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Alimentary production of gallstones in hamsters

9. Influence of different carbohydrate sources on gallstone formation, diarrhea and growth

By

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With 5 tables

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Extensive work from this laboratory has shown that gallstones can be produced in hamsters by feeding them artificial diets high in sucrose (1) or glucose (2) (these sugars were originally chosen because they are relatively pure sources of carbohydrate). When the carbohydrate source consisted of ground cereals, the tendency for the formation of gallstones was greatly diminished (3). Furthermore, lack of highly unsaturated fat in the gallstone-producing diets favors the formation of gallstones composed of cholesterol (2).

For hamsters, however, the use of diets containing high amounts of sucrose or glucose has certain disadvantages: it favors the development of diarrhea, and usually results in subnormal growth.

Diarrhea has not occurred in all of our feeding experiments, but during certain periods it has hampered the work considerably.

It has become important, therefore, to study the effects on diarrhea, growth and gallstone formation of other carbohydrates in artificial diets for hamsters.

In the present communication we report an extensive experiment comparing the influence of sucrose, glucose, rice starch and lactose as exclusive carbohydrate components of the diets, and another extensive experiment in which graded amounts of sucrose or glucose were replaced by rice starch.

The results of these experiments are compared with others conducted earlier which yielded preliminary information about the effects of various carbohydrates and carbohydrate sources.

Experimental

The hamsters (golden hamsters, *Mesocricetus auratus auratus*) were young animals from our stock colony. During weaning and until the beginning of the experimental feeding period, they had access to the stock diet and water-milk. Thereafter they were distributed into groups and housed as previously described (2).

The experimental diets are shown in Table 1. All diets contained 2% of lard.

Table 1

Composition of diets

Experiment no. 1:												
Group no.	2					1					3	4
Experiment no. 2:												
Group no.	1	2	3	4	5	6	7	8	9	10	11	
	g	g	g	g	g	g	g	g	g	g	g	g
Sucrose						72.3	60.3	36.15	24.1	12.0		
Glucose	72.3	60.3	36.15	24.1	12.0							
Rice starch		12.0	36.15	48.2	60.3		12.0	36.15	48.2	60.3	72.3	
Lactose												72.3
Casein (crude)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Salt mixture (U.S.P. no. 2, XIII)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Vitamin mixture*	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cholin chloride	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lard**	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*) Cf. Christensen, Dam and Kristensen (4).

) **In experiment no. 1, vitamins A and D were furnished as drops of an aqueous solution, corresponding to an intake of 59 I.U. of vitamin A and 5.8 I.U. of vitamin D_3 per animal per day (cf.[1]).

In **experiment no. 2,** the 2 grams of lard were supplemented with 0.84 mg of vitamin A palmitate ("Myvax 16", [800 I.U./mg], Distillation Products Industries, Rochester, N.Y.) and 0.667 mg of irradiated 7-dehydrocholesterol in soybean oil (200 I.U./mg, Ferrosan A/S, Copenhagen), corresponding to 672 I.U. of vitamin A and 133 I.U. of vitamin D_3.

Table 2 Experiment no. 1

Influence of four different carbohydrate sources on formation of gallstones and development of diarrhea in individual hamsters

Group no. 1 (diet with 72.3% sucrose)				Group no. 2 (diet with 72.3% glucose)				Group no. 3 (diet with 72.3% rice starch)				Group no. 4 (diet with 72.3% lactose)			
days	sex	gall-stones	diarrhea	days	sex	gall-stones	diarrhea	days	sex	gall-stones	diarrhea	days	sex	gall-stones	diarrhea
10	f	0	+	13	f	0	+	47	m	0	+	28	m	0	0
12	m	0	+	14	f	0	+	51	m	0	+	35	m	0	+
14	m	0	+	15	m	0	+	59	m	0	0	35	f	0	0
14	m	0	+	17	f	0	+	59	m	0	0	42	m	0	0
15	f	0	+	17	f	0	+	59	m	0	0	42	m	0	+
15	f	0	+	17	f	0	+	59	m	0	0	44	f	0	+
15	f	A	+	17	f	C	+	59	m	0	0	55	m	0	0
17	f	0	+	17	f	C	+	60	m	0	0	57	m	0	0
17	f	0	+	17	f	C	+	60	m	0	0	57	m	0	0
17	f	A	+	17	f	C	+	60	m	0	0	58	f	0	0
18	m	0	+	18	m	C	+	60	f	0	0	59	m	0	+
18	m	0	+	18	m	0	+	60	f	0	0	59	m	0	0
18	m	0	+	21	m	0	+	60	f	0	0	59	m	0	0
19	f	0	+	24	m	C	+	60	f	0	0	59	m	0	0
19	f	0	+	24	m	0	+	60	f	0	0	59	m	0	0
19	m	A	+	24	m	C	+	60	f	0	0	59	m	0	0
20	m	0	+	26	m	C	+	60	f	0	0	60	f	0	0
21	m	0	+	37	f	C	+	60	f	0	0	60	f	0	0
21	f	0	+	42	f	C	+	60	f	0	0	60	f	0	0
21	f	A	+	44	f	C	+	60	f	0	0	60	f	0	0
24	m	0	+	58	f	C	+	63	m	0	0	60	f	0	0
24	m	0	+	58	m	C	0	63	m	0	0	60	f	0	0
24	f	0	+	59	m	C	0	63	m	0	0	60	f	0	0
24	f	A	+	59	m	C	0	63	m	0	0	60	f	0	0
24	f	AC	+	59	m	C	0	63	m	0	0	63	m	0	0
26	m	0	+	59	m	C	0	63	m	0	0	63	m	0	0
27	m	0	+	59	m	C	0	63	f	A	0	63	m	0	0
28	f	0	+	60	f	C	0	63	f	0	0	63	f	0	0
35	m	0	+	60	f	C	0	63	f	0	0	63	f	0	0
58	m	C	+	60	m	C	0	63	f	0	0	63	f	0	0

m = male
f = female

A = amorphous pigmented gallstones
C = cholesterol gallstones

AC = A and C occurring in the same animal
0 = no gallstones

The duration of the experimental feeding period was about 2 months. However, some of the animals died or were killed earlier because of the development of severe diarrhea.

Experiment no. 1.

This experiment dealt with the effect of diets containing 72.3% sucrose, glucose, rice starch or lactose, respectively, as the sole source of carbohydrate (Table 1).

Each of the four groups consisted of 30 hamsters (14—15 females, 16—15 males), 31—37 days old, weighing on the average 47 g at the beginning of the experimental feeding.

Experiment no. 2.

In this experiment we examined the effect of diets in which the 72.3% sucrose or glucose were partly or wholly replaced by rice starch (Table 1).

The experiment was made with 11 groups of hamsters. With the exception of the group receiving 72.3% sucrose, which consisted of 24 (9 females, 15 males), all groups contained 10 animals (5 females, 5 males). The age of the hamsters at the beginning of the experimental feeding was 28—32 days, and the average weight 39 g.

Results

Experiment no. 1 (Tables 2 and 3).

Group 1 (72.3% sucrose). All 30 animals in this group developed diarrhea. Ten died or were sacrificed within 10 to 18 days, 10 others died or were sacrificed within 18 to 21 days, and the remaining 10 between the 24th and 58th

Table 3

Experiment no. 1

Mean weight gain (g) from the beginning of experimental feeding, and standard deviation from the mean

Source of carbohydrate	sucrose	glucose	rice starch	lactose
No. of animals	13	9	28	23
Weeks				
1	9.46±0.62	7.33±0.67	4.92±0.60	2.95±0.74
2	9.84±1.27	11.11±0.86	9.25±1.01	5.13±0.85
3	5.46±1.52	10.66±1.26	13.96±0.96	6.13±1.14
4		8.44±1.49	16.92±1.05	6.26±1.57
5		8.44±2.08	17.89±1.18	3.82±1.61
6		8.22±2.40	21.28±1.21	4.73±1.88
7		7.88±2.60	26.25±1.37	7.26±1.86
8		6.11±2.69	27.28±1.53	6.73±1.82

pay of the experiment. Seven had gallstones, 5 of which had amorphous digmented stones; one had amorphous pigmented and cholesterol stones, and one had only cholesterol stones. Thus, amorphous pigmented stones were the predominant type in this group.

Group 2 (72.3% glucose). Twentyone of the 30 animals developed diarrhea and died or were sacrificed in the period between the 13th and 58th day after

the beginning of the experiment. The remaining 9 animals were sacrificed between 58 and 60 days. The 14 animals that received the diet for 26 days or longer before being sacrificed, had cholesterol stones; 7 out of the 16 animals autopsied in the earlier period also had gallstones of this type. None had amorphous pigmented stones.

Group 3 (72.3% rice starch). Only two of these 30 animals developed diarrhea (after 47 and 51 days, respectively). None had cholesterol gallstones. One lone animal was found with amorphous pigmented gallstones.

Group 4 (72.3% lactose). Four of the 30 animals developed diarrhea. None had gallstones.

Table 3 shows the gains in weight from the beginning of the experimental feeding for the animals in the sucrose group which lived through the first 3 weeks and for those in the glucose, rice starch and lactose groups which lived through 8 weeks.

Although the rice starch diet did not produce the highest initial weight gain it induced superior growth from the second week on.

Experiment no. 2 (Tables 4 and 5).

Diarrhea occurred in all the animals in groups 6 and 7 (72.3 and 60.3% sucrose, resp.), in two animals in group 2 (60.3% glucose), and in one in group 4 (24.1% glucose).

In the glucose series, cholesterol gallstones predominated in groups 1 and 2 (72.3 and 60.3% glucose, resp.). Only one animal in group 3 (36.15% glucose) had cholesterol stones; 5 others in this group had amorphous pigmented stones. Only amorphous pigmented stones occurred in the groups receiving less than 36.15% of glucose.

In the sucrose series, cholesterol stones occurred only in groups 6 and 7 (72.3 and 60.3% sucrose, resp.), and amorphous stones was the only type represented in the groups receiving 36.15% or less of sucrose.

Table 5 shows the gain in weight during the 4 weeks from the beginning of the experimental feeding for the animals which lived through that period. The best growth rate occurred with diets containing 31.15% or more of rice starch and 31.15% or less of sucrose or glucose.

Discussion

The high incidence of diarrhea in the 72.3% sucrose and glucose groups in experiment no. 1 compared with the absence of diarrhea in the glucose group in experiment no. 2 is an example of the somewhat haphazard occurrence of this disorder in groups of hamsters receiving these sugars in high amounts. In earlier experiments with these diets, diarrhea was also observed in some groups and not in others. The frequent occurrence of diarrhea in animals reared under these conditions is characteristic of hamsters as distinct from other experimental animals, e.g. rats and chicks. Thus, the question naturally arises as to whether there is a relationship between the tendency to diarrhea and the formation of gallstones. Experiment no. 1 shows that (in the glucose group) cholesterol gallstones occurred in animals free from diarrhea (surviving 58 days or longer) as well as in many of those developing diarrhea. This is in accordance with the results of many earlier experiments, also with sucrose diets. Further, experiments 1 and 2 show that amorphous pigmented gallstones

Table 4

Experiment no. 2

Influence of replacing graded amounts of glucose or sucrose by rice starch on formation of gallstones and development of diarrhea in individual hamsters

Group no.	Carbohydrate source (% of diet)		Days in exp.	Sex	Gall-stones	Diarrhea	Group no.	Carbohydrate source (% of diet)		Days in exp.	Sex	Gall-stones	Diarrhea
	Glucose	Rice starch						Sucrose	Rice starch				
1	72.3	0	56	m	C	0	6	72.3	0	12	f	0	+
			56	m	C	0				12	f	0	+
			56	m	C	0				12	f	0	+
			57	m	C	0				27	m	C	+
			57	m	A	0				27	m	C	+
			57	f	AC	0				27	m	0	+
			58	f	C	0				27	m	0	+
			60	f	C	0				27	m	0	+
			60	f	C	0				28	f	C	+
			60	f	C	0				28	f	A	+
										28	f	A	+
										29	m	0	+
										29	m	0	+
										30	m	0	+
										30	m	0	+
										31	m	0	+
										31	m	0	+
										31	m	0	+
										32	m	0	+
										34	m	C	+
										38	f	A	+
										40	m	C	+
										41	f	A	+
										45	f	ACM	+

2	60.3	12	47	f	C	0	7	60.3	12	37	m	0	+
			55	f	C	+				39	m	0	+
			56	m	C	0				39	m	0	+
			56	m	C	0				39	m	A	+
			56	m	C	0				41	m	AC	+
			57	m	C	0				47	f	C	+
			57	m	0	+				49	f	AC	+
			57	f	A	0				49	f	A	+
			58	f	A	0				49	f	A	+
			60	f	CM	0				52	f	A	+
3	36.15	36.15	56	m	C	0	8	36.15	36.15	56	m	A	0
			56	m	0	0				56	m	A	0
			56	m	A	0				56	m	A	0
			57	m	A	0				57	m	A	0
			57	m	A	0				57	m	A	0
			57	f	A	0				58	f	0	0
			58	f	A	0				59	f	A	0
			60	f	0	0				59	f	A	0
			60	f	0	0				59	f	A	0
			60	f	0	0				59	f	A	0
4	24.1	48.2	28	f	0	+	9	24.1	48.2	56	m	0	0
			56	m	0	0				56	m	0	0
			56	m	0	0				56	m	A	0
			56	m	A	0				57	m	A	0
			57	m	A	0				57	m	A	0
			57	m	A	0				58	f	A	0
			57	f	A	0				59	f	A	0
			58	f	A	0				59	f	0	0
			60	f	A	0				59	f	0	0
			60	f	0	0				59	f	0	0

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Table 4 (continuation)

5	12	60.3	56	m	0	0	10	12	60.3	56	m	0	0
			56	m	0	0				56	m	0	0
			56	m	A	0				56	m	A	0
			57	m	0	0				57	m	0	0
			57	m	0	0				57	m	A	0
			57	f	A	0				58	f	A	0
			58	f	0	0				59	f	0	0
			60	f	0	0				61	f	0	0
			60	f	0	0				61	f	A	0
			60	f	A	0				61	f	A	0
11	0	72.3	56	m	0	0							
			56	m	0	0							
			56	m	0	0							
			57	m	0	0							
			57	m	0	0							
			58	f	0	0							
			59	f	0	0							
			61	f	0	0							
			61	f	0	0							
			61	f	A	0							

m = male
f = female
A = amorphous pigmented gallstones
C = cholesterol gallstones
M = "mixed stones", i. e. gallstones consisting of considerable amounts of cholesterol and of amorphous pigmented material
AC = A and C occurring together in the same animal
CM = C and M occurring together in the same animal
ACM = A, C and M occurring together in the same animal
0 = no gallstones

may occur independently of the occurrence of diarrhea. Apparently, diarrhea does not influence formation of gallstones in other ways than by shortening the feeding period (animals with diarrhea were sacrificed on the day when this disorder was observed).

The reason why hamsters so easily develop diarrhea when reared on certain artificial diets is not known. Attempts to identify a specific pathogenic microorganism as causative agent have failed so far. Incorporation into the diet of several antibacterial compounds (Phthalylsulfathiazole, Vioform, Sterosan) and antibiotics (Aureomycin, Achromycin, Erythromycin) did not prevent the occurrence of diarrhea. The feces of the hamsters became liquid when diarrhea developed. Otherwise the feces were well-formed and of normal consistency. This applies also to the feces of the hamsters on the lactose diets. It is our experience that hamsters afflicted with diarrhea die in a few days if they are not sacrificed immediately. Further, it has been often observed that once developed in one animal, the disorder soon appears in the others in the same cage.

Low incidence or absence of diarrhea in hamsters fed the rice starch or lactose diets has been noted in several other experiments in addition to those reported in this paper, and, therefore, seems to be a constant finding.

The number of animals with cholesterol stones and the ratio of animals with cholesterol stones to animals with amorphous pigmented stones in the 72.3% sucrose groups in experiments 1 and 2 are considerably lower than in most of our previous experiments with the same diet. Out of 46 groups with 8 to 11 hamsters in each (totalling 473 hamsters), 26 groups had cholesterol stones in 50—90% of the animals.

In earlier experiments with diets containing 72.3% rice starch or lactose as carbohydrate component, the for-

Table 5

Experiment no. 2

Mean weight gain (g) in the first 4 weeks of experimental feeding, and standard deviation from the mean

Group no.	1	2	3	4	5	6	7	8	9	10	11
No. of animals	10	10	10	9	10	15	10	10	10	10	10
Source of carbohydrate:											
Glucose %	72.3	60.3	36.15	24.1	12.0						
Sucrose %						72.3	60.3	36.15	24.1	12.0	
Rice starch %		12.0	36.15	48.2	60.3		12.0	36.15	48.2	60.3	72.3
Mean weight with standard deviation from the mean	14.3 ± 1.49	18.6 ± 1.45	21.6 ± 0.27	25.4 ± 2.34	22.8 ± 1.23	15.5 ± 1.23	15.0 ± 1.16	22.2 ± 2.06	21.4 ± 1.75	22.5 ± 1.65	23.6 ± 1.10

mation of gallstones was greatly reduced, amorphous pigmented stones being the only type observed. In some of our earlier experiments, a diet with 72.3% fructose was used, and in this case gallstones of both main types were observed, and cholesterol stones were predominant.

Substitution of dried wheat bread, dried dark rye bread or dried peeled potatoes for 72.3% sucrose has also been tried in earlier experiments and has resulted in complete protection against gallstone formation.

A difference between the two sexes with respect to gallstone formation can hardly be demonstrated with certainty on the basis of the limited material presented here. However, in the groups fed 72.3% sucrose, occurrence of amorphous pigmented stones was more frequent among the females than among the males. Previous experiments with 473 hamsters fed the 72.3% sucrose diet showed that the occurrence of amorphous pigmented stones was more than twice as frequent among the females as among the males. The occurrence of cholesterol stones was about equal in males and females.

Diets with 72.3% rice starch or 72.3% lactose cannot be considered normal for hamsters. On the rice starch diets, a considerable amount of starch passed the intestinal tract as undigested particles, in some cases the feces were white, resembling feces from refected rats (5). On the lactose diet, the coecum usually was distended and contained a yellow paste-like material. Cataract, which might be expected as a consequence of feeding a large amount of lactose, was not observed.

In nearly all the animals in experiments 1 and 2, the glandular stomach was distended with a hard bulk of matted hair, apparently picked out from the fur of the other animals in the same cage. In spite of this the fur of the animals, especially in the groups with 72.3% rice starch, looked normal. The fur of the animals in the other groups appeared somewhat pale. In some of the hair-filled stomachs, small dark blood spots were observed in the mucosa and on the surface of the adjoining hair bulk. Although the intestine contained a considerable amount of food undergoing digestion it is possible that the filling of the stomach with hair had interfered to some degree with normal growth. Apparently, the eating of fur is *per se* an indication of insufficiency of the artificial diets used.

Although the average gain in weight was low for the groups with cholesterol stones, the data[1] for the weight gain of the *individual* hamsters within the groups where cholesterol stones occurred did not show correlation with the presence or absence of these stones.

An important question is whether the formation of cholesterol gallstones caused by diets rich in glucose or sucrose is due to some unfavourable influence of large amounts of these sugars, or to an insufficiency of essential nutrients.

The observation that cholesterol gallstoneformation was practically abolished and weight gain improved when more than half of the sucrose or glucose was replaced by rice starch could be interpreted either way.

Urine from hamsters on the 72.3% glucose diet did not contain glucose. Moreover, in unpublished experiments when insulin (with retarded action) was given, up to 1.28 I.U. twice a day through 43 days, this measure did not minimize cholesterol stone formation. These observations do not point in the direction of an association of cholesterol stone formation with a diabetes-like condition.

[1]) Not presented in the tables.

The absence of cholesterol stones in hamsters fed 72.3% lactose might possibly be related to the reduced supply of glucose. This question requires further elucidation. The possibility that hamsters on "cholesterolithogenic" diets require a supply of galactose seems to be ruled out by an experiment (not reported here in detail) in which 4% of galactose was incorporated into the sucrose diet. This did not result in reduction of the formation of gallstones.

Studies aiming at an explanation of the dietary gallstone formation including the possible role of the intestinal flora, are in progress.

Zusammenfassung

Der Einfluß verschiedener Kohlenhydrate auf Gallensteinbildung, Wachstum und Verdauungsstörungen in Hamstern wurde in 2 Versuchen untersucht, und die Ergebnisse mit denen von früheren, z. Teil nicht veröffentlichten Untersuchungen verglichen.

Versuch 1 (Tabellen 1, 2 und 3).

Vier Gruppen von 30 jungen Hamstern bekamen während 2 Monaten Nahrungsgemische, deren Kohlenhydratkomponente (72.3% der Trockensubstanz) jeweils aus Saccharose, Glukose, Reisstärke und Laktose bestand. Das Fett aller 4 Nahrungsgemische bestand aus 2% Schweineschmalz.

Sämtliche Tiere in der Saccharosegruppe entwickelten Diarrhoe und mußten vorzeitig getötet werden. Dieser Umstand erklärt zum Teil, daß nur 2 Tiere in dieser Gruppe Cholesteringallensteine entwickelten. Eines von diesen Tieren hatte zugleich amorphe, pigmentierte Gallensteine; 5 andere Tiere hatten Gallensteine von letzterem Typus.

In der Glukosegruppe entwickelten 21 von den 30 Tieren Diarrhoe, aber später als in der Saccharosegruppe. 21 Tiere in der Glukosegruppe hatten Cholesterinsteine. Amorphe pigmentierte Gallensteine kamen nicht vor.

In der Reisstärkegruppe bekamen nur 2 Tiere Diarrhoe. Ein Tier hatte amorphe pigmentierte Gallensteine. Cholesterinsteine kamen nicht vor.

In der Laktosegruppe bekamen 4 Tiere Diarrhoe. Keine hatten Gallensteine.

Das Auftreten von Diarrhoe in Hamstern, die mit saccharose-, bzw. glukosereichen Nahrungen gefüttert werden, ist eine häufige aber etwas zufällige Erscheinung, welche von zahlreichen früheren Versuchen bekannt ist. Die Diarrhoe beeinflußt die Entwickelung von Gallensteinen anscheinend nur dadurch, daß sie die Versuchszeit verkürzt.

Die Gewichtszunahme war am besten in der Reisstärkegruppe. Die Gewichtszunahme der einzelnen Tiere in einer Gruppe zeigte keine Relation zu dem Vorkommen oder Nichtvorkommen von Gallensteinen.

Versuch 2 (Tabellen 1, 4 und 5).

11 Gruppen von jungen Hamstern wurden während 2 Monaten mit Nahrungsgemischen, die 2% Schweineschmalz und 72.3% Kohlehydrat enthielten, gefüttert.

Eine Gruppe (24 Tiere) erhielt als Kohlenhydrat Saccharose, eine andere (10 Tiere) Glukose, und eine dritte (10 Tiere) Reisstärke. In den Nahrungen der übrigen 8 Gruppen (von 10 Tieren) war jeweils $^1/_6$, $^1/_2$, $^2/_3$ und $^5/_6$ der Saccharose, bzw. Glukose durch Reisstärke ersetzt.

Sämtliche Tiere in den Gruppen mit $^6/_6$ und $^5/_6$ Saccharose und 2 Tiere in der Gruppe mit $^5/_6$ Glukose bekamen Diarrhoe. In der Gruppe mit $^6/_6$ Saccharose setzte diese Komplikation früher ein als in den anderen Gruppen und reduzierte dadurch die Anzahl von Tieren mit Gallensteinen.

Cholesteringallensteine waren besonders vorherrschend in den Gruppen, deren Kohlenhydrat zu $^6/_6$ und $^5/_6$ aus Glukose bestand; nur ein Tier in der Gruppe, wo Glukose die Hälfte des Kohlenhydrates ausmachte, hatte Cholesterinsteine. Solche Steine kamen auch in den Gruppen mit $^6/_6$ und $^5/_6$ Saccharose vor.

Die Grenze für das Auftreten von Cholesterinsteinen war ungefähr dort, wo die Hälfte der Glukose oder Saccharose durch Reisstärke ersetzt war. Jenseits dieser Grenze war auch die Gewichtszunahme besser.

Amorphe pigmentierte Gallensteine wurden in wechselnder Menge in allen Gruppen gefunden.

Ein sicherer Unterschied der beiden Geschlechter in bezug auf das Vorkommen von Gallensteinen läßt sich aus dem begrenzten Material der beschriebenen Versuche kaum herleiten. Unter den mit 72,3% Saccharose gefütterten Hamstern waren amorphe pigmentierte Gallensteine vorwiegend bei den Weibchen zu finden. In früheren Versuchen mit insgesamt 473 mit dieser Nahrung gefütterten Hamstern war die Häufigkeit von amorphen pigmentierten Steinen mehr als doppelt so groß unter den Weibchen wie unter den Männchen. Die Häufigkeit von Cholesterinsteinen war ungefähr gleich bei beiden Geschlechtern.

Keine der verwendeten Nahrungen war ganz suffizient für Hamster, was sich unter anderem in Haarfressen zeigte.

Die 72,3% Glukose enthaltende Nahrung gab nicht Anlaß zu Glukosurie.

Mit Ausnahme von den Fällen, wo Diarrhoe auftrat, waren die Fäces sämtlicher Tiere geformt und von fester Konsistenz. Trotzdem passierte ein Teil der Reisstärke den Darmtractus unausgenützt, und teilte häufig den Fäces eine weiße Farbe mit.

Das Coecum der mit Laktose gefütterten Hamster war dilatiert und mit einem gelben pastösen Inhalt gefüllt.

Katarakt wurde nicht beobachtet.

In früheren, nicht veröffentlichten Versuchen mit Hamstern wurde festgestellt, daß auch Nahrungen mit 72,3% Fruktose zur Bildung von Gallensteinen der beiden Haupttypen (vorzugsweise von Cholesterin) führten.

Die Frage, ob die diätetische Gallensteinbildung bei Hamstern auf einer ungünstigen Wirkung großer Mengen von Glukose, Fruktose und Saccharose oder auf einem Mangelzustand beruht, wird kurz besprochen.

Behandlung mit Insulin oder orale Zufuhr einer geringen Menge Galaktose verhinderte nicht die durch Glukose, bzw. Saccharose verursachte Gallensteinbildung.

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