CCXLIX. UTILIZATION OF POLY-GLYCEROL ESTERS

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THE polymerization of glycerol to di- and tri-glycerol and to more highly polymerized glycerols has been described by a number of investigators, including Harris [1935], who has also prepared mixed esters of these polyglycerols with fatty acids. The large variety of esters which may be thus synthesized, though in many respects resembling fats, are distinguished by their wetting, emulsifying and other capillary-active properties, these being apparently related to the structure of the molecule in that it has a lipophilic group, in the form of a long-chain fatty acid residue, and hydrophilic groups in the form of free hydroxyl at or near an end of the molecule. These surface-active functions of the polyglyceride esters are being utilized in various industries, and Harris [1933] describes their mechanism and suggests the use of these esters as emulsifying agents in edible emulsions. He also suggests their use in small percentages in margarine with the object of reducing the spattering of the margarine during frying. Because of the uniqueness of this group of compounds and their utility, it seemed of interest to investigate their utilization in the animal organism, the present report being principally concerned with growth and faecal excretion of fat.

EXPERIMENTAL

Albino rats were used, the stock in this laboratory being a pure inbred Wistar strain, reared under favourable conditions. The basic diet and the one fed to the controls consisted of ground Purina chow, to which was added a dried milk preparation (5%), yeast (1%) and water to proper consistency. For the experimental animals the basic ration was supplemented either with lard (5 or 10%), or polyglycerol ester (5 or 10%). In one large series of experiments the diet was begun soon after weaning (25–30 days old) and continued for as long as 14 months. Observations on over 100 rats revealed that both in the lard and polyglycerol ester-fed rats the rate of growth was normal or better than normal, the criterion for normal growth being that of the controls, which in our experience exceeded somewhat the standards obtained for the Wistar colony, as recorded by Greenman & Duhring [1931].

Generally the lard-fed rats attained somewhat greater weights than the rats in the polyglycerol ester group, the difference being apparently related to the much greater accumulation of fat in the depots (perirenal, mesenteric, omental, genital etc.) in the former. Histological examination of the tissues disclosed no abnormalities in either of the experimental groups. Rats were maintained successfully on the polyglycerol ester and lard diets through three generations,

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the diets being continued without interruption throughout, including the periods of gestation and lactation. A number of typical growth curves of first generation rats fed with polyglycerol ester and lard are given in the accompanying charts.

Fig. 1. Growth curves of rats: solid lines, 10% lard; dots and dashes, 10% polyglycerol ester; broken lines, controls.

Fig. 2. Composite growth curves of three rats fed polyglycerol ester and three which received a comparable amount of lard (10% of diet). The six rats were male litter-mates and the offspring of parents reared on a polyglycerol ester-containing diet.

The fatty acids of the polyglycerol preparation used in these studies were chiefly stearic and oleic. The compound had i.v. 31.6 and sap. equiv. 143. Its utilization was determined in a series of mature male and female rats as indicated in Table I. During the experimental period of 24 days a record was kept of the daily food consumption. The faeces for each 3-day interval were collected separately and weighed, the excreta for eight such periods being combined and sampled for analysis. In the control group the data are based on 21 days of observation, as one 3-day specimen was discarded owing to incomplete collection. There were no striking differences in the water contents of the faeces of the various groups. It is to be noted further that the ratio of food consumed to the weight of faeces varied within narrow limits and was not significantly

Table I. *Utilization of fat in rats receiving supplements of lard or polyglycerol ester*

Exp.	Duration days	Rats no. and sex	Initial and final wt. g.	Food con- sumed g.	Faeces		Faecal fat		Depot fat i.v.
					g.	% of food consumed	%	i.v.	
Lard, 5%	24	45 ♂	369-390	1398	224	16.0	3.96	76.4	76.6
		46 ♂	410-448						75.5
		64 ♀	215-240	961	172	17.9	2.29	89.5	77.3
		65 ♀	209-232						
Lard, 10%	24	25 ♂	333-340	1018	178	17.5	3.82	78.7	—
		26 ♂	330-338						
		3 ♀	225-245	812	127	15.6	2.30	87.2	78
		28 ♀	227-208						
Polyglycerol ester, 5%	24	62 ♂	273-322	1164	194	16.6	4.40	66.6	—
		63 ♂	290-339						
		35 ♀	222-225	857	157	18.3	2.63	81.2	78.1
		5 ♀	253-256						
Polyglycerol ester, 10%	24	21 ♂	356-360	1047	166	15.8	6.26	58.3	68.8
		23 ♂	309-348						
		13 ♀	193-210	704	111	15.8	3.41	63.8	76.6
		14 ♀	172-200						78.4
Control	21	51 ♂	332-358	925	126	13.5	1.66	77.3	—
		52 ♂	322-332						
		39 ♀	216-227	865	145	16.8	2.24	91.2	67.3
		32 ♀	213-225						

different in the lard and polyglycerol ester groups. In the rats receiving polyglycerol ester, the amounts of faecal lipins were somewhat greater than those in the lard group, which in turn exceeded the values found in the controls. However, even if all the ether-soluble material of the faeces in rats 21, 23, 13 and 14 represented unabsorbed polyglycerol compound, the results would nevertheless indicate 90% utilization in the males and 94.62% in the females. But judging from the faecal fat in the controls as well as the i.v., it is conservative to estimate that at least 95-98% of the polyglycerol esters of the rations were digested and absorbed even when they constituted 10% of the food mixture.

Polyglycerol esters of oleic and linoleic acids. The observation by Hansen [1933] that in infantile eczema the serum fatty acids have an abnormally low i.v. and his subsequent statement [1933-4] concerning the therapeutic action of unsaturated oils, such as linseed oil, stimulated in us further interest in the problem. It seemed that if unsaturated fatty acids actually exercised a beneficial effect their administration in polyglycerol combination would be of advantage, if for no other reason than the ease of preparing suitable emulsions. Accordingly, polyglycerol was esterified with commercial oleic acid and with a good grade of linseed oil. The constants for oleic acid ester were: i.v. 69.4, sap. equiv. 151. Those for the linseed oil fatty acid ester mixture were 116.7 and 137.2, respectively. The esters were fed at levels of 5% as indicated in Table II. The controls were maintained on the basal ration, while for further comparison other groups of rats received butter, 10%; oleomargarine, 10%; linseed oil, 5%; cocoa butter, 5%. As we were especially interested in the utilization of linseed oil and the polyglycerol esters of the unsaturated fatty acids in the young, the rats selected for this work were not more than 40 days old (oleic and linoleic ester groups and the controls, Table II, were 30 days old at the beginning of the experiment). It will be noted that the rate of growth was normal, or somewhat

Table II. *Utilization of various fats, including polyglycerol esters of oleic and linoleic acids*

Exp.	Duration days	Rats no. and sex	Initial and final wt. g.	Food con- sumed g.	Faeces		Faecal fat		Depot fat	
					g.	% of food consumed	%	I.V.	I.V.	Sap. equiv.
Oleic ester, 5%	24	68 ♂	56-160	971	157	16.2	4.45	86.5	73.5	216.5
		69 ♂	54-158						80.5	205.5
		70 ♀	53-142	783	116	14.8	4.9	92.3	76.9	—
		71 ♀	50-144						—	—
Linoleic ester, 5%	24	72 ♂	58-162	932	124	13.3	3.79	77.6	81.2	198.5
		73 ♂	56-152						80.5	197.5
		74 ♀	45-128	737	132	17.9	4.34	87.2	91.5	—
		75 ♀	50-126						81.1	—
Control	24	76 ♂	52-159	945	160	17.05	4.14	80.5	73.2	199.5
		77 ♂	55-160						—	—
		78 ♀	56-137	927	191	20.6	2.83	89.7	81.2	202
		79 ♀	58-148						—	—
Butter, 10%	21	80 ♂	67-151	878	125	14.3	4.16	57.0	76.5	201
		81 ♂	75-165						—	—
		82 ♀	64-140	827	138	16.7	3.58	72.5	65.1	199
		83 ♀	63-124						—	—
Oleomargarine 10%	21	86 ♀	53-128	710	127	17.6	2.94	73.0	79.6	198.5
		87 ♀	60-143						—	—
		89 ♂	76-163	874	137	15.7	3.59	72.1	94.0	192.5
		90 ♂	78-174						—	—
Linseed oil, 5%	24	91 ♀	73-132	545	107	19.6	4.18	78.2	81.5	182.5
		92 ♀	75-140						—	—
		93 ♂	70-150	944	152	16.1	5.11	65.1	82.8	—
		94 ♂	78-180						—	—
Cocoa butter, 5%	24	95 ♀	64-118	748	117	15.7	4.54	67.0	79.9	203.5
		96 ♀	74-149						—	—

better than normal in all groups (note especially the excellent growth of the polyglycerol ester groups). As shown by the data for faecal lipins, there was almost complete utilization of the polyglycerol esters of oleic and linoleic acids, as well as of the linseed oil and other fats used. Under the conditions of the experiments, the composition of the depot fat was only slightly influenced by the kind of fat incorporated in the diet.

The faeces were analysed essentially according to the method of Sperry & Bloor [1924], while for the analysis of the tissues the methods of Reed and associates [1930; 1932] were used.

COMMENT

The composition of the "fat" of the faeces, while not altogether unrelated to that of the fat consumed, is remarkably constant and independent of the diet, as has been shown by a number of investigators [Hill & Bloor, 1922; Holmes & Kerr, 1923-4; Sperry & Bloor, 1924]. Only under conditions in which digestion and absorption of fat are diminished, whether through disease or otherwise, does the composition of the faecal fat reflect that of the diet. Accordingly, analysis of the faeces may afford an accurate measure of the utilization of a fat in the alimentary tract. In the light of existing knowledge the results of the present study demonstrate that the coefficients of digestibility (including absorption) of the polyglycerol esters of stearic, oleic and linoleic

acids are essentially the same as those of naturally occurring fats (compare with data of Holmes & Kerr [1923-4]. *In vitro* experiments have confirmed the digestibility of these esters by lipase.

SUMMARY

Compounds produced by partial esterification of the polymerides of glycerol (diglycerol, triglycerol, tetraglycerol etc.) with fat-forming fatty acids, when fed at levels of 5 and 10% of the diet were found to be as well utilized in the alimentary tract of the albino rat as were naturally occurring fats. No untoward effects, as regards growth, reproduction, lactation and the microscopic appearance of the tissues, were observed as the result of long-continued feeding of these compounds.

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