XXII. LACTIC ACID FORMATION IN MUSCLE EXTRACTS.

V. A COMPARISON BETWEEN SOLUBLE STARCH AND GLYCOGEN IN RESPECT OF LACTIC ACID FORMATION AND PHOSPHORIC ESTER ACCUMULATION.

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IN a previous paper [Stiven, 1929] glucose and glycogen were used in investigations similar to those described in this paper. It was found in these experiments that, with the phosphate-bicarbonate extracts of cat muscle prepared in this laboratory, glucose differed from glycogen in showing practically no phosphoric ester accumulation while at the same time showing in general more extensive formation of lactic acid at the end of 2 hours' incubation. The experiments reported in this paper have been made to compare soluble starch and glycogen with regard to lactic acid formation and phosphoric ester accumulation.

RESULTS.

In a previous paper [Stiven, 1928] will be found the details of the method of preparing the extract from perfused cat muscle and of the manner of incubation. The "inorganic" phosphorus, which, as estimated by the method of Fiske and Subbarow [1925], includes the phosphorus of phosphagen along with the true inorganic phosphorus, was determined at the intervals shown in the tables. The lactic acid was estimated by the method of Friedemann, Cotonio and Shaffer [1927] at the same intervals. The soluble starch used was supplied by British Drug Houses and yielded on hydrolysis 89 % of its weight of glucose. A correction was made for this in making up the stock 10 % solution to be added to the extract and a similar procedure was adopted with the glycogen. Thus the concentration of soluble starch in the extract was made comparable with that of the glycogen on the basis of the yield of glucose on hydrolysis.

In six of the eight experiments recorded, the yields of lactic acid from soluble starch and glycogen respectively, at the end of 2 hours' incubation, are much alike. In No. 260, starch has given rise to less lactic acid than glycogen

Table I. *Lactic acid formation from glycogen and soluble starch both present to 0.5 %.*

(Average concentration of lactic acid at start 250 mg. per 100 cc.)

		Lactic acid formed (mg. per 100 cc.) in							
	Exp.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.	90 min.	120 min.
258	Glycogen	68	126	178	228	275	309	342	357
	Soluble starch	59	116	154	202	250	284	—	356
260	Glycogen	87	127	159	183	207	229	260	260
	Soluble starch	63	108	140	159	171	178	186	190
261	Glycogen	46	101	139	154	175	192	259	301
	Soluble starch	43	72	105	136	173	199	266	302
262	Glycogen	54	90	125	161	194	216	250	252
	Soluble starch	26	50	77	106	135	163	284	304
263	Glycogen	36	72	107	134	150	160	189	220
	Soluble starch	18	37	60	82	103	120	168	219
267	Glycogen	49	75	86	110	126	140	172	200
	Soluble starch	26	53	77	99	120	138	192	218
268	Glycogen	54	73	88	127	143	162	195	216
	Soluble starch	34	54	82	107	131	158	188	194
272	Glycogen	56	98	123	169	208	237	309	331
	Soluble starch	41	72	104	135	167	196	268	336

Table II. *Phosphoric ester accumulation with soluble starch and glycogen both present to 0.5 %.*

(Average concentration of "inorganic" phosphorus at start 55 mg. per 100 cc.)

Decrease of "inorganic" phosphorus (mg. per 100 cc.) below initial concentration at

		10 min.	20 min.	30 min.	40 min.	50 min.	60 min.	90 min.	120 min.
258	Glycogen	16	6	8	14	27	24	7	0
	Soluble starch	6	4	4	4	4	4	4	0
260	Glycogen	27	38	32	24	15	5	0	0
	Soluble starch	11	5	0	0	0	0	0	0
261	Glycogen	11	20	44	46	40	31	7	0
	Soluble starch	2	4	6	8	10	10	20	16
262	Glycogen	6	4	3	3	2	1	0	0
	Soluble starch	2	0	0	0	0	0	0	0
263	Glycogen	5	7	9	15	18	33	28	15
	Soluble starch	0	0	0	0	0	0	0	17
267	Glycogen	44	53	47	42	35	30	15	3
	Soluble starch	1	0	0	0	0	0	15	16
268	Glycogen	39	41	32	24	15	7	0	0
	Soluble starch	2	0	0	0	0	6	13	4
272	Glycogen	13	25	32	37	31	22	0	0
	Soluble starch	3	4	6	4	3	3	5	0

but this is reversed in No. 262. By following the lactic acid production during the first hour, it will be seen that in every case during the first 40 to 50 minutes the rate of lactic acid production is less with soluble starch than with glycogen. This more rapid formation of lactic acid from glycogen is associated, as will be seen from Table II, with the more rapid formation of phosphoric ester from glycogen. While it is the case that starch shows ester accumulation, in this respect differing from glucose, yet it never shows this phenomenon to nearly

the same extent as glycogen nor does the point of maximum ester accumulation in the case of starch coincide as regards time with that shown by glycogen. In four of the cases, the ester accumulation with starch is delayed until the second hour.

Meyerhof [1926] has investigated the lactic acid production from starch, glycogen, amylopectin, trihexosan and allied compounds and he has found that at the end of 90 minutes' incubation these compounds have yielded practically the same amount of lactic acid. The above experiments are in agreement with Meyerhof's findings as regards lactic acid production at the end of that period of time. Meyerhof suggests, on the basis of an idea of Pringsheim, that this similarity is due to the formation from each of these polysaccharides of a trihexosan. Lohmann [1926] has isolated a triamylose as an intermediate product of the action of muscle-diestase on glycogen. It does not follow, however, that this common intermediate is formed from starch at the same rate as from glycogen. The lower rate of lactic acid formation from starch in the early period of the incubation and the less rapid phosphoric ester formation from starch seem to indicate that the production of intermediates suitable as substrates for the esterifying enzyme takes place more slowly from starch than from glycogen. This great rapidity of ester formation when glycogen is used is one of the outstanding features of this carbohydrate and serves to distinguish it from soluble starch and glucose, which, in the type of extract prepared in this laboratory, resemble glycogen as regards lactic acid production at the end of an incubation of 1-2 hours.

SUMMARY.

Details are given of the results of lactic acid production and phosphoric ester accumulation with glycogen and soluble starch respectively in extracts from the perfused skeletal muscle of eight cats. During the first 40-50 minutes of the incubation, the rate of lactic acid formation and the rate of phosphoric ester accumulation are greater with glycogen than with soluble starch. At the end of 2 hours, however, the lactic acid formation from soluble starch is practically the same as that from glycogen.

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