b]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

were shown in most periods (Appendix Table 37).

Chicks fed the diet that contained 2700 kcal/kg consumed more water ($P < .05$) than those fed the diet that contained 3300 kcal/kg (1378 vs. 1227 ml, Table 20). This result might be related to the amount of feed consumed by chicks. The chicks consumed more diet ($P < .05$) when they were fed the diet that contained low energy (Table 19). Chicks consumed less water when they consumed less diet. This observation was confirmed by the data on the ratio of feed to water consumed. There was no significant difference in the ratio of feed to water consumed between chicks fed these two diets as shown in Table 21 (.31 vs .33).

The ratio of feed to water consumed by chicks given the 4% of either glucose, galactose or lactose was less ($P < .05$) than for those chicks receiving the tap water as shown in Table 21 (.31, .27 or .30 vs .39, respectively). This result indicated that chicks given the 4% of glucose or galactose in their water consumed more water than those receiving the tap water when there was a comparison to the amount of their feed consumption. The low ratio of feed to water consumed by chicks given the 4% lactose solution was due to their significantly higher amounts of water intake (Table 20) when compared to the chicks receiving the tap water.

<u>Dietary energy consumed</u>: The dietary energy consumed by chicks for 19-day trial is shown in Table 22. Chicks that were given the 4% galactose consumed less

Table 21. Ratio of feed to water consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Ratio of feed and water consumed (gm/ml/bird for 19 days)						
	Carbohydrate in drinking water no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	.38	.33	.24	.32	.31	.29	$.31^{a}$
3300	.39	.28	.29	.35	.35	.31	$.33^{a}$
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	$.39^{a}$	$.31^{bc}$	$.27^{bc}$	$.34^{ac}$	$.33^{ac}$	$.30^{bc}$	

Table 22. Dietary energy consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed (kcal/bird for 19 days)						
	Carbohydrate in drinking water no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	1229	1282	898	1023	1197	1304	1156^{a}
3300	1284	1206	1161	1255	1441	1492	1307^{b}
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	1257^{ac}	1244^{ac}	1030^{b}	1139^{bc}	1319^{ac}	1398^{a}	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

dietary energy (P< .05) than those given the tap water (1030 vs. 1257 kcal). The 4% of either glucose, fructose, sucrose or lactose did not induce any significant differences in the amount of energy consumed when compared to the amount consumed by chicks given the tap water. There was a tendency for an increasing dietary energy consumed when chicks were given the 4% sucrose or lactose in their water in most periods (Appendix Table 43) and for the 19-day trial (Table 22).

Chicks fed the diet that contained 3300 kcal/kg consumed a higher (P < .05) amount of dietary energy than those fed the diet that contained 2700 kcal/kg (1307 vs. 1156 kcal, Table 22). Therefore, the dietary energy consumptions by chicks were highest in groups of chicks receiving the diet that contained 3300 kcal/kg and the 4% lactose (1492 kcal). The lowest amount of dietary energy consumed was by the chicks given the diet that contained 2700 kcal/kg and the 4% of galactose (898 kcal). The details of data on dietary energy consumed by chicks for each period are shown in Appendix Table 42, 43 and 44.

"Water-energy" consumed or Energy consumed from the 4% of various carbohydrates in drinking water: The heats of combustion for glucose, galactose, fructose, sucrose and lactose are 673.0, 670.7, 675.6, 1349.6 and 1350.8 kcal/mole, respectively*. The molecular weight for the

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* Handbook of Chemistry and Physics, pp. 1579-1587, (Heat of Combustion) Hodgman, Charles D., Ed. Chemical Rubber Company, Cleveland, Ohio.

first three monosaccharides was 180 each, the molecular weight for the last two disaccharides was 342 each. Thus the gross energy per gram for each kind of carbohydrate was 3.74, 3.73, 3.75, 3.95 and 3.95 kcal/gm, respectively. Shannon _et al_. (1969) studied the utilization of the energy of pure sugars by chicks, and they reported that the percentage of the metabolized energy of fructose and lactose were 95.5% and 44.5%, respectively. The ME of glucose was 3.64 kcal/gm (Anderson _et al_., 1958). The gross energy of glucose was 3.74 kcal/gm, therefore the percent ME of glucose was 97.3%. The percent ME of sucrose was approximated from the average value of fructose and glucose, and it is 96.4%. No data on the percent ME of galactose in chicks was obtained, so the ME of galactose was not known. The ME (dry weight) of fructose, sucrose and lactose was 3.58, 3.81 and 1.76 kcal/gm. The moisture contents in glucose, galactose, fructose, sucrose and lactose were found to be 0.2, 0.3, 0.08, 0.03 and 4.8%, respectively. Therefore, the ME (as used) for glucose, fructose, sucrose and lactose was 3.63, 3.58, 3.81 and 1.68 kcal/gm, respectively. When calculating the availability of the ME per ml of 4% glucose, fructose, sucrose and lactose solutions, results were 0.145, 0.143, 0.152 and 0.067 kcal/ml of drinking water. The summary of all values is shown in Appendix Table 45.

Since no energy was obtained from the water consumed by the chicks given the tap water, and because there were no available data on the ME of galactose, the comparison on the "water-energy" consumed was only among birds given the 4% of glucose, fructose, sucrose and lactose (Table 23). Although those chicks given the 4% of lactose in their drinking water drank the highest amount of water (Table 20), their "water-energy" consumptions were lowest. This was due to the markedly lower value in the ME of the lactose when compared to sucrose, glucose or fructose as shown in Appendix Table 45 (1.68 vs, 3.81, 3.63 or 3.58 kcal/gm, as used, respectively). The "water-energy" consumed by chicks given the 4% of lactose was significantly lower ($P < .05$) than for those treated with the 4% of glucose, fructose or sucrose as shown in Table 23 (104 vs. 199, 163 or 204 kcal, respectively). No significant differences in the "water-energy" consumptions by chicks given the 4% of glucose or sucrose were shown in most periods (Appendix Table 47) and for the 19-day trial (Table 23). Chicks that were given the 4% of fructose had a lower amount of "water-energy" consumed ($P < .05$) when compared to the chicks given the 4% of glucose (163 vs. 199 kcal, Table 23).

The data on the water consumed (Table 20) showed that chicks fed the diet that contained 2700 kcal/kg drank more water ($P < .05$) than those fed the diet that contained 3300 kcal/kg. This resulted in the higher ($P < .05$) amount of "water-energy" consumed by chicks fed the

Table 23. "Water-energy" consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed (kcal/bird for 19 days)						
	Carbohydrate in drinking water no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	0	207	-	168	219	109	176^a
3300	0	190	-	157	188	99	159^b
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	0	199^a	-	163^b	204^a	104^c	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

low energy diet (2700 kcal/kg) than those fed the high energy diet (3300 kcal/kg) as shown in Table 23 (176 vs. 159 kcal).

Total energy consumed from feed and the 4% of various carbohydrates in drinking water: In Table 24 are the values for the total energy consumed by chicks for the 19-day trial. The total energy consumption by chicks given the different kinds of drinking water are in the following increasing order: tap water (1257), fructose (1303), glucose (1443), lactose (1502) and sucrose (1522 kcal/bird). There were no significant differences in the amounts of total energy intake among chicks given the 4% of fructose, glucose or the tap water. Chicks given 4% of either sucrose or

Table 24. Total energy consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Total energy consumed (kcal/bird for 19 days)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	1229	1490	-	1192	1415	1413	1348^a
3300	1285	1396	-	1413	1629	1590	1463^b
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	1257^a	1443^{ab}	-	1303^a	1522^b	1502^b	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

lactose in drinking water consumed more total energy ($P < .05$) than those receiving 4% of fructose or tap water. Similar results are shown in most periods (Appendix Table 50).

Total energy consumed was higher ($P < .05$) in chicks fed the diet that contained 3300 kcal/kg than for those fed the diet with 2700 kcal/kg. This is shown in Table 24 (1463 vs. 1348 kcal) and Appendix Table 51 (periods 2 and 3).

<u>Dietary energy consumed and "water-energy" consumed expressed as percent of total energy consumed</u>: Percentages of dietary energy consumed by chicks for 19-day trial were not significantly different among chicks given the 4% of glucose, fructose or sucrose as shown in Table 25 (86.3 vs. 87.4 vs. 86.6%). Chicks given the 4% of lactose in

Table 25. Dietary energy consumed as percent of total energy consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed as percent of total energy consumed (%)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	100	86.1	-	85.8	84.6	92.3	87.2^a
3300	100	86.5	-	89.0	88.5	93.8	89.5^b
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	100	86.3^a	-	87.4^a	86.6^a	93.1^b	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different (P < .05), according to the Tukey's test.

drinking water had a higher percentage of dietary energy consumed (P < .05) than chicks given the other carbohydrates (93.1% vs. all percentages above). Similar results were produced in all five periods (Appendix Table 53).

Percentages of dietary energy consumed were higher (P < .05) in chicks fed the diet that contained 3300 kcal/kg than for those treated with the diet that contained 2700 kcal/kg (89.5 vs. 87.2%, Table 25). Similar results are shown in most periods (Appendix Table 54).

Chicks given the 4% of either glucose, fructose or sucrose showed no significant difference in the percentages of "water-energy" consumed as shown in Table 26 (13.8 vs. 12.7 vs. 13.6%). The 4% of lactose solution caused

Table 26. "Water-energy" consumed as percent of total energy consumed by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed as percent of total energy consumed (%)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	0	14.0	-	14.3	15.3	7.7	12.9[a]
3300	0	13.5	-	11.1	11.6	6.2	10.6[b]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	0	13.8[a]	-	12.7[a]	13.6[a]	7.0[b]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

the lowest ($P < .05$) percent of "water-energy" consumed by chicks (7.0% vs. all percentages above). Chicks fed the low energy diet (2700 kcal/kg) had a higher percentages of "water-energy" consumed than those fed the high energy diet (3300 kcal/kg) as shown in Table 26 (12.9 vs. 10.6%). The percentages of "water-energy" consumed by chicks for each period are shown in Appendix Table 55 and 56.

<u>Body weight gain and feed efficiency</u>: The results showed that the body weight gain of chicks by the end of the 19-day trial fall in the following order: sucrose 313, lactose 296, glucose 274, fructose 262, tap water 250 and galactose 223 gm as shown in Table 27. Chicks given the 4% of either lactose, glucose or fructose solution gained moderately

Table 27. Body weight gain of broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Body weight gain (gm/bird for 19 days)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	260	280	201	234	291	276	257[a]
3300	239	268	245	289	335	316	282[b]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	250[ac]	274[abc]	223[a]	262[abc]	313[b]	296[bc]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

more than the control chicks given the tap water. Chicks receiving the 4% sucrose solution had heavier ($P < .05$) weight gains than those given the tap water or the 4% galactose solution. The retarded weight gains of chicks given the 4% galactose solution were shown in most periods (Appendix Table 59). The chicks given the 4% sucrose in their water gained best in all five periods (Appendix Table 59).

Chicks receiving the 4% lactose solution showed the symptoms of diarrhea but they consumed more diet and water than other carbohydrate treatments (Table 19 and 20). The weight gains of chicks on this treatment were almost as high as those for the chicks given the 4% of sucrose solution in all five periods (Appendix Table 59).

In this second experiment, the chicks gained less than those chicks in the first experiment, particularly, when there was a comparison between chicks given the tap water or between chicks given the 4% glucose solution in both trials. This was due to the length of the light time provided in the housing. In the first experiment, the light was on continuously but, only 14 hours daily for the second experiment. The light provided affects the amounts of feed and water consumed by chicks. Therefore, the chicks from the first trial had more time to consume food than those chicks in the second trial. This was the reason why the chicks in the second experiment gained less.

Chicks given the high energy diet consumed less feed (Table 19) but they gained more (Table 27) than those receiving the low energy diet. This resulted in better feed efficiency ($P < .05$) by chicks fed the high energy diet as shown in Table 28 (1.42 vs. 1.67). Similar results were shown in most periods (Appendix Table 63).

Feed efficiency by chicks for the 19-day trial or for each period were not significantly different whether chicks were given the tap water or the 4% of any of five different kinds of carbohydrate in drinking water (Table 28 and Appendix Table 62). However, the ratios of feed consumed to weight gain were lowest in chicks fed the sucrose solution in 3 of 5 periods: number 2, 3 and 4 (Appendix Table 62).

Table 28. Feed efficiency by broiler-type chicks during 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Feed efficiency (gm feed/gm bird for 19 days)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	1.75	1.71	1.67	1.62	1.53	1.75	1.67[a]
3300	1.63	1.37	1.47	1.32	1.30	1.43	1.42[b]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	1.69[a]	1.54[a]	1.57[a]	1.47[a]	1.41[a]	1.59[a]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Maximum weight gain of chicks for the 19-day trial was 335 gm (Table 27). This weight gain was obtained with the diet that contained 3300 kcal/kg and the 4% sucrose solution in the drinking water. Minimum weight gain, 201 gm/bird/19 days, was found in chicks fed the diet that contained 2700 kcal/kg and 4% of galactose solution in the drinking water. The best feed efficiency was produced by chicks fed the diet that contained 3300 kcal/kg and the 4% of sucrose solution in the drinking water, and the worst feed efficiency was found in chicks fed the diet that contained 2700 kcal/kg and the tap water, as shown in Table 28 (1.30 vs. 1.75).

Liver weight and lipids in liver: The liver weights and the concentration of lipids in livers given the 4% of either glucose, galactose, fructose, sucrose or lactose were not significantly different from those livers removed from the chicks given the tap water as shown in Table 29 and 30. However, chicks given the sucrose treatment had the heaviest livers. The liver weights of these chicks were significantly higher when compared to the liver weights of chicks on the galactose treatment which had the lowest weight (14.9 vs. 11.0 gm/bird). This difference of organ weight might be due to the size of the chicks. Chicks given the 4% sucrose solution had the highest body weight gain while the lowest was found in chicks given the 4% galactose solution (Table 27). As shown in Table 31, there was no significant difference in the liver weight when expressed as the percent of body weight of chicks that were given any of the treatments.

The difference in dietary energy between diets that contained 2700 and 3300 kcal/kg did not cause any significant difference in liver weight, percent of liver weight or lipids in liver.

<u>Pancreatic weight</u>: Pancreatic weights of chicks given the 4% of any carbohydrate solution were not significantly different from those of chicks receiving the tap water (Table 32). However, the chicks given the sucrose treatment had both the heaviest livers and the heaviest pancreases. Chicks given the 4% galactose solution had the lowest liver weight and also lowest pancreatic weight. This was due to the size of the chicks: large when given sucrose and small when given galactose. Normally,

Table 29. Liver weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Liver weight (gm/bird)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	12.6	13.7	10.7	12.5	14.3	12.7	12.7[a]
3300	12.0	13.0	11.3	13.7	15.6	14.7	13.4[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	12.3[ab]	13.3[ab]	11.0[a]	13.1[ab]	14.9[b]	13.7[ab]	

Table 30. Percent lipids in the livers of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Percent lipids in the livers						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	4.2	4.4	4.7	3.9	4.2	3.8	4.2[a]
3300	4.3	4.5	4.3	4.5	4.7	4.0	4.4[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	4.2[a]	4.4[a]	4.5[a]	4.2[a]	4.4[a]	3.9[a]	

* represented the number of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Table 31. Liver weight as percent of body weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Liver weight as percent of body weight						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	4.0	4.1	4.2	4.2	4.1	3.8	4.1[a]
3300	4.1	4.0	3.8	3.9	3.9	3.9	3.9[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	4.0[a]	4.1[a]	3.9[a]	4.1[a]	4.0[a]	3.8[a]	

Table 32. Pancreatic weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Pancreatic weight (gm/bird)						
	Carbohydrate in drinking water						
	no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	1.7	1.5	1.2	1.3	1.7	1.6	1.5[a]
3300	1.2	1.4	1.4	1.5	1.8	1.9	1.5[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	1.4[ab]	1.4[ab]	1.3[a]	1.4[ab]	1.8[b]	1.7[ab]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

when the size of an animal increases the size of its organs will increase also. This was supported by the results shown in Table 33. There was no significant difference in the percent of pancreatic weight found among birds given the tap water or 4% of any carbohydrate solution.

Pancreatic weights and percent of pancreatic weights were not significantly different between chicks fed the diet that contained 2700 or 3300 kcal/kg.

Mortality: The percent mortality of chicks was calculated from the number of chicks that died during the 19-day trial and the number of chicks started at the beginning of the experiment. Data on the percent mortality of chicks for 19-day trial is shown in Table 34. Energy in the diet did not significantly affect the percent mortality. The percent mortality for chicks fed the diets that contained 2700 and 3300 kcal/kg were the same (15.6%).

Galactose was the only sugar that significantly increased mortality in chicks. The chicks given the 4% galactose solution showed many strange actions: jumping and flying about the cage; having a peculiar stare and peeping loudly. When the convulsions occurred, the chicks fell to the cage floor and lay on their backs with excessive movement of their legs and wings. After a few seconds all movements ceased, the eyes closed, the legs became spastic, food sometimes was thrown from the mouth and respiration ceased. Within 1-2 minutes the chicks' respiration slowly returned. Then the chicks rose and walked

Table 33. Pancreatic weight as percent of body weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Pancreatic weight as percent of body weight						
	Carbohydrate in drinking water: no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	.52	.44	.49	.44	.49	.47	.47[a]
3300	.42	.42	.46	.44	.46	.50	.45[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	.47[a]	.43[a]	.47[a]	.44[a]	.47[a]	.48[a]	

Table 34. Chick mortality in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Percent of mortality						
	Carbohydrate in drinking water: no carbohydrate	4% glucose	4% galactose	4% fructose	4% sucrose	4% lactose	mean
	(2)*	(2)	(2)	(2)	(2)	(2)	(12)*
2700	6.3	12.5	62.5	6.3	0	6.3	15.6[a]
3300	12.5	0	37.5	18.8	6.3	18.8	15.6[a]
	(4)*	(4)	(4)	(4)	(4)	(4)	
mean	9.3[a]	6.3[a]	50.0[b]	12.5[a]	3.1[a]	12.5[a]	

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

slowly looking perfectly normal. However, convulsions reoccurred during the 19-day trial but decreased in frequency and severity.

DISCUSSION

The dietary energy consumed by chicks decreased as the level of glucose in drinking water increased. However, there was no significant difference in the total energy consumed between those chicks given plain tap water and those given graded levels of glucose in their water. These results indicated that the chicks responded to the calories in the glucose solution by regulating their feed consumption to maintain a steady total energy consumed. Bogner (1957 and 1961) and Bogner and Haines (1961) reported that chicks have fully developed the absorption of glucose by a few days of age. Thus, it may be possible that the young chicks in the experiment here had the capability of utilizing glucose and that energy from the glucose solution can constitute a substantial portion of their total caloric intake.

Kare and Medway (1959) found that the level of sugar had little, if any, influence on the amount of water consumed. They reported that the glucose solutions at 2.5% up to 20% were accepted by the chicks equally with water. In this experiment, the amounts of water consumed by chicks in most periods were not significantly influenced when chicks given solutions with glucose at 2, 4 or 8%. However, during the 19-day trial, the chicks receiving the 2% glucose solution consumed less water ($P < .05$) than those given the other glucose solutions (at 4 and 8%) or the tap water. There was not enough information to explain why this occurred. Perhaps the chicks' physiological processes were able to adjust their energy consumed from the glucose (in drinking water) and their diet to maintain a consistent energy consumption.

The equal amounts of total energy consumed did not produce equivalent body weight gains. The chicks given the 8% glucose solution had retarded growth ($P < .05$) when compared to the control chicks. This was due to the significant decrease in feed consumed by chicks given the high level of glucose (8%) in drinking water. The reduction in feed consumption may have induced some nutrient deficiencies that caused the poor body weight gain.

Hill and Dansky (1954), by varying caloric density of feed, demonstrated that energy requirements influenced feed intake. They reported that although the rate of feed consumption was determined primarily by the energy level of the ration, the fact that equal amounts of energy were not consumed by the lots receiving rations of different energy levels indicated that some other factor affected the amount of feed consumed. This finding has been confirmed by the results of both experiments 1 and 2. The chicks fed the rations of low energy value did not consume enough additional feed to equal the energy intake of those on the high energy ration. Thus, more growth and better feed efficiency were found in chicks fed the high energy diet.

Pearce (1970) reported that birds receiving the diet that contained 70% glucose had heavier livers than birds fed the control diet. In the first trial there was no evidence of heavy liver weight produced by any level of glucose solution (2% up to 8%). This might indicate that energy consumed from glucose in drinking water was used by the chicks and not deposited as fat in the liver. The lack of change in liver weight and pancreatic weight suggested that the levels of glucose up to 8% in drinking water may not be high enough to alter the activity of liver and pancreas in regulation of carbohydrate metabolism.

Galactose was a toxic compound and caused neurotoxicity in chicks (Kozak and Wells, 1969; Malone et al., 1971). Malone et al. (1971) reported that galactose neurotoxicity was induced by feeding chicks 10% (w/v) galactose in drinking water. In the experiment here, chicks given the 4% galactose solution appeared weak and developed a fine tremor within 24 to 48 hours. Some had convulsions and died during the first and second periods. When the convulsions occurred, chicks could not eat. Therefore, chicks receiving the 4% galactose solution consumed less diet ($P < .05$) than the control chicks, resulting in poor growth. Malone et al. (1971) observed that the galactose-toxic chicks excreted large amounts of watery material not seen in the control chicks. This result suggested alteration of body fluids and dehydration. They also reported that chicks, one day of age, given the 10% of galactose in drinking water for 7 days developed severe hyperosmolar dehydration. Although the hyperosmolality did not correlate with neurotoxicity as reported by Knull and Wells (1973), it might affect the amount of water consumed. In this study, the galactose-toxic chicks consumed less diet ($P < .05$) but their water consumption was not different from the control given the tap water. Thus, the chicks receiving the 4% galactose solution had the lowest feed to water consumption ratio.

Rutter _et al_. (1053) reported more feed consumed when chicks were fed a diet that contained 53% lactose, and there was considerable diarrhea. Monson _et al_. (1950) observed that chicks fed the diet that contained 60% lactose consumed about twice the amount of water consumed by the control chicks, indicating the extent of diarrhea. In this study, chicks given the 4% of lactose in their water also showed the symptoms of diarrhea, and consumed more diet and more water than the control chicks. The pronounced diarrhea in chicks could be the causative factor of increased feed and water consumption.

Paul and Hans (1963) fed diets containing 58% of different carbohydrates to chicks. They reported that the chicks gained best with sucrose. The response to fructose was poor, and that to glucose intermediate. Chalupa and Fisher (1963) also found that chicks fed a diet containing 71% sucrose grew more than chicks those fed a diet containing 71% glucose. In this study, chicks given the 4% sucrose in their water also had the best gains and best feed efficiencies. This result correlated with the increased amounts of feed and water consumed by chicks receiving the 4% sucrose solution. Chicks from this treatment consumed the highest amount of total energy. Those chicks given the 4% fructose solution had body weight gains only slightly less than those given the 4% glucose solution. However, chicks from these two treatments (the 4% fructose or glucose) gained moderately better than the control chicks.

Heald (1962, 1963) and Hawkins and Heald (1966) reported that fructose stimulated the rate of respiration of liver slices more than glucose did, and also that lipids accumulated in liver slices incubated in the presence of fructose more than in the presence of glucose. Pearce (1970) fed pullets (7-8 weeks of age) with either 70% fructose, glucose or cereal-based control diet. He reported that the fructose diet produced the heaviest livers and the greatest hepatic lipid contents. Chicks fed the control diet had the lowest liver weights and smallest hepatic lipid contents. In this experiment, the author suggested that the 4% of various carbohydrates in drinking water were not enough to induce any difference in the liver weights or hepatic lipid contents of chicks.

Malone et al. (1971) reported a high rate of mortality between the third and fifth days of his experiment when chicks were given a 10% galactose solution, starting at one day of age. In this experiment, chicks given the

4% galactose in drinking water also had a high rate of mortality (50%). Death due to galactose was generally attributed to neurotoxicity. The galactose-toxic chicks in this study showed the same signs as described by Rigdon et al. (1963). Chicks developed a fine tremor and appeared weak. Some had convulsions and died. Some galactose-toxic chicks excreted large amounts of watery waste material not seen in chicks given the tap water. This sign was also reported by Malone et al. (1971).

The mortality rate of galactose-toxic chicks given the low energy diet was about twice as high as the mortality rate of the galactose-toxic chicks given the high energy diet. This might be due to the greater amount of water consumed by the chicks that were fed the low energy diet. The more water consumed, the more galactose consumed, which might have caused more toxicity and therefore a higher death rate.

Four percent lactose in drinking water did not affect the mortality of chicks but it affected the development of diarrhea. Since undigested lactose cannot be absorbed, an excess quantity of fluid entered the bowel lumen to dilute the sugar; gut motility was increased, and the subject developed diarrhea. However, chicks did not appear weak. They consumed more water and more diet. Chicks developed a symptom of diarrhea during the first period. In this period chicks given the lactose treatment consumed 31 ml of drinking water daily which meant providing 1.24 gms of lactose/chick/day. This indicated that chicks are very sensitive to lactose. Hamilton and Card (1924) reported that diarrhea resulted when a chicken consumed more than 2 gms of lactose per day.

CONCLUSION

The presence of glucose up to 8% in drinking water did not affect water consumption in most periods. Thus, the energy consumed from glucose solutions increased as the level of glucose in drinking water increased. The energy obtained from glucose solutions depressed the dietary energy consumption (decreased the amount of feed consumption) and resulted in an equal amount of total energy consumed whether chicks were given the tap water or the glucose solutions at 2, 4 or 8%. Although equal amounts of total energy were consumed by chicks on any level of glucose treatments (0% up to 8%), body weight gain of chicks were not equal. The weight gain tended to be lower for chicks given glucose solution, especially those given the 8% glucose solution. The ratio of feed consumed to weight gain (feed efficiency) was improved as the level of glucose in drinking water increased.

Chicks consumed less diet and less water when they were fed the diet that contained high energy. However, the total energy consumed by chicks fed the high energy diet was more than by those fed the lower energy diet. The total energy consumed by chicks fed the diets that contained 2700 or 3000 kcal/kg was significantly less than by those fed the diet that contained 3300 kcal/kg. Chicks fed the diet containing 3300 kcal/kg had a significantly higher body weight gain than those fed the diets with 2700 or 3000 kcal/kg. Therefore, feed efficiencies by chicks were improved as the level of dietary energy increased. Maximum weight gain was obtained from the control chicks fed the diet with 3300 kcal/kg and the minimum weight gain was by chicks fed the diet with 2700 kcal/kg and the 8% glucose solution.

Dietary energy and glucose solution (2% up to 8%) did not affect liver and pancreatic weights.

The first experiment indicated that young chicks have a capability to utilize glucose supplied in their drinking water and the energy from glucose can constitute a substantial portion of their total caloric intake. The chicks are able to adjust their energy intake from glucose solution and diet to maintain a steady total caloric intake. The energy added (glucose) in drinking water did not increase weight gain of chicks but it improved feed efficiency.

Galactose at 4% in drinking water induced a toxicity in chicks, with a mortality of 50%. Chicks on galactose treatment consumed significantly less diet and thus less dietary energy as compared to controls. Thus, the body weight gains of chicks given the 4% galactose solution were lowest but the significance was not found when compared to the control or those given the 4% of either glucose or fructose solution.

The 4% of either glucose, fructose, sucrose or lactose solution did not significantly affect the amounts of feed consumed or dietary energy consumed. However, chicks given the 4% of either lactose or sucrose solution tended to consume more diet while those receiving the 4% of fructose solution tended to consume less diet. The water consumption of chicks receiving glucose, fructose or sucrose at 4% in drinking water was not significantly different from that of the controls. Chicks given the 4% lactose solution showed the symptom of diarrhea and consumed more water ($P < .05$) than the controls.

The 4% levels of the carbohydrates: glucose, fructose, sucrose and lactose added to the chicks' drinking water increased the total energy consumed. Results were significant in groups receiving sucrose or lactose. Body weight gains were higher in all groups than in the control group. Gains were significant in the sucrose test group ($P < .05$). Feed efficiency in the test groups did not differ significantly from feed efficiency in the control group. However, the 4% addition of sucrose induced the best feed efficiency in chicks for most periods.

Chicks consumed less diet with 3300 kcal/kg, but their total energy consumptions were more than for those fed the diet containing 2700 kcal/kg. The body weight gains of chicks fed the high energy diet were significantly higher than those of the chicks fed the low energy diet. Feed efficiency of chicks fed the high energy diet was better than that of those fed the low energy diet. The energy level of the diet fed had no significant effect on the liver weight, pancreatic weight, or liver lipids of chicks in this experiment.

The results of the second trial with four different carbohydrate solutions indicated that there was no significant change in liver weight or pancreatic weight (when expressed as percents of body weight) or in liver lipids (when expressed as a percent of liver weight), when compared to the control. However, when comparing actual weight, there was a significant difference between those chicks given sucrose solution, which resulted in the greatest liver and pancreatic weights, and those given galactose solution, which resulted in the lowest liver and pancreatic weights. These weights though, when calculated as percents of total body weight, were not significantly different. This is because the chicks given sucrose solution had the greatest weight gain, and the chicks receiving galactose solution had the lowest weight gain. This indicated that the sucrose was not the direct cause of the larger liver or pancreases. It was, however, the cause of increased body weight, which in turn, resulted in the larger liver and pancreas. Likewise, the galactose solution caused less weight gain, and resulted in a small liver and pancreas.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anderson, D. L., Hill, F. W., and Renner, R., 1958. Studies of the metabolizable and productive energy of glucose for the growing chick. J. Nutri. 65, 561.

Ashcraft, D. W., 1933. Effect of milk products on pH of intestinal contents of domestic fowl. Poult. Sci. 12, 292.

Bath, W., 1906. Die Geschmacksorgane der Vogel. Inaug. Diss. Berlin.

Beach, J. R. and Davis, D. E., 1925. The influence of feeding lactose or dry skim milk on artificial infection of chicks with Eimeria avium. Hilgardia 1(8), 167.

Bogner, P. H., 1957. Alimentary absorption of reducing sugars by embryos and young chicks. Dissert. Abst. 17, 2654.

Bogner, P. H., 1961. Alimentary absorption of reducing sugars by embryos and young chicks. Proc. Soc. Biol. Med. 107, 263.

Bogner, P. H. and Haines, I. A., 1961. Development of intestinal selective absorption of glucose in newly-hatched chicks. Pro. Soc. Exp. Biol. Med. 107, 265.

Botezart, E., 1904. Geschmacksorgane und andere nervose Endapparate im Schnabel der Vogel. Biol. Centralblatt 24, 722.

Brindley, L. D. and Prior, S., 1968. Effect of age on taste discrimination in the bobwhite quail. Anim. Behav. 16, 304.

Brown, K. M., 1971. Sucrose activity in the intestine of the chick. J. Exp. Biol. 177, 493.

Cameron, A. T., 1947. The taste sense and the relative sweetness of sugars and other sweet substances. Report No. 9. Sugar Research Foundation Inc. New York.

Chalupa, W. and Fisher, H., 1963. Comparative protein evaluation studies by carcass retention and nitrogen balance methods. J. Nutri. 81, 139.

Dam, H., 1944. Galactose-poisoning in chicks. Proc. Soc. Exp. Biol. Med. 55, 57.

Duncan, C. J., 1960. The sense of taste in birds. Ann. appl. Biol. 42(2), 409.

Emslie, A. R. G. and Henry, K. M., 1933. Glycogen formation in the fowl. Biochem J. 27, 705.

Engelmann, C., 1934. Versuche uber den Geschmack von Taube, Ente und Huhn, Z. verg. Physiol. 20, 626.

Engelmann, C., 1937. Weitere Versuche uber den Vesschmackssinn des Huhns. Z. verg. Physiol. 24, 451.

Fischer, J. E. and Sutton, T. S., 1949. Effects of lactose on gastrointestinal motility: A review J. Dairy Sci. 32, 139.

Folch, J., Lees, M., and Stanley, G. H. S., 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226, 497.

Fuerst, W. F. and Kare, M. R., 1962. The influence of pH on fluid tolerance and preference. Poult. Sci. 41, 71.

Gentle, M. J., 1972. Taste preference in the chicken (Gallus domesticus L.) J. Poult. Sci. 13, 141.

Golden, W. R. C. and Long, C. N. H., 1942. Absorption and disposition of glucose in the chick. Am. J. Physiol. 136, 244.

Goodridge, A. G., 1968. Conversion of (U-^{14}C) Glucose into carbondioxide, glycogen, cholesterol and fatty acid in liver slices from embryonic and growing chicks. Biochem. J. 108, 655.

Goodridge, A. G., 1969. The effects of dietary fat on fatty acid synthesis and malic enzyme activity in liver from growing chicks. Can. J. Biochem. 47, 743.

Grant, W. C. and Fahrenbach, M. J., 1959. Effect of dietary sucrose and glucose on plasma cholesterol in chicks and rabbits. Pro. Soc. Exp. Biol. Med. 100, 250.

Hamilton, T. S. and Card, L. E., 1924. The utilization of lactose by the chicken. J. Agr. Research 27, 597.

Hansen, R. G., Freedland, R. A., and Scott, H. M., 1956. The uridine nucleotides in galactose toxicity. J. Biol. Chem. 219, 391.

Harriman, A. E. and Milner, J. S., 1969. Preference for sucrose solutions by Japanese Quail (Coturnix coturnix japonica) in Two-Bottle Drinking Tests. Am. Midland Naturalist 81, 575.

Hawkins, R. A. and Heald, P. J., 1966. Lipid metabolism and the laying hen: The synthesis of triglycerides by slices of avian liver in vitro. Biochem. Biophys. Acta. 116, 41.

Heald, P. J., 1962. Oxidation of fructose by liver of the domestic fowl. Nature 195, 603.

Heald, P. J., 1963. The metabolism of carbohydrate by liver of the domestic fowl. Biochem, J. 86, 103.

Hill, F. W. and Dansky, L. H., 1954. Studies of the energy requirements of chickens. Poult. Sci. 33, 112.

Jacobs, H. L. and Scott, M. L., 1957. Factors mediating food and liquid intake in chickens. Poult. Sci. 36,8.

Kare, M. R., Black, R., and Allison, E. B., 1957. The sense of taste in the fowl. Poult. Sci. 36, 129.

Kare, M. R. and Ficken, M. S., 1963. Comparative studies on the sense of taste. In: Olfaction and Taste. Edit. Zotterman, Y. London, Pergamon pp. 285.

Kare, M. R. and Maller, O., 1967. Taste and food intake in domesticated and jungle fowl. J. Nutri. 92, 191.

Kare, M. R. and Medway, W., 1959. Discrimination between carbohydrate by the fowl. Poult. Sci. 38, 1119.

Kare, M. R. and Pick, H. L., 1960. The influence of the sense of taste on feed and fluid consumption. Poult. Sci. 39, 697.

Kilsheimer, G. S., Weber, D. R., and Ashmore, J., 1960. Hepatic glucose production in developing chicken embryo. Pro. Soc. Exp. Biol. Med. 104, 515.

Kline, O. L., Keeman, J. A., Elvehjem, A. C., and Hart, E. B., 1932. Lactose in nutrition. J. Biol. Chem. 98, 121.

Knull, H. R. and Wells, W. W., 1973. Recovery from galactose-induced neurotoxicity in chick by the administration of glucose. J. Neurochemistry 20, 415.

Knull, H. R., Wells, W. W., and Kozak, J. P., 1972. Galactose toxicity in the chicks: Hyperosmolality or depressed brain energy reserves? Science 176, 815.

Kozak, L. P. and Wells, W. W., 1969. Effect of galactose on energy and phospholipid metabolism in the chick brain. Archs. Biochem. Biophys. 135, 371.

Kritchevsky, D., Kolman, R. R., Guttmacher, R. M., and Forbes, M., 1959. Influence of dietary carbohydrate and protein on serum and liver cholesterol in germ-free chickens. Archs. Biochem. Biophys. 85, 444.

Leveille, G. A., O'Hea, E. K., and Chakrabarty, K., 1968. In vivo lipogenesis in the domestic chicken. Pro. Soc. Exp. Biol. Med. 128, 398.

Lindenmaier, P. and Kare, M. R., 1959. The taste end-organs of the chicken. Poult. Sci. 38, 545.

Malone, J. I., Wells, H. J., and Segal, S., 1971. Galactose toxicity in the chicks: Hyperosmolality. Science 174, 952.

Masoro, E. J., Chaikoff, I. L., Chernick, S. S., and Felts, J. M., 1950. Previous nutritional state and glucose conversion to fatty acids in liver slices. J. Biol. Chem. 185, 845.

Monson, W. J., Dietrich, L. S., and Elvehjem, C. A., 1950. Studies on the effect of different carbohydrates on chick growth. Pro. Soc. Exp. Biol. Med. 75, 256.

Paul, G. and Hans, F., 1963. Fructose utilization in the growing chicken. Poult. Sci. 42, 1471.

Pearce, J., 1970. The effects of dietary fructose and glucose on hepatic lipogenesis in the domestic fowl. Int. J. Biochem. 1, 306.

Pick, H. L. and Kare, M. R., 1962. The effect of artificial cues on the measurement of taste preference in the chicken. J. Comp. Physiol. Psychol. 55, 342.

Rigdon, R. H., Couch, J. R., Creger, C. R., and Fergus, T. M., 1963. Galactose intoxication pathologic study in the chick. Experientia 19, 349.

Rutter, W. J., Krichevsky, P., Scott, H. M., and Hansen, R. G., 1953. The metabolism of lactose and galactose in the chick. Poult. Sci. 32, 706.

Schoenheimer, R. and Rittenberg, D., 1936. Deuterium as an indicator in the study of intermediary metabolism: VI Synthesis and destruction of fatty acids in the organism. J. Biol. Chem. 114, 381.

Schutz, H. G. and Pilgrim, F. J., 1957. Sweetness of various compounds and its measurement. Food Research 22, 206.

Shannon, D. W. F., Waring, J. J., and Brown, W. O., 1969. In "Energy Metabolism of Farm Animal" (K. L. Blaxter, J. Kielanowski and G. Thorbek, eds.) Oriel Press Limited, Newcastle upon Tyne. pp. 349.

Shaw, T. P., 1913. Digestion in chick. Am. J. Physiol. 31, 439.

Sondergaard, E., Prange, I., Dam, H., and Christensen, E., 1957. Uricemia and kidney damage in galactose-poisoned chicks. Acta. Path. Microbiol. Scandin. 40, 303.

Tukey, J. W., 1953. The problem of multiple comparisons. Mimeographed Notes. Princeton, N. J., Prince Univ. Math. Dept.

Yeh, Yu-Yan and Leveille, G. A., 1969. Effect of dietary protein on hepatic lipogenesis in the chick. J. Nutri. 98, 356.

APPENDIX

Appendix Table 1 Feed consumed by broiler-type chicks in Experiment 1.

Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	Group #	Feed consumed period (gm/bird/day) 1	2	3	4	5	gm/bird for 19 days
no glucose (tap water)	2700	1	13.0	22.7	33.5	41.7	58.9	619
		2	13.4	25.4	35.9	43.2	67.3	673
		mean	13.2	25.4	34.7	42.5	63.1	646
	3000	3	13.6	23.3	30.8	35.1	47.7	555
		4	14.3	24.9	35.7	39.9	53.9	621
		mean	14.0	24.1	33.3	37.5	50.8	588
	3300	5	12.2	21.5	31.8	33.9	57.5	570
		6	8.6	23.1	32.8	38.7	51.3	567
		mean	10.4	22.3	32.3	36.3	54.4	568
2%	2700	7	11.3	22.0	32.7	39.1	50.5	572
		8	11.1	20.3	29.6	40.0	54.9	569
		mean	11.2	21.2	31.2	39.6	52.7	570
	3000	9	12.3	21.9	32.3	39.3	53.2	583
		10	12.0	21.9	30.2	40.3	42.9	546
		mean	12.2	21.9	31.3	39.8	48.1	565
	3300	11	10.7	20.1	25.7	37.6	50.4	528
		12	13.1	22.5	25.0	38.9	51.4	552
		mean	11.9	21.3	25.4	38.3	50.9	540
4%	2700	13	13.1	21.6	30.5	36.3	50.8	558
		14	14.2	24.4	33.3	37.4	55.2	603
		mean	13.7	23.0	31.9	36.9	53.0	581
	3000	15	12.8	22.8	31.9	39.3	51.2	581
		16	10.4	19.8	27.6	34.0	48.4	512
		mean	11.6	21.3	29.8	36.7	49.8	547
	3300	17	11.4	20.4	28.2	37.5	47.9	534
		18	11.7	22.1	31.1	37.1	49.5	557
		mean	11.6	21.3	29.7	37.3	48.7	545
8%	2700	19	13.6	21.8	29.8	35.5	48.3	548
		20	11.1	21.4	29.3	35.9	42.4	518
		mean	12.4	21.6	29.6	35.7	45.4	533
	3000	21	8.9	17.6	26.0	31.8	42.3	464
		22	9.4	19.3	26.9	32.9	42.8	482
		mean	9.2	18.5	26.5	32.4	42.6	473
	3300	23	7.9	17.1	24.4	31.3	44.0	455
		24	9.4	17.6	25.4	30.4	41.5	456
		mean	8.7	17.4	24.9	30.9	42.8	455

Appendix Table 2 Feed consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Feed consumed (gm/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	12.5^{a}	23.5^{a}	33.4^{a}	38.8^{a}	56.1^{a}
2%	11.8^{ab}	21.5^{a}	29.3^{bc}	39.2^{a}	50.6^{b}
4%	12.3^{ab}	21.9^{a}	30.4^{ab}	36.9^{a}	50.5^{b}
8%	10.1^{b}	19.1^{b}	27.0^{c}	33.0^{b}	43.6^{c}

Appendix Table 3 Feed consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Feed consumed (gm/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	12.6^{a}	22.5^{a}	31.8^{a}	38.6^{a}	53.5^{a}
3000	11.7^{ab}	21.4^{ab}	30.2^{ab}	36.6^{ab}	47.8^{b}
3300	10.6^{b}	20.6^{b}	28.1^{b}	35.7^{b}	49.2^{ab}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 4 Water consumed by broiler-type chicks in Experiment 1.

Treatment: Glucose in drinking water (%)	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Water consumed: period (ml/bird/day) 1	2	3	4	5	ml/bird for 19 days
no glucose (tap water)	2700	1	36	52	73	109	135	1485
		2	33	56	76	112	140	1528
		mean	35	54	75	111	138	1507
	3000	3	36	56	84	98	116	1444
		4	36	56	84	98	116	1444
		mean	36	56	84	98	116	1444
	3300	5	39	59	84	118	131	1593
		6	36	51	70	104	115	1389
		mean	38	55	77	111	123	1491
2%	2700	7	40	53	71	85	113	1335
		8	40	55	78	92	124	1432
		mean	40	54	75	89	119	1384
	3000	9	36	54	77	90	127	1409
		10	30	44	61	81	108	1188
		mean	33	49	69	86	118	1299
	3300	11	37	48	68	107	123	1409
		12	37	48	68	107	123	1409
		mean	37	48	68	107	123	1409
4%	2700	13	39	57	80	103	124	1488
		14	40	55	79	98	135	1493
		mean	40	56	80	101	130	1491
	3000	15	33	48	67	88	110	1274
		16	40	51	79	87	118	1382
		mean	37	50	73	88	114	1328
	3300	17	38	50	81	99	120	1432
		18	38	50	81	99	120	1432
		mean	38	50	81	99	120	1432
8%	2700	19	38	58	82	98	123	1473
		20	38	58	82	98	123	1473
		mean	38	58	82	98	123	1473
	3000	21	35	53	76	91	116	1368
		22	32	48	69	86	121	1303
		mean	34	51	73	89	119	1336
	3300	23	46	51	76	98	129	1471
		24	39	55	73	95	124	1420
		mean	43	53	75	97	124	1446

Appendix Table 5 Water consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Water consumed (ml/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	36^{a}	55^{a}	79^{a}	107^{a}	126^{a}
2%	37^{a}	50^{a}	71^{a}	94^{b}	120^{a}
4%	38^{a}	52^{a}	78^{a}	96^{b}	121^{a}
8%	38^{a}	54^{a}	76^{a}	94^{b}	123^{a}

Appendix Table 6 Water consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Water consumed (ml/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	38^{ab}	56^{a}	78^{a}	99^{a}	127^{a}
3000	35^{a}	51^{b}	75^{a}	90^{b}	117^{b}
3300	39^{b}	52^{b}	75^{a}	103^{a}	123^{ab}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b, means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 7 Ratio of feed to water consumed by broiler-type chicks in Experiment 1.

Treatment		Group	Ratio of feed and water consumed					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period (gm/ml/bird/day)					gm/ml/bird for 19 days
			1	2	3	4	5	
no glucose (tap water)	2700	1	.36	.44	.46	.38	.44	.41
		2	.41	.41	.47	.39	.48	.43
		mean	.39	.43	.47	.39	.46	.42
	3000	3	.38	.42	.37	.36	.41	.38
		4	.40	.45	.43	.41	.47	.43
		mean	.39	.44	.40	.39	.44	.41
	3300	5	.31	.36	.38	.29	.44	.35
		6	.24	.45	.47	.37	.45	.39
		mean	.28	.41	.43	.33	.45	.37
2%	2700	7	.28	.42	.46	.46	.45	.41
		8	.28	.37	.38	.44	.44	.40
		mean	.28	.40	.42	.45	.45	.40
	3000	9	.34	.41	.42	.44	.40	.40
		10	.40	.50	.50	.50	.31	.45
		mean	.37	.46	.46	.47	.36	.43
	3300	11	.29	.42	.38	.35	.41	.37
		12	.35	.47	.37	.36	.42	.39
		mean	.32	.45	.38	.36	.42	.36
4%	2700	13	.34	.38	.38	.35	.41	.37
		14	.36	.44	.42	.38	.41	.40
		mean	.35	.41	.40	.37	.41	.39
	3000	15	.39	.48	.48	.45	.47	.45
		16	.26	.39	.35	.39	.41	.36
		mean	.33	.44	.42	.42	.44	.41
	3300	17	.30	.41	.35	.38	.40	.37
		18	.31	.44	.38	.38	.41	.38
		mean	.31	.43	.37	.38	.41	.38
8%	2700	19	.36	.38	.36	.36	.39	.37
		20	.29	.37	.36	.37	.35	.35
		mean	.33	.38	.36	.37	.37	.36
	3000	21	.25	.33	.34	.35	.37	.33
		22	.29	.40	.39	.38	.35	.37
		mean	.27	.37	.37	.37	.36	.35
	3300	23	.17	.34	.32	.32	.34	.30
		24	.24	.32	.35	.32	.34	.31
		mean	.21	.33	.34	.32	.34	.31

Appendix Table 8 Ratio of feed to water consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Ratio of feed and water consumed (gm/ml/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	$.35^{a}$	$.42^{ab}$	$.43^{a}$	$.37^{a}$	$.45^{a}$
2%	$.32^{ab}$	$.43^{a}$	$.42^{ab}$	$.42^{b}$	$.41^{a}$
4%	$.32^{ab}$	$.42^{a}$	$.39^{ab}$	$.39^{ab}$	$.42^{a}$
8%	$.27^{b}$	$.36^{b}$	$.35^{b}$	$.35^{a}$	$.36^{b}$

Appendix Table 9 Ratio of feed to water consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Ratio of feed and water consumed (gm/ml/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	$.33^{a}$	$.40^{a}$	$.41^{a}$	$.39^{a}$	$.42^{a}$
3000	$.34^{a}$	$.42^{a}$	$.41^{a}$	$.41^{a}$	$.40^{a}$
3300	$.28^{b}$	$.40^{a}$	$.37^{a}$	$.35^{b}$	$.40^{a}$

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 10 Dietary energy consumed by broiler-type chicks in Experiment 1.

Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	Group #	Dietary energy consumed period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no glucose (tap water)	2700	1	35.1	61.3	90.5	112.5	159.0	1677
		2	36.2	68.6	96.6	116.6	181.1	1817
		mean	35.7	65.0	93.7	114.6	170.1	1746
	3000	3	40.8	69.9	92.4	105.3	143.1	1663
		4	42.9	74.7	107.1	119.7	161.7	1863
		mean	41.9	72.3	99.8	112.5	152.4	1763
	3300	5	40.3	71.0	104.9	111.9	189.8	1882
		6	28.4	76.2	108.2	127.7	169.3	1870
		mean	34.4	73.6	106.6	119.8	179.6	1876
2%	2700	7	30.5	59.4	88.3	105.6	136.4	1544
		8	30.0	54.8	79.9	108.0	148.2	1535
		mean	30.3	57.1	84.1	106.8	142.3	1540
	3000	9	36.9	65.7	96.9	117.9	159.6	1748
		10	36.0	65.7	90.6	120.9	126.9	1634
		mean	36.5	65.7	93.8	119.4	143.3	1691
	3300	11	35.3	66.3	84.8	124.1	166.3	1741
		12	43.2	74.3	82.5	128.4	169.6	1822
		mean	39.3	70.3	83.7	126.3	168.0	1782
4%	2700	13	35.4	58.3	82.4	98.0	137.2	1508
		14	38.3	65.9	89.9	101.0	149.0	1627
		mean	36.9	62.1	86.2	99.5	143.1	1568
	3000	15	38.4	68.4	95.7	117.9	153.6	1742
		16	31.2	59.4	82.8	102.0	145.2	1537
		mean	34.8	63.9	89.3	110.0	149.4	1640
	3300	17	37.6	67.3	93.1	123.8	158.1	1762
		18	38.6	72.9	102.6	122.4	163.4	1836
		mean	38.1	70.1	97.9	123.1	160.8	1799
8%	2700	19	36.7	58.9	80.5	95.9	130.4	1479
		20	30.0	57.8	79.1	96.9	114.5	1399
		mean	33.4	58.4	79.8	96.4	122.5	1439
	3000	21	26.7	52.8	78.0	95.4	126.4	1391
		22	28.2	57.9	80.7	98.7	128.4	1447
		mean	27.5	55.4	79.4	97.1	127.4	1419
	3300	23	26.1	56.4	80.5	103.3	145.2	1501
		24	31.0	58.1	83.8	100,3	137.0	1504
		mean	28.6	57.3	82.2	101.8	141.1	1502

Appendix Table 11 Dietary energy consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Dietary energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	37.3[a]	70.3[a]	100.0[a]	115.6[a]	167.4[a]
2%	35.3[ab]	64.4[a]	87.2[bc]	117.5[a]	151.2[a]
4%	36.6[a]	65.4[a]	91.1[b]	110.8[a]	151.1[a]
8%	29.8[b]	57.0[b]	80.4[c]	98.4[b]	130.4[b]

Appendix Table 12 Dietary energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	34.0[a]	60.6[a]	85.9[a]	104.3[a]	144.6[a]
3000	35.1[a]	64.3[ab]	90.5[a]	109.7[a]	143.2[a]
3300	35.1[a]	67.8[b]	92.6[a]	117.7[b]	162.3[b]

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 13 "Water-energy" consumed by broiler-type chicks in Experiment 1.

Treatment		Group	"Water-energy" consumed					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no glucose (tap water)	2700	1	-	-	-	-	-	-
		2	-	-	-	-	-	-
		mean	-	-	-	-	-	-
	3000	3	-	-	-	-	-	-
		4	-	-	-	-	-	-
		mean	-	-	-	-	-	-
	3300	5	-	-	-	-	-	-
		6	-	-	-	-	-	-
		mean	-	-	-	-	-	-
2%	2700	7	2.6	3.5	4.7	5.6	7.5	88
		8	2.6	3.6	5.2	6.1	8.2	95
		mean	2.6	3.6	5.0	5.9	7.9	91
	3000	9	2.4	3.6	5.1	6.0	8.4	94
		10	2.0	2.9	4.0	5.4	7.1	79
		mean	2.2	3.3	4.6	5.7	7.8	86
	3300	11	2.4	3.2	4.5	7.1	8.1	93
		12	2.4	3.2	4.5	7.1	8.1	93
		mean	2.4	3.2	4.5	7.1	8.1	93
4%	2700	13	5.2	7.5	10.6	13.6	16.4	197
		14	5.3	7.3	10.5	13.0	17.9	198
		mean	5.3	7.4	10.6	13.3	17.2	198
	3000	15	4.4	6.4	8.9	11.7	14.6	169
		16	5.3	6.8	10.5	11.5	15.6	183
		mean	4.9	6.6	9.7	11.6	15.1	176
	3300	17	5.0	6.6	10.7	13.1	15.9	189
		18	5.0	6.6	10.7	13.1	15.9	189
		mean	5.0	6.6	10.7	13.1	15.9	189
8%	2700	19	10.1	15.4	21.7	26.0	32.6	391
		20	10.1	15.4	21.7	26.0	32.6	391
		mean	10.1	15.4	21.7	26.0	32.6	391
	3000	21	9.3	14.0	20.1	24.1	30.7	362
		22	8.5	12.7	18.3	22.8	32.0	345
		mean	8.9	13.4	19.2	23.5	31.4	354
	3300	23	12.2	13.5	21.1	26.0	34.2	390
		24	10.3	14.6	19.3	25.2	32.8	376
		mean	11.3	14.1	19.7	25.6	33.5	383

Appendix Table 14 "Water-energy" consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	"Water-energy" consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	-	-	-	-	-
2%	2.4^{a}	3.3^{a}	4.7^{a}	6.2^{a}	7.8^{a}
4%	5.0^{b}	6.9^{b}	10.3^{b}	12.7^{b}	16.1^{b}
8%	10.1^{c}	14.3^{c}	20.3^{c}	25.2^{c}	32.5^{c}

Appendix Table 15 "Water-energy" consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	6.0^{ab}	8.8^{a}	12.4^{a}	15.1^{a}	19.2^{a}
3000	5.3^{a}	7.7^{b}	11.1^{b}	13.6^{b}	18.1^{b}
3300	6.2^{b}	8.0^{b}	11.8^{ab}	15.4^{a}	19.2^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 16 Total energy consumed by broiler-type chicks in Experiment 1.

Treatment: Glucose in drink-water (%)	Treatment: Metabolizable energy in diet (kcal kg)	Group #	Total energy consumed: period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no glucose (tap water)	2700	1	35.1	61.3	90.5	112.5	159.0	1675
		2	36.2	68.6	96.9	116.6	181.1	1817
		mean	35.7	65.0	93.7	114.6	170.1	1746
	3000	3	40.8	69.9	92.4	105.3	143.1	1663
		4	42.9	74.7	107.1	119.7	161.7	1863
		mean	41.9	72.3	99.8	112.5	152.4	1763
	3300	5	40.3	71.0	104.9	111.9	189.8	1882
		6	28.4	76.2	108.2	127.7	169.3	1870
		mean	34.4	73.6	106.6	119.8	179.6	1876
2%	2700	7	33.1	62.9	93.0	111.2	143.9	1633
		8	32.6	58.4	85.1	114.1	156.4	1630
		mean	32.9	60.7	89.1	112.7	150.2	1631
	3000	9	39.4	69.3	102.0	123.9	168.0	1842
		10	37.0	68.6	94.6	126.3	134.0	1708
		mean	38.2	69.0	98.3	125.1	151.0	1775
	3300	11	37.7	69.5	89.3	131.2	174.4	1834
		12	45.6	77.5	87.0	135.5	177.7	1916
		mean	41.7	73.5	88.2	133.4	176.1	1875
4%	2700	13	40.6	65.8	93.0	116.6	153.6	1705
		14	43.6	73.2	100.4	114.0	116.9	1826
		mean	42.1	69.5	96.7	112.8	160.3	1765
	3000	15	42.8	74.8	104.6	129.6	168.2	1911
		16	36.5	66.2	93.3	113.5	160.8	1720
		mean	39.7	70.5	99.0	121.6	164.5	1816
	3300	17	42.6	73.9	103.8	136.9	174.0	1951
		18	43.6	79.5	113.3	135.5	179.3	2026
		mean	43.1	76.7	108.6	136.2	176.7	1988
8%	2700	19	46.8	74.3	102.2	121.9	153.0	1840
		20	40.1	73.2	100.8	122.9	147.1	1789
		mean	43.5	73.8	101.5	122.4	150.0	1814
	3000	21	36.0	66.8	98.1	119.5	157.1	1753
		22	36.7	70.6	99.0	121.5	160.4	1792
		mean	36.4	68.7	98.6	120.5	158.8	1773
	3300	23	38.3	69.9	100.6	129.3	179.4	1891
		24	41.3	72.7	103.1	125.5	169.8	1880
		mean	39.8	71.3	101.9	127.4	174.6	1886

Appendix Table 17 Total energy consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Total energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	37.3[a]	70.3[a]	100.0[ab]	115.6[a]	167.3[a]
2%	37.7[a]	67.7[a]	91.8[a]	123.7[a]	159.1[a]
4%	41.6[a]	72.2[a]	101.4[b]	123.5[a]	167.1[a]
8%	39.9[a]	71.3[a]	100.6[b]	123.4[a]	161.1[a]

Appendix Table 18 Total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energin in diet (kcal/kg)	Total energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	38.6[a]	67.2[a]	95.2[a]	115.6[a]	157.6[a]
3000	39.0[a]	70.1[ab]	98.9[a]	119.9[a]	156.7[a]
3300	39.7[a]	73.8[b]	101.3[a]	127.2[b]	176.7[b]

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a, b means, in vertical row, carrying different superscripts are significantly different (P< .05), according to the Tukey's test.

Appendix Table 19 Dietary energy consumed as percent of total energy consumed by broiler-type chicks in Experiment 1.

Treatment		Group	Dietary energy consumed as percent of total energy consumed (%)					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period					
			1	2	3	4	5	19-day trial
no glucose (tap water)	2700	1			100			
		2			100			
		mean			100			
	3000	3			100			
		4			100			
		mean			100			
	3300	5			100			
		6			100			
		mean			100			
2%	2700	7	92.1	94.4	94.9	95.0	94.8	94.6
		8	92.0	93.8	93.9	94.7	94.8	94.2
		mean	92.1	94.1	94.4	94.9	94.8	94.4
	3000	9	93.9	94.8	95.0	95.2	95.0	94.9
		10	97.3	95.8	95.8	95.7	94.7	95.6
		mean	95.6	95.3	95.4	95.5	94.9	95.3
	3300	11	93.6	95.4	95.0	94.6	95.4	94.9
		12	94.7	95.9	94.8	94.8	95.4	95.1
		mean	94.2	95.7	94.9	94.7	95.4	95.0
4%	2700	13	87.2	88.6	88.6	87.8	89.3	88.5
		14	87.8	90.0	89.5	88.6	89.3	89.1
		mean	87.5	89.3	89.1	88.2	89.3	88.8
	3000	15	89.7	91.4	91.5	91.0	91.3	90.1
		16	85.5	89.7	88.7	89.9	90.3	89.4
		mean	87.6	90.6	90.1	90.5	90.8	89.8
	3300	17	88.3	91.1	89.7	90.4	90.9	90.3
		18	88.5	91.7	90.6	90.3	91.1	90.7
		mean	88.4	91.4	90.2	90.4	91.0	90.5
8%	2700	19	78.4	79.3	82.3	78.7	85.2	79.2
		20	74.8	79.0	78.5	78.8	77.8	78.3
		mean	76.6	79.2	80.4	78.8	81.5	78.8
	3000	21	74.2	79.0	79.5	79.8	80.5	79.4
		22	76.8	82.0	81.5	81.2	80.0	80.7
		mean	75.5	80.5	80.5	80.5	80.3	80.1
	3300	23	68.1	80.7	80.0	79.9	80.9	79.5
		24	75.1	79.9	81.3	79.9	80.7	79.8
		mean	71.6	80.3	80.7	79.9	80.8	79.7

Appendix Table 20 Dietary energy consumed as percent of total energy consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Dietary energy consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	100	100	100	100	100
2%	94.1[a]	95.1[a]	94.9[a]	95.0[a]	95.0[a]
4%	87.9[b]	90.4[b]	89.8[b]	89.7[b]	90.4[b]
8%	74.7 [c]	80.0[c]	80.6[c]	79.7[c]	80.9[c]

Appendix Table 21 Dietary energy consumed as percent of total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	86.0[a]	88.2[a]	88.6[a]	88.1[a]	89.2[a]
3000	87.5[a]	89.6[ab]	89.5[a]	89.6[bc]	89.3[a]
3300	85.9[a]	90.0[b]	89.2[a]	89.0[c]	89.8[a]

* represented the number of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different (P< .05), according to the Tukey's test.

Appendix Table 22 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks in Experiment 1.

Treatment		Group	"Water-energy" consumed as percent of total energy consumed (%)					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period					
			1	2	3	4	5	19-day trial
no glucose (tap water)	2700	1			0			
		2			0			
		mean			0			
	3000	3			0			
		4			0			
		mean			0			
	3300	5			0			
		6			0			
		mean			0			
2%	2700	7	7.9	5.6	5.1	5.0	5.2	5.4
		8	8.0	6.2	6.1	5.3	5.2	5.8
		mean	7.9	5.9	5.6	5.1	5.2	5.6
	3000	9	6.1	5.2	5.0	4.8	5.0	5.1
		10	2.7	4.2	4.2	4.3	5.3	4.4
		mean	4.4	4.7	4.6	4.5	5.1	4.7
	3300	11	6.4	4.6	5.0	5.4	4.6	5.1
		12	5.3	4.1	5.2	5.2	4.6	4.9
		mean	5.8	4.3	5.1	5.3	4.6	5.0
4%	2700	13	12.8	11.4	11.4	12.2	10.7	11.5
		14	12.2	10.0	10.5	11.4	10.7	10.9
		mean	12.5	10.7	10.9	11.8	10.7	11.2
	3000	15	10.3	8.6	8.5	9.0	8.7	9.9
		16	14.5	10.3	11.3	10.1	9.7	10.6
		mean	12.4	9.4	9.9	9.5	8.2	10.2
	3300	17	11.7	8.9	10.3	9.6	9.1	9.7
		18	11.5	8.3	9.4	9.7	8.9	9.3
		mean	11.6	8.6	9.8	9.6	9.0	9.5
8%	2700	19	21.6	20.7	17.7	21.3	14.8	20.7
		20	25.2	21.0	21.5	21.2	22.2	21.7
		mean	23.4	20.8	19.6	21.2	18.5	21.2
	3000	21	25.8	21.0	20.5	20.2	19.5	20.6
		22	23.2	18.0	18.5	18.8	20.0	19.3
		mean	24.5	19.5	19.5	19.5	19.7	19.9
	3300	23	31.9	19.3	20.0	20.1	19.1	20.5
		24	24.9	20.1	18.7	20.1	19.3	20.2
		mean	28.4	19.7	19.3	20.1	19.2	20.3

Appendix Table 23 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	"Water-energy" consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	0	0	0	0	0
2%	5.9^{a}	4.9^{a}	5.1^{a}	5.0^{a}	5.0^{a}
4%	12.1^{b}	9.6^{b}	10.2^{b}	10.3^{b}	9.6^{b}
8%	25.3^{c}	20.0^{c}	19.4^{c}	20.3^{c}	19.1^{c}

Appendix Table 24 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	14.0^{a}	11.8^{a}	11.4^{a}	11.9^{a}	10.8^{a}
3000	12.5^{a}	10.4^{ab}	10.5^{a}	10.4^{bc}	10.7^{a}
3300	14.1^{a}	10.0^{b}	10.8^{a}	11.0^{c}	10.2^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 25 Body weight of broiler-type chicks in Experiment 1.

Treatment		Group	Body weight gain					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period (gm/bird/day)					gm/bird for 19 days
			1	2	3	4	5	
no glucose (tap water)	2700	1	10.5	15.1	20.0	29.7	30.0	391
		2	11.3	16.1	22.4	28.3	19.5	371
		mean	10.9	15.6	21.2	29.0	24.8	381
	3000	3	10.8	15.4	20.3	22.5	27.8	359
		4	11.4	17.5	25.2	25.6	21.2	382
		mean	11.1	16.5	22.8	24.1	24.5	371
	3300	5	10.6	17.2	24.3	27.2	35.9	425
		6	11.5	17.1	23.4	29.3	34.8	431
		mean	11.1	17.2	24.1	28.3	35.4	428
2%	2700	7	10.3	14.5	22.0	23.7	26.3	361
		8	19.9	15.3	22.8	20.6	29.6	363
		mean	10.1	14.9	22.4	22.2	28.0	362
	3000	9	9.1	16.3	23.1	25.5	32.2	393
		10	9.6	14.9	21.8	23.9	22.3	348
		mean	9.4	15.9	22.5	24.7	27.3	370
	3300	11	11.8	15.6	16.1	33.4	30.9	400
		12	12.4	16.8	16.8	32.4	21.0	377
		mean	12.1	16.2	16.5	32.9	25.8	389
4%	2700	13	9.8	15.2	22.2	25.8	25.5	369
		14	12.8	17.2	23.2	26.1	25.0	392
		mean	11.3	16.2	22.8	26.0	25.3	380
	3000	15	11.3	15.7	23.7	27.2	28.6	397
		16	10.1	15.0	20.5	23.4	26.9	357
		mean	10.7	15.4	22.1	25.3	27.8	377
	3300	17	10.4	16.6	24.8	26.1	32.0	408
		18	11.1	17.8	25.7	28.9	31.2	428
		mean	10.8	17.2	25.3	27.5	31.6	418
8%	2700	19	9.9	16.6	22.6	25.8	23.2	369
		20	9.6	16.1	22.2	24.1	14.3	331
		mean	9.8	16.4	22.4	25.0	18.8	350
	3000	21	8.1	13.7	20.4	23.2	35.4	368
		22	9.0	14.8	20.6	24.6	24.3	349
		mean	8.6	14.3	20.5	23.9	29.9	358
	3300	23	7.0	13.7	21.1	26.3	31.2	366
		24	8.8	13.7	22.0	25.8	27.8	367
		mean	7.9	14.0	21.6	26.1	29.5	367

Appendix Table 26 Body weight gain of broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Body weight gain (gm/bird/day) period 1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	11.0^{a}	16.4^{a}	22.7^{a}	27.1^{a}	28.2^{a}
2%	10.5^{a}	15.6^{ab}	20.4^{b}	26.6^{a}	27.1^{a}
4%	10.9^{a}	16.3^{a}	23.4^{a}	26.3^{a}	28.2^{a}
8%	8.7^{b}	14.9^{b}	21.5^{ab}	25.0^{a}	26.0^{a}

Appendix Table 27 Body weight gain of broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Body weight gain (gm/bird/day) period 1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	10.5^{a}	15.8^{a}	22.2^{a}	25.5^{a}	24.2^{a}
3000	9.9^{a}	15.4^{a}	22.0^{a}	24.5^{a}	27.3^{a}
3300	10.5^{a}	16.1^{a}	21.8^{a}	28.7^{b}	30.6^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means , in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 28 Feed efficiency by broiler-type chicks in Experiment 1.

Treatment		Group	Feed efficiency					
Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	#	period (gm feed/gm bird/day)					gm feed/gm bird for 19 days
			1	2	3	4	5	
no glucose (tap water)	2700	1	1.24	1.50	1.78	1.40	1.96	1.56
		2	1.19	1.57	1.60	1.53	3.45	1.78
		mean	1.22	1.54	1.69	1.49	2.71	1.67
	3000	3	1.26	1.51	1.52	1.56	1.72	1.50
		4	1.25	2.42	1.42	1.56	2.54	1.57
		mean	1.26	1.47	1.47	1.56	2.13	1.54
	3300	5	1.15	1.25	1.31	1.25	1.60	1.30
		6	0.94	1.35	1.38	1.32	1.47	1.28
		mean	1.04	1.30	1.34	1.28	1.54	1.29
2%	2700	7	1.10	1.52	1.49	1.65	1.92	1.52
		8	1.12	1.33	1.30	1.94	1.85	1.49
		mean	1.11	1.42	1.39	1.80	1.89	1.51
	3000	9	1.35	1.34	1.40	1.54	1.65	1.45
		10	1.25	1.47	1.39	1.69	1.92	1.52
		mean	1.30	1.41	1.39	1.61	1.79	1.49
	3300	11	0.91	1.29	1.60	1.13	1.63	1.29
		12	1.06	1.34	1.49	1.20	2.45	1.46
		mean	0.98	1.31	1.54	1.16	2.04	1.38
4%	2700	13	1.34	1.42	1.37	1.41	1.99	1.48
		14	1.11	1.42	1.43	1.43	2.21	1.48
		mean	1.22	1.42	1.40	1.42	2.10	1.48
	3000	15	1.13	1.45	1.35	1.44	1.79	1.41
		16	1.03	1.32	1.35	1.45	1.80	1.37
		mean	1.08	1.39	1.35	1.45	1.79	1.39
	3300	17	1.10	1.23	1.14	1.44	1.50	1.27
		18	1.05	1.24	1.21	1.28	1.59	1.26
		mean	1.08	1.24	1.17	1.36	1.54	1.27
8%	2700	19	1.37	1.31	1.32	1.38	2.07	1.46
		20	1.16	1.33	1.32	1.49	2.97	1.58
		mean	1.26	1.32	1.32	1.43	2.52	1.52
	3000	21	1.10	1.28	1.27	1.37	1.19	1.24
		22	1.04	1.30	1.60	1.34	1.76	1.39
		mean	1.07	1.29	1.44	1.35	1.48	1.32
	3300	23	1.13	1.25	1.16	1.19	1.41	1.22
		24	1.07	1.23	1.15	1.18	1.49	1.21
		mean	1.10	1.24	1.16	1.18	1.45	1.22

Appendix Table 29 Feed efficiency by broiler-type chicks given different levels of glucose in drinking water in Experiment 1.

Glucose in drinking water (%)	Feed efficiency (gm feed/ gm bird/day) period 1	2	3	4	5
	(6)*	(6)	(6)	(6)	(6)
no glucose (tap water)	1.17^{a}	1.43^{a}	1.50^{a}	1.44^{ab}	2.12^{a}
2%	1.13^{a}	1.38^{ab}	1.45^{ab}	1.53^{a}	1.90^{a}
4%	1.13^{a}	1.35^{ab}	1.31^{b}	1.41^{ab}	1.81^{a}
8%	1.15^{a}	1.28^{b}	1.30^{b}	1.33^{b}	1.82^{a}

Appendix Table 30 Feed efficiency by broiler-type chicks fed different levels of dietary energy in Experiment 1.

Metabolizable energy in diet (kcal/kg)	Feed efficiency (gm feed/gm bird/day) period 1	2	3	4	5
	(8)*	(8)	(8)	(8)	(8)
2700	1.20^{a}	1.43^{a}	1.45^{a}	1.53^{a}	2.30^{a}
3000	1.18^{a}	1.39^{a}	1.41^{ab}	1.49^{a}	1.80^{ab}
3300	1.05^{b}	1.27^{b}	1.31^{b}	1.25^{b}	1.64^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means, in vertical row, carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Appendix Table 31 Liver weight and percent liver weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 1.

Glucose in drinking water (%)	Metabolizable energy in diet (kcal/kg)	Group #	Liver weight (gm/bird)	Liver weight as percent body weight (%)
	2700	1	16.8	3.9
		2	20.6	4.9
		mean	18.7	4.4
no glucose (tap water)	3000	3	14.4	3.5
		4	16.5	3.8
		mean	15.4	3.7
	3300	5	17.8	3.8
		6	16.9	3.6
		mean	17.4	3.7
	2700	7	16.8	4.2
		8	17.1	4.2
		mean	17.0	4.2
2%	3000	9	16.8	3.8
		10	15.5	4.0
		mean	16.1	3.9
	3300	11	15.4	3.5
		12	17.1	4.0
		mean	16.2	3.8
	2700	13	16.2	4.0
		14	19.0	4.3
		mean	17.6	4.1
4%	3000	15	17.2	3.9
		16	18.0	4.6
		mean	17.6	4.2
	3300	17	17.5	3.9
		18	17.7	3.7
		mean	17.6	3.8
	2700	19	18.3	4.4
		20	17.2	4.6
		mean	17.7	4.5
8%	3000	21	15.9	3.9
		22	16.3	4.2
		mean	16.1	4.0
	3300	23	16.6	4.1
		24	16.0	3.9
		mean	16.3	4.0

Appendix Table 32 Pancreatic weight and percent of pancreatic weight of broiler-type chicks sacrificed at the end of 19-day trial in Experiment 1.

Treatment: Glucose in drinking water (%)	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Pancreatic weight (gm/bird)	Pancreatic weight as percent of body weight (%)
	2700	1	1.8	.42
		2	2.6	.62
		mean	2.2	.52
no glucose	3000	3	1.4	.35
		4	2.1	.48
		mean	1.7	.42
	3300	5	2.2	.46
		6	2.2	.47
		mean	2.2	.47
	2700	7	1.6	.40
		8	1.8	.45
		mean	1.7	.43
2%	3000	9	1.8	.41
		10	1.6	.42
		mean	1.7	.42
	3300	11	2.1	.48
		12	1.9	.44
		mean	2.0	.46
	2700	13	2.1	.50
		14	2.4	.54
		mean	2.2	.52
4%	3000	15	2.2	.49
		16	1.8	.46
		mean	2.0	.48
	3300	17	1.7	.38
		18	2.0	.42
		mean	1.8	.40
	2700	19	1.7	.42
		20	1.8	.47
		mean	1.8	.45
8%	3000	21	1.7	.41
		22	1.7	.44
		mean	1.7	.43
	3300	23	1.8	.44
		24	1.8	.45
		mean	1.8	.45

Appendix Table 33 Feed consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Feed consumed: period (gm/bird/day) 1	2	3	4	5	Feed consumed: gm/bird for 19 days
no carbohydrate (tap water)	2700	1	9.1	15.7	18.9	32.4	45.0	439
		2	9.5	15.5	25.9	32.8	45.3	471
		mean	9.3	15.6	22.4	32.6	45.1	455
	3300	3	8.8	13.1	20.8	26.6	50.5	429
		4	8.8	14.7	21.0	21.9	27.8	349
		mean	8.8	13.9	20.9	24.3	39.2	389
4% glucose	2700	5	8.4	14.0	21.3	33.3	54.9	473
		6	9.4	16.1	26.7	31.4	47.5	477
		mean	8.9	15.1	24.0	32.4	51.2	475
	3300	7	8.6	13.4	23.0	22.0	36.8	378
		8	9.1	12.9	20.5	20.8	33.1	353
		mean	8.9	13.2	21.8	21.4	35.0	366
4% galactose	2700	9	6.6	11.8	18.6	23.5	36.4	351
		10	7.4	12.5	19.1	17.8	28.8	314
		mean	7.0	12.2	18.9	20.7	32.6	333
	3300	11	6.9	13.5	20.4	24.5	37.7	374
		12	8.8	10.8	16.7	16.2	39.7	329
		mean	7.9	12.1	18.6	20.4	38.7	352
4% fructose	2700	13	7.4	14.0	22.6	28.0	40.7	410
		14	7.8	13.1	18.1	26.0	29.3	348
		mean	7.6	13.6	20.4	27.0	35.0	379
	3300	15	4.0	14.9	21.3	25.9	37.7	378
		16	6.2	13.3	20.9	25.3	40.1	383
		mean	5.1	14.1	21.1	25.6	38.9	381
4% sucrose	2700	17	9.7	14.9	22.8	28.6	41.1	428
		18	10.1	15.6	24.5	31.1	44.5	459
		mean	9.9	15.3	23.7	29.9	42.8	443
	3300	19	8.7	16.3	24.1	30.5	46.0	456
		20	8.1	15.5	22.5	27.0	41.5	416
		mean	8.4	15.9	23.3	28.8	43.8	436
4% lactose	2700	21	8.1	16.6	24.3	35.1	56.3	505
		22	10.1	15.1	23.3	30.0	48.8	462
		mean	9.1	15.9	23.8	32.7	52.6	484
	3300	23	6.9	15.2	26.0	33.3	49.0	473
		24	7.7	14.0	23.8	30.1	43.0	431
		mean	7.3	14.6	24.9	31.7	46.0	452

Appendix Table 34 Feed consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Feed consumed (gm/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	9.1^{a}	14.8^{a}	21.7^{ab}	28.4^{a}	42.2^{a}
4% glucose	8.9^{a}	14.1^{ab}	22.9^{ab}	26.9^{ab}	43.1^{a}
4% galactose	7.4^{ab}	12.2^{b}	18.7^{a}	20.5^{b}	35.7^{a}
4% fructose	6.4^{b}	13.8^{ab}	20.7^{ab}	26.3^{ab}	37.0^{a}
4% sucrose	9.2^{a}	15.6^{a}	23.5^{ab}	29.3^{a}	43.3^{a}
4% lactose	8.2^{ab}	15.2^{a}	24.4^{b}	32.2^{a}	49.3^{a}

Appendix Table 35 Feed consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet	Feed consumed (gm/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	8.6^{a}	14.6^{a}	22.2^{a}	29.2^{a}	43.2^{a}
3300	7.7^{b}	14.0^{a}	21.8^{a}	25.3^{b}	40.2^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means, in vertical row, carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Appendix Table 36 Water consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Water consumed: period (ml/bird/day) 1	2	3	4	5	Water consumed: ml/bird for 19 days
no carbohydrate (tap water)	2700	1	23.4	37.9	67.5	73.8	108.1	1135
		2	25.6	36.6	64.8	90.2	119.6	1228
		mean	24.5	36.3	66.2	82.0	113.9	1182
	3300	3	22.3	35.5	71.1	74.5	83.3	1064
		4	25.9	35.5	62.1	63.8	68.6	955
		mean	24.1	35.5	66.6	69.2	75.9	1009
4% glucose	2700	5	25.8	41.1	86.3	88.4	118.1	1321
		6	31.9	49.3	88.4	109.8	141.9	1543
		mean	28.9	45.2	87.4	99.1	130.0	1432
	3300	7	31.6	43.5	88.0	107.3	114.6	1425
		8	30.9	43.5	70.8	79.8	94.2	1183
		mean	31.3	43.5	79.4	93.6	104.4	1304
4% galactose	2700	9	30.4	32.6	77.5	80.3	115.4	1229
		10	40.2	41.5	107.5	109.4	120.0	1554
		mean	35.3	37.0	92.5	94.9	117.7	1392
	3300	11	28.1	41.9	78.5	84.3	126.7	1311
		12	35.9	38.5	69.6	72.6	96.0	1154
		mean	32.0	40.2	74.1	78.5	111.4	1233
4% fructose	2700	13	31.3	36.5	58.8	71.4	96.3	1081
		14	26.3	41.0	73.2	85.2	122.6	1271
		mean	28.8	38.7	66.0	78.3	109.5	1176
	3300	15	26.2	36.3	64.3	69.1	90.0	1054
		16	29.7	41.4	68.8	72.3	100.6	1151
		mean	28.0	38.8	66.6	70.7	92.3	1102
4% sucrose	2700	17	32.3	45.1	85.8	91.4	134.6	1422
		18	38.0	49.5	90.8	92.3	123.8	1453
		mean	35.2	47.3	88.3	91.9	129.2	1438
	3300	19	27.7	35.2	68.4	87.3	108.1	1199
		20	31.1	39.6	84.4	74.2	118.8	1274
		mean	29.4	37.4	76.4	80.8	113.5	1236
4% lactose	2700	21	33.7	58.1	109.3	115.4	114.0	1698
		22	35.9	54.3	100.4	102.2	140.2	1592
		mean	34.8	56.2	104.9	108.8	142.1	1645
	3300	23	27.1	50.1	99.2	106.7	146.9	1573
		24	27.4	41.4	82.5	93.2	135.5	1385
		mean	27.3	45.6	90.9	100.0	141.2	1479

Appendix Table 37 Water consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Water consumed (ml/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	24^{a}	36^{a}	66^{a}	76^{a}	95^{a}
4% glucose	30^{ab}	44^{ab}	83^{ab}	96^{ab}	117^{ab}
4% galactose	34^{b}	39^{ab}	83^{ab}	87^{ab}	115^{a}
4% fructose	28^{ab}	39^{ab}	66^{a}	75^{a}	102^{a}
4% sucrose	32^{b}	42^{ab}	82^{ab}	86^{ab}	121^{ab}
4% lactose	31^{ab}	51^{b}	98^{b}	104^{b}	142^{b}

Appendix Table 38 Water consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Water consumed (ml/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	31^{a}	44^{a}	84^{a}	92^{a}	124^{a}
3300	29^{a}	40^{b}	76^{b}	82^{b}	107^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a, b means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 39 Ratio of feed to water consumed by broiler-type chicks in Experiment 2.

Treatment		Group	Ratio of feed and water consumed					
Carbo-hydrate in drinking water	Metabolizable energy in diet (kcal/kg)	#	period (gm/ml/bird day)					gm/ml/bird for 19 days
			1	2	3	4	5	
no carbo-hydrate (tap water)	2700	1	.39	.41	.28	.44	.42	.39
		2	.37	.42	.40	.36	.38	.38
		mean	.38	.42	.34	.40	.40	.38
	3300	3	.39	.37	.29	.36	.61	.40
		4	.34	.41	.34	.34	.41	.37
		mean	.37	.39	.31	.35	.51	.39
4% glucose	2700	5	.33	.34	.25	.37	.46	.36
		6	.29	.33	.30	.28	.33	.31
		mean	.31	.34	.28	.33	.40	.33
	3300	7	.27	.31	.26	.21	.44	.27
		8	.29	.30	.29	.26	.35	.30
		mean	.28	.31	.27	.24	.40	.28
4% galac-tose	2700	9	.22	.36	.24	.29	.32	.29
		10	.18	.30	.18	.16	.24	.20
		mean	.20	.33	.21	.23	.28	.24
	3300	11	.25	.32	.26	.29	.30	.29
		12	.25	.28	.24	.22	.41	.29
		mean	.25	.30	.25	.26	.36	.29
4% fructose	2700	13	.24	.38	.38	.39	.42	.38
		14	.30	.32	.25	.31	.24	.27
		mean	.27	.35	.31	.35	.33	.32
	3300	15	.15	.41	.33	.37	.42	.36
		16	.21	.32	.30	.35	.40	.33
		mean	.18	.37	.32	.36	.41	.35
4% sucrose	2700	17	.30	.33	.27	.31	.31	.30
		18	.27	.32	.27	.34	.36	.32
		mean	.28	.32	.27	.32	.33	.31
	3300	19	.31	.46	.35	.35	.43	.38
		20	.26	.39	.27	.36	.35	.33
		mean	.29	.43	.31	.36	.39	.35
4% lactose	2700	21	.24	.29	.22	.30	.39	.30
		22	.28	.28	.23	.30	.35	.29
		mean	.26	.29	.23	.30	.37	.29
	3300	23	.25	.30	.26	.31	.33	.30
		24	.28	.34	.29	.32	.32	.31
		mean	.27	.32	.27	.32	.33	.31

Appendix Table 40 Ratio of feed to water consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Ratio of feed and water consumed (gm/ml/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	.37[a]	.40[a]	.33[a]	.38[ac]	.46[a]
4% glucose	.30[b]	.32[b]	.28[a]	.28[abc]	.40[a]
4% galactose	.23[c]	.32[b]	.23[a]	.24[b]	.32[a]
4% fructose	.23[c]	.36[ab]	.32[a]	.36[c]	.37[a]
4% sucrose	.29[bc]	.38[ab]	.29[a]	.34[c]	.36[a]
4% lactose	.26[bc]	.30[b]	.25[a]	.31[bc]	.35[a]

Appendix Table 41 Ratio of feed to water consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Ratio of feed and water consumed (gm/ml/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	.28[a]	.34[a]	.27[a]	.32[a]	.35[a]
3300	.27[a]	.35[a]	.29[a]	.31[a]	.40[a]

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Appendix Table 42 Dietary energy consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Dietary energy consumed period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no carbohydrate (tap water)	2700	1	24.6	42.4	51.0	87.5	121.4	1186
		2	25.7	41.9	69.9	88.6	122.3	1271
		mean	25.2	42.2	60.5	88.1	121.9	1229
	3300	3	29.0	43.2	68.6	87.8	166.7	1415
		4	29.0	48.5	69.3	72.3	91.7	1152
		mean	29.0	45.9	69.0	80.1	129.2	1284
4% glucose	2700	5	22.7	37.8	57.5	89.9	148.2	1276
		6	25.4	43.5	72.1	84.8	128.3	1288
		mean	24.1	40.7	64.8	87.4	138.3	1282
	3300	7	28.4	44.2	75.9	72.6	121.4	1249
		8	30.0	42.6	67.7	68.6	109.2	1163
		mean	29.2	43.4	71.8	70.6	115.3	1206
4% galactose	2700	9	17.8	31.9	50.2	63.5	98.3	949
		10	20.0	33.8	51.6	48.1	77.8	847
		mean	18.9	32.9	50.9	55.8	88.1	898
	3300	11	22.8	44.6	67.3	80.9	124.4	1236
		12	29.0	35.6	55.1	53.5	131.0	1086
		mean	25.9	40.1	61.2	67.2	127.7	1161
4% sucrose	2700	13	20.0	37.8	61.0	75.6	109.9	1107
		14	21.1	35.4	48.9	70.2	79.1	939
		mean	20.6	36.6	55.0	72.9	94.5	1023
	3300	15	13.2	49.2	70.3	85.5	124.4	1246
		16	20.5	43.9	69.0	83.5	132.3	1265
		mean	16.9	46.6	69.7	84.5	128.4	1255
4% sucrose	2700	17	26.2	40.2	61.6	77.2	111.0	1154
		18	27.3	42.1	66.2	84.0	120.2	1239
		mean	26.8	41.2	63.9	80.6	115.6	1197
	3300	19	28.7	53.8	79.5	100.7	151.8	1506
		20	26.7	51.2	74.3	89.1	137.0	1376
		mean	27.7	52.5	76.9	94.9	144.4	1441
4% lactose	2700	21	21.9	44.8	65.6	94.8	152.0	1364
		22	27.3	40.5	62.9	81.5	131.8	1244
		mean	24.6	42.7	64.3	88.2	141.9	1304
	3300	23	22.8	50.2	85.8	110.0	161.7	1560
		24	25.4	46.2	78.5	99.3	141.9	1423
		mean	24.1	48.2	82.2	104.7	151.8	1492

Appendix Table 43 Dietary energy consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Dietary energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	27.1^{a}	44.0^{a}	64.7^{ab}	84.1^{a}	125.5^{a}
4% glucose	26.6^{a}	42.0^{ab}	68.3^{ab}	79.0^{ab}	126.8^{a}
4% galactose	22.4^{ab}	36.5^{b}	56.1^{a}	61.5^{b}	107.9^{a}
4% fructose	18.7^{b}	41.6^{ab}	62.3^{ab}	78.7^{ab}	111.4^{a}
4% sucrose	27.2^{a}	46.8^{a}	70.4^{ab}	87.7^{a}	130.0^{a}
4% lactose	24.4^{a}	45.4^{a}	73.2^{b}	96.4^{a}	146.9^{a}

Appendix Table 44 Dietary energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	23.3^{a}	39.3^{a}	59.9^{a}	78.8^{a}	116.7^{a}
3300	25.5^{b}	46.1^{b}	71.8^{b}	83.6^{a}	132.8^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 45 Metabolizable energy of various sugars used in Experiment 2.

Item	Monosaccharide ($C_6H_{12}O_6$, M.W. 180)			Disaccharide ($C_{12}H_{22}O_{11}$, M.W. 342)	
	glucose	galactose*	fructose	sucrose	lactose
Gross energy/ mole	673.0	670.7	675.6	1349.6	1350.8
Gross energy/gm	3.74	3.73	3.75	3.95	3.95
% Metabolize	97.3	-	95.5	96.4	44.5
M.E./gm (dry weight)	3.64	-	3.58	3.81	1.76
% moisture	0.2	0.3	0.08	0.03	4.8
M.E./gm (as used)	3.63	-	3.58	3.81	1.68
M.E./ ml of the 4% sugar solution	0.145	-	0.143	0.152	0.067

* No available data on the % metabolize of galactose in chicks, thus the M.E. of galactose was not known.

Appendix Table 46 "Water-energy" consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	"Water-energy" consumed: period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no carbohydrate (tap water)	2700	1			0			0
		2			0			0
		mean			0			0
	3300	3			0			0
		4			0			0
		mean			0			0
4% glucose	2700	5	3.7	6.0	12.5	12.8	17.1	191
		6	4.6	7.1	12.8	15.9	20.6	223
		mean	4.2	6.6	12.7	14.4	18.9	207
	3300	7	4.6	6.3	12.8	15.6	16.6	207
		8	4.5	6.3	10.3	11.6	13.7	172
		mean	4.6	6.3	11.6	13.6	15.2	192
4% galactose	2700	9	No available data on M.E. of galactose in chicks					
		10						
		mean						
	3300	11						
		12						
		mean						
4% fructose	2700	13	4.5	5.2	8.4	10.2	13.8	155
		14	3.8	5.9	4.5	12.2	17.5	182
		mean	4.2	5.6	9.5	11.2	15.7	168
	3300	15	3.4	5.2	9.2	9.9	12.9	151
		16	4.2	5.9	9.8	10.3	14.4	164
		mean	4.0	5.6	9.5	10.1	13.7	157
4% sucrose	2700	17	4.9	6.9	13.0	13.9	20.5	216
		18	5.8	7.5	13.8	14.0	18.8	221
		mean	5.4	7.2	13.4	14.0	19.7	219
	3300	19	4.2	5.4	10.4	13.3	16.4	182
		20	4.7	6.0	12.8	11.3	18.1	194
		mean	4.5	5.7	11.6	12.3	17.3	188
4% lactose	2700	21	2.3	3.9	7.3	7.7	9.6	114
		22	2.4	3.6	6.7	6.8	8.8	104
		mean	2.4	3.8	7.0	7.3	9.2	109
	3300	23	1.8	3.4	6.6	7.1	9.8	105
		24	1.8	2.8	5.5	6.2	9.1	93
		mean	1.8	3.1	6.1	6.7	9.5	99

Appendix Table 47 "Water-energy" consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	"Water-energy" consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	-	-	-	-	-
4% glucose	4.4^{ab}	6.4^{a}	12.1^{a}	14.0^{a}	17.0^{ab}
4% galactose	No available data on M.E. of galactose in chicks				
4% fructose	4.1^{a}	5.6^{a}	9.5^{b}	10.7^{b}	14.7^{b}
4% sucrose	4.9^{b}	6.5^{a}	12.5^{a}	13.1^{ab}	18.5^{a}
4% lactose	2.1^{c}	3.4^{b}	6.5^{c}	7.0^{c}	9.3^{c}

Appendix Table 48 "Water-energy" consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	4.0^{a}	5.8^{a}	10.6^{a}	11.7^{a}	15.8^{a}
3300	3.7^{a}	5.2^{b}	9.7^{a}	10.7^{a}	13.9^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 49 Total energy consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinkwater	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Total energy consumed period (kcal/bird/day) 1	2	3	4	5	kcal/bird for 19 days
no carbohydrate (tap water)	2700	1	24.6	42.4	51.0	87.5	121.4	1186
		2	25.7	41.9	69.9	88.6	122.3	1271
		mean	25.2	42.2	60.5	88.1	121.9	1229
	3300	3	29.0	43.2	68.6	87.8	166.7	1415
		4	29.0	48.5	69.3	72.3	91.7	1152
		mean	29.0	45.9	69.0	80.1	129.2	1285
4% glucose	2700	5	26.4	43.8	70.0	102.7	165.3	1468
		6	30.0	50.6	84.9	100.7	148.9	1512
		mean	28.2	47.2	77.5	101.7	157.1	1490
	3300	7	33.0	50.5	88.7	88.2	138.0	1456
		8	34.5	48.9	78.0	80.2	122.9	1335
		mean	33.8	49.7	83.4	84.2	130.5	1396
4% galactose	2700	9	No available data on M. E. of galactose in chicks					
		10						
		mean						
	3300	11						
		12						
		mean						
4% fructose	2700	13	24.5	43.0	69.4	85.8	123.7	1262
		14	24.9	41.3	59.4	82.4	96.6	1122
		mean	24.7	42.2	64.4	84.1	110.2	1192
	3300	15	16.9	54.4	79.5	95.4	137.3	1397
		16	24.7	49.8	78.8	93.8	146.7	1429
		mean	20.8	52.1	79.2	94.6	142.0	1413
4% sucrose	2700	17	31.1	47.1	74.6	91.1	131.5	1370
		18	33.1	49.6	80.0	98.0	139.0	1460
		mean	32.1	48.4	77.3	94.6	135.3	1415
	3300	19	32.9	59.2	89.9	114.0	168.2	1689
		20	31.4	57.2	87.1	100.4	155.0	1569
		mean	32.2	58.2	88.5	107.2	161.6	1629
4% lactose	2700	21	24.2	48.7	72.9	102.5	161.6	1478
		22	29.7	44.1	69.6	88.3	140.6	1349
		mean	27.0	46.4	71.3	95.4	151.1	1413
	3300	23	24.6	53.6	92.4	117.0	171.5	1665
		24	27.2	49.0	84.0	105.5	151.0	1516
		mean	25.9	51.3	88.2	111.3	161.3	1590

Appendix Table 50 Total energy consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Total energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	27.1^{abc}	44.0^{a}	64.7^{a}	84.1^{a}	125.5^{a}
4% glucose	31.0^{bc}	48.5^{ab}	80.4^{b}	93.0^{ab}	143.8^{ab}
4% galactose	No available data on M.E. of galactose in chicks				
4% fructose	22.8^{a}	47.1^{ab}	71.8^{ab}	89.4^{ab}	126.1^{a}
4% sucrose	32.1^{b}	53.3^{b}	82.9^{b}	100.4^{b}	148.4^{b}
4% lactose	26.4^{ac}	48.9^{ab}	79.7^{ab}	103.3^{b}	156.2^{b}

Appendix Table 51 Total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Total energy consumed (kcal/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	27.4^{a}	45.3^{a}	70.2^{a}	92.8^{a}	135.1^{a}
3300	28.3^{a}	51.4^{b}	81.6^{b}	95.5^{a}	144.9^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 52 Dietary energy consumed as percent of total energy consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Period 1	Period 2	Period 3	Period 4	Period 5	19-day trial
no carbohydrate (tap water)	2700	1			100			100
		2			100			100
		mean			100			100
	3300	3			100			100
		4			100			100
		mean			100			100
4% glucose	2700	5	86.0	86.3	82.1	87.5	89.7	86.9
		6	84.7	86.0	84.9	84.2	86.2	85.2
		mean	85.4	86.2	83.5	85.9	88.0	86.1
	3300	7	86.1	87.5	85.6	82.3	88.0	85.8
		8	87.0	87.1	86.8	85.5	88.9	87.2
		mean	88.6	87.3	86.2	83.9	88.5	86.5
4% galactose	2700	9	No available data on M. E. of galactose in chicks					
		10						
		mean						
	3300	11						
		12						
		mean						
4% fructose	2700	13	81.6	87.9	87.9	88.1	88.8	87.8
		14	84.7	85.7	82.3	85.2	81.9	83.7
		mean	83.2	86.8	85.1	86.7	85.4	85.8
	3300	15	78.1	90.4	88.4	89.6	90.6	89.3
		16	83.0	88.2	87.6	89.0	90.2	88.6
		mean	80.6	89.3	88.0	89.3	90.4	89.0
4% sucrose	2700	17	84.2	85.4	82.6	84.7	84.4	84.2
		18	82.5	84.9	82.7	85.7	86.5	84.9
		mean	83.4	85.2	82.7	85.2	85.5	84.6
	3300	19	87.2	90.9	88.4	88.3	90.2	89.2
		20	85.0	89.5	85.3	88.7	88.3	87.7
		mean	86.1	90.2	86.9	88.5	89.3	88.5
4% lactose	2700	21	90.5	92.0	90.0	92.5	94.1	92.3
		22	91.9	91.8	90.4	92.3	93.7	92.3
		mean	91.2	91.9	90.2	92.4	93.9	92.3
	3300	23	92.7	93.7	92.9	93.9	94.3	93.7
		24	93.4	94.3	93.5	94.1	94.0	93.9
		mean	92.9	94.0	93.2	94.0	94.2	93.8

Appendix Table 53 Dietary energy consumed as percent of total energy consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Dietary energy consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)			100		
4% glucose	86.0^{a}	86.7^{a}	84.9^{a}	84.9^{a}	88.2^{a}
4% galactose	No available data on M.E. of galactose in chicks				
4% fructose	81.9^{b}	88.1^{a}	86.6^{a}	88.3^{b}	88.1^{a}
4% sucrose	84.8^{ab}	87.8^{a}	84.8^{a}	86.9^{ab}	87.4^{a}
4% lactose	91.2^{c}	93.0^{b}	91.8^{b}	93.2^{c}	94.0^{b}

Appendix Table 54 Dietary energy consumed as percent of total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Dietary energy consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	86.0^{a}	87.6^{a}	85.5^{a}	87.7^{a}	88.5^{a}
3300	86.9^{a}	90.4^{b}	88.7^{b}	89.3^{b}	90.7^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Appendix Table 55 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	"Water-energy" consumed as percent of total energy consumed (%): period 1	2	3	4	5	
no carbohydrate (tap water)	2700	1			0			0
		2			0			0
		mean			0			0
	3300	3			0			0
		4			0			0
		mean			0			0
4% glucose	2700	5	14.0	13.7	17.9	12.5	10.3	13.1
		6	15.3	14.0	15.1	15.8	13.8	14.8
		mean	14.7	13.9	16.5	14.2	12.1	14.0
	3300	7	13.9	12.5	14.4	17.7	12.0	14.2
		8	13.0	12.9	13.2	14.5	11.1	12.8
		mean	13.5	12.7	13.8	16.1	11.6	13.5
4% galactose	2700	9	No available data on M. E. of galactose in chicks					
		10						
		mean						
	3300	11						
		12						
		mean						
4% fructose	2700	13	18.4	12.1	12.1	11.9	11.2	12.2
		14	15.3	14.3	17.7	14.8	18.1	16.3
		mean	16.9	13.2	14.9	13.4	14.7	14.3
	3300	15	21.9	9.6	11.6	10.4	9.4	10.7
		16	17.0	11.8	12.4	11.0	9.8	11.4
		mean	19.5	10.7	12.0	10.7	9.6	11.1
4% sucrose	2700	17	15.8	14.6	17.4	15.3	15.6	15.8
		18	17.5	15.1	17.3	14.3	13.5	15.1
		mean	16.7	14.9	17.4	14.8	14.6	15.5
	3300	19	12.8	9.1	11.6	11.7	9.8	10.8
		20	15.0	10.5	14.7	11.3	11.7	12.3
		mean	13.9	9.8	13.2	11.5	10.8	11.6
4% lactose	2700	21	9.5	8.0	10.0	10.5	5.9	7.7
		22	8.1	8.2	9.6	7.7	6.3	7.7
		mean	8.8	8.1	9.8	7.6	6.1	7.7
	3300	23	7.3	6.3	7.1	6.1	5.7	6.3
		24	6.6	5.7	6.5	5.9	6.0	6.1
		mean	7.0	6.0	6.8	6.0	5.9	6.2

Appendix Table 56 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	"Water-energy" consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)			0		
4% glucose	14.0^{a}	13.3^{a}	15.1^{a}	15.1^{a}	11.8^{a}
4% galactose	No available data on M.E. of galactose in chicks				
4% fructose	18.1^{b}	11.9^{a}	13.4^{a}	11.7^{b}	11.9^{a}
4% sucrose	15.2^{ab}	12.2^{a}	15.2^{a}	13.1^{ab}	12.6^{a}
4% lactose	7.8^{c}	7.0^{b}	8.2^{b}	6.8^{c}	6.0^{b}

Appendix Table 57 "Water-energy" consumed as percent of total energy consumed by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	"Water-energy" consumed as percent of total energy consumed (%)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	14.0^{a}	12.4^{a}	14.5^{a}	12.3^{a}	11.5^{a}
3300	13.1^{a}	9.6^{b}	11.3^{b}	10.7^{b}	9.3^{b}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b, means, in vertical row, carrying different superscripts are significantly different (P <.05), according to the Tukey's test.

Appendix Table 58 Body weight gain of broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Body weight gain period (gm/bird/day) 1	2	3	4	5	gm/bird for 19 days
no carbohydrate (tap water)	2700	1	6.8	8.9	11.3	19.6	22.0	252
		2	7.0	10.2	14.0	19.2	22.2	268
		mean	6.9	9.6	12.7	19.4	22.1	260
	3300	3	6.7	9.4	14.3	17.1	18.4	245
		4	8.2	10.1	12.7	14.2	17.0	232
		mean	7.5	9.8	13.5	15.7	17.7	239
4% glucose	2700	5	7.5	7.1	15.5	16.9	20.5	250
		6	9.9	11.1	18.8	20.7	23.0	311
		mean	8.7	9.1	17.2	18.8	21.8	280
	3300	7	7.7	10.0	15.7	19.5	23.3	282
		8	8.0	10.0	15.8	15.1	19.4	254
		mean	7.9	10.0	15.8	17.3	21.4	268
4% galactose	2700	9	6.0	8.0	12.8	15.7	19.1	227
		10	7.3	5.9	8.6	10.6	15.0	175
		mean	6.7	7.0	10.7	13.2	17.1	201
	3300	11	8.0	8.8	16.1	20.5	25.2	289
		12	8.5	7.0	12.6	14.0	10.8	201
		mean	8.3	7.9	14.4	17.3	18.0	245
4% fructose	2700	13	5.5	5.6	14.6	16.1	23.5	254
		14	4.4	6.5	12.7	14.6	20.7	215
		mean	5.0	8.1	13.7	15.4	22.1	234
	3300	15	5.4	9.2	18.3	20.1	23.8	283
		16	6.6	5.8	17.4	19.7	27.0	295
		mean	6.0	9.5	17.9	19.9	25.4	289
4% sucrose	2700	17	7.9	9.3	16.6	17.9	26.3	286
		18	8.3	10.0	17.4	19.6	24.9	296
		mean	8.1	9.7	17.0	18.6	25.9	291
	3300	19	9.4	11.6	20.2	22.2	30.0	344
		20	8.5	11.3	18.5	21.5	29.3	327
		mean	9.0	11.5	19.4	21.9	29.7	335
4% lactose	2700	21	7.4	9.1	16.6	18.5	24.7	281
		22	7.8	8.3	16.7	16.5	24.6	271
		mean	7.6	8.7	16.7	17.5	24.7	276
	3300	23	8.9	10.3	19.8	21.0	28.4	325
		24	7.8	9.0	17.8	21.6	27.4	307
		mean	8.4	9.7	18.8	21.3	27.9	316

Appendix Table 59 Body weight gain of broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Body weight gain (gm/bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	7.2^{a}	9.7^{a}	13.1^{ab}	17.5^{ab}	19.9^{ab}
4% glucose	8.3^{a}	9.5^{a}	16.5^{ac}	18.1^{ab}	21.6^{ab}
4% galactose	7.5^{a}	7.4^{b}	12.5^{b}	15.2^{a}	17.5^{a}
4% fructose	5.5^{b}	8.8^{a}	15.8^{abc}	17.6^{ab}	23.8^{ab}
4% sucrose	8.5^{a}	10.6^{a}	18.2^{c}	20.3^{b}	27.6^{b}
4% lactose	8.0^{a}	9.2^{a}	17.7^{c}	19.4^{ab}	26.3^{b}

Appendix Table 60 Body weight gain of broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet (kcal/kg)	Body weight gain (gm/bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	7.2^{a}	8.7^{a}	14.7^{a}	17.2^{a}	22.2^{a}
3300	7.8^{a}	9.7^{a}	16.6^{b}	18.9^{a}	23.3^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a,b,c means, in vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 61 Feed efficiency by broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Feed efficiency: period (gm feed/gm bird/day) 1	2	3	4	5	Feed efficiency: gm feed/gm bird for 19 days
no carbohydrate (tap water)	2700	1	1.34	1.76	1.67	1.65	2.04	1.74
		2	1.36	1.52	1.85	1.71	2.04	1.76
		mean	1.35	1.64	1.76	1.68	2.04	1.75
	3300	3	1.31	1.39	1.45	1.56	2.74	1.75
		4	1.07	1.46	1.65	1.54	1.64	1.51
		mean	1.19	1.43	1.55	1.55	2.19	1.63
4% glucose	2700	5	1.12	1.97	1.37	1.97	2.68	1.89
		6	0.95	1.45	1.42	1.52	2.07	1.53
		mean	1.04	1.71	1.40	1.75	2.38	1.71
	3300	7	1.12	1.34	1.46	1.13	1.58	1.34
		8	1.14	1.29	1.20	1.38	1.71	1.39
		mean	1.13	1.32	1.38	1.26	1.65	1.37
4% galactose	2700	9	1.11	1.48	1.45	1.50	1.91	1.55
		10	1.01	2.12	2.22	1.68	1.92	1.79
		mean	1.06	1.80	1.84	1.59	1.92	1.67
	3300	11	0.86	1.53	1.27	1.20	1.50	1.29
		12	1.04	1.55	1.33	2.84	3.68	1.64
		mean	0.95	1.54	1.30	2.02	2.59	1.47
4% fructose	2700	13	1.35	1.46	1.55	1.74	1.73	1.61
		14	1.77	2.02	1.43	1.78	1.42	1.62
		mean	1.56	1.74	1.49	1.76	1.58	1.62
	3300	15	0.74	1.62	1.16	1.29	1.58	1.34
		16	0.94	1.36	1.20	1.28	1.49	1.30
		mean	0.84	1.49	1.18	1.29	1.54	1.32
4% sucrose	2700	17	1.23	1.60	1.37	1.60	1.56	1.49
		18	1.22	1.56	1.41	1.59	1.79	1.56
		mean	1.23	1.48	1.39	1.60	1.68	1.53
	3300	19	0.93	1.41	1.19	1.37	1.53	1.33
		20	0.95	1.37	1.22	1.26	1.42	1.27
		mean	0.94	1.39	1.21	1.32	1.48	1.30
4% lactose	2700	21	1.09	1.82	1.46	1.90	2.28	1.80
		22	1.29	1.82	1.40	1.83	1.98	1.70
		mean	1.19	1.82	1.43	1.87	2.13	1.75
	3300	23	0.78	1.48	1.31	1.59	1.73	1.46
		24	0.99	1.56	1.34	1.39	1.57	1.40
		mean	0.89	1.52	1.33	1.49	1.65	1.43

Appendix Table 62 Feed efficiency by broiler-type chicks given different kinds of carbohydrates in drinking water in Experiment 2.

Carbohydrate in drinking water	Feed efficiency (gm feed/gm bird/day)				
	period				
	1	2	3	4	5
	(4)*	(4)	(4)	(4)	(4)
no carbohydrate (tap water)	1.27^{a}	1.53^{a}	1.66^{a}	1.62^{a}	2.12^{a}
4% glucose	1.08^{a}	1.51^{a}	1.39^{ab}	1.50^{a}	2.01^{a}
4% galactose	1.01^{a}	1.67^{a}	1.57^{ab}	1.81^{a}	2.25^{a}
4% fructose	1.20^{a}	1.62^{a}	1.34^{ab}	1.52^{a}	1.56^{a}
4% sucrose	1.08^{a}	1.49^{a}	1.30^{b}	1.46^{a}	1.58^{a}
4% lactose	1.04^{a}	1.67^{a}	1.38^{ab}	1.68^{a}	1.89^{a}

Appendix Table 63 Feed efficiency by broiler-type chicks fed different levels of dietary energy in Experiment 2.

Metabolizable energy in diet	Feed efficiency (gm feed/gm bird/day)				
	period				
	1	2	3	4	5
	(12)*	(12)	(12)	(12)	(12)
2700	1.24^{a}	1.72^{a}	1.55^{a}	1.71^{a}	1.95^{a}
3300	0.99^{b}	1.45^{b}	1.32^{b}	1.49^{a}	1.85^{a}

* represented the number of groups of chicks which gave the average value, at eight chicks per group, started.

a, b means, vertical row, carrying different superscripts are significantly different ($P < .05$), according to the Tukey's test.

Appendix Table 64 Liver weight, percent liver weight and lipids in liver of broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Liver weight (gm/bird)	Liver weight as percent of body weight (%)	Lipids in liver as percent of wet liver weight (%)
no carbohydrate (tap water)	2700	1	11.9	3.8	4.2
		2	13.3	4.1	4.1
		mean	12.6	4.0	4.2
	3300	3	13.0	4.4	4.6
		4	11.0	3.9	3.9
		mean	12.0	4.1	4.3
4% glucose	2700	5	12.0	4.0	4.0
		6	15.3	4.2	4.8
		mean	13.4	4.1	4.4
	3300	7	13.2	3.9	4.8
		8	12.7	4.1	4.3
		mean	13.0	4.0	4.5
4% galactose	2700	9	12.4	4.4	4.2
		10	8.9	4.0	5.0
		mean	10.7	4.2	4.7
	3300	11	13.4	3.9	4.3
		12	9.2	3.7	4.2
		mean	11.3	3.8	4.3
4% fructose	2700	13	13.7	4.4	4.3
		14	11.2	4.1	3.5
		mean	12.5	4.2	3.9
	3300	15	14.2	4.2	4.9
		16	13.1	3.7	4.2
		mean	13.7	3.9	4.6
4% sucrose	2700	17	13.8	4.0	4.3
		18	14.9	4.2	4.0
		mean	14.3	4.1	4.2
	3300	19	15.3	3.7	4.8
		20	15.8	4.0	4.5
		mean	15.6	3.9	4.7
4% lactose	2700	21	13.2	3.9	3.9
		22	12.1	3.7	3.8
		mean	12.7	3.8	3.8
	3300	23	15.4	4.0	3.9
		24	14.0	3.8	4.1
		mean	14.7	3.9	4.0

Appendix Table 65 Pancreatic weight and percent pancreatic weight of broiler-type chicks in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable Energy in diet (kcal/kg)	Group #	Pancreatic weight (gm/bird)	Pancreatic weight as percent of body weight (%)
no carbohydrate (tap water)	2700	1	1.6	.52
		2	1.7	.52
		mean	1.7	.52
	3300	3	1.2	.40
		4	1.2	.43
		mean	1.2	.42
4% glucose	2700	5	1.2	.40
		6	1.8	.48
		mean	1.5	.44
	3300	7	1.4	.42
		8	1.3	.42
		mean	1.4	.42
4% galactose	2700	9	1.3	.45
		10	1.2	.52
		mean	1.3	.49
	3300	11	1.5	.44
		12	1.2	.47
		mean	1.4	.46
4% fructose	2700	13	1.3	.43
		14	1.3	.45
		mean	1.3	.44
	3300	15	1.6	.46
		16	1.5	.42
		mean	1.5	.44
4% sucrose	2700	17	1.8	.50
		18	1.7	.47
		mean	1.8	.49
	3300	19	2.0	.48
		20	1.7	.43
		mean	1.8	.46
4% lcatose	2700	21	1.6	.48
		22	1.5	.45
		mean	1.6	.47
	3300	23	2.0	.50
		24	1.8	.49
		mean	1.9	.50

Appendix Table 66 Chick mortality in Experiment 2.

Treatment: Carbohydrate in drinking water	Treatment: Metabolizable energy in diet (kcal/kg)	Group #	Number dead: period 1	2	3	4	5	, %
no carbohydrate (tap water)	2700	1	1	-	-	-	-	1 , 12.5%
		2	-	-	-	-	-	- , 0 %
		mean						6.3%
	3300	3	1	-	-	-	-	1 , 12.5%
		4	1	-	-	-	-	1 , 12.5%
		mean						12.5%
4% glucose	2700	5	1	-	-	-	-	1 , 12.5%
		6	1	-	-	-	-	1 , 12.5%
		mean						12.5%
	3300	7	-	-	-	-	-	- , 0 %
		8	-	-	-	-	-	- , 0 %
		mean						0 %
4% galactose	2700	9	3	1	-	-	-	4 , 50 %
		10	5	1	-	-	-	6 , 75 %
		mean						62.5%
	3300	11	3	-	-	-	-	3 , 37.5%
		12	1	1	-	1	-	3 , 37.5%
		mean						37.5%
4% fructose	2700	13	-	-	-	-	-	- , 0 %
		14	1	-	-	-	-	1 , 12.5%
		mean						6.3%
	3300	15	1	-	-	-	-	1 , 12.5%
		16	2	-	-	-	-	2 , 25 %
		mean						18.8%
4% sucrose	2700	17	-	-	-	-	-	- , 0 %
		18	-	-	-	-	-	- , 0 %
		mean						0 %
	3300	19	1	-	-	-	-	1 , 12.5%
		20	-	-	-	-	-	- , 0 %
		mean						6.3%
4% lactose	2700	21	1	-	-	-	-	1 , 12.5%
		22	-	-	-	-	-	- , 0 %
		mean						6.3%
	3300	23	2	-	-	-	-	2 , 25 %
		24	1	-	-	-	-	1 , 12.5%
		mean						18.8%