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Biokinetics of Carbohydrate and Lipid Metabolism in Normal Laying Hen [Part 1]

Determination of Turnover of Glucose

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正常產卵鷄에 있어서 炭水化物과 脂質代謝의 生動力學 [第一報]

포도당 代謝回轉의 測定

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SUMMARY

The pool size of plasma glucose, turnover rate and other concerned items for glucose metabolism in normal laying hen were investigated by a single-injection method using U-C^{14}-glucose. The 11.6 nCi of pure dose was injected to a hen normally fed through the wing vein. The glucose concentration in plasma sample taken at 5 minutes after injection was 214mgper 100ml. From the plottings of logarithmic standard specific activities of plasma taken from 5 to 120 minutes against the time after injection and from the regresion analysis, metabolic states were determined. The pool size was 1.07g, turnover rate was 0.024 per minute, turnover time was 41 minutes, utilization rate was 26mg/min. (0.83 g/hr/kg B.W. 3/4) and glucose space(extracellular fluid volume) was 25.3 per cent of body weight. The values obtained from 10—50 minutes samples were similar to those described above, which we from 5—120 minutes samples.

INTRODUCTION

Annison and White (1961) studied glucose utilization in sheep using C^{14} Baker et al (1954) experimented the oxidation of glucose in normal human subject with C^{14}. Cook (1966, ruminants), Dunn et al. (1957, normal dog), Feller et al. (1950, normal and alloxan diabetic rats), Head et al. (1964, dairy cattle), Riis and Herstad (1967, normal laying hens), and Riis (1968, swine) studied carbohydrate metabolism using radioactive carbon.

The glucose pool size, turnover rate, turnover time, utilization rate, glucose space, and many

interesting articles were measured to study kinetics of glucose metabolism. When treated insulin or other hormone to control metabolical function, the kinetics were clarified at different figures. In order to compare the values from a normal laying hen with those of other animals, the kinetics of glucose metabolism were observed using glucose-U-C^{14} dilution method.

MATERIALS AND METHODS

A White Leghorn hen, 1980 grams body weight, was anesthetized by the gas of fluothane. This hen had been feeding 100-120g concentrates per day. Apolyethylene catheter was led into wing vein, was filled with sodium citrate solution to prevent blood clotting, and was plugged tightly.

The one ml glucose-U-C^{14} solution (14.2 nCi in raw activity) was injected through catheter in the morning shortly after the a.m. feeding. At 5, 10, 15, 21, 25, 30, 40, 50, 60, 90, and 120 minutes after injection, blood samplees were taken into tubes containing one drop of heparin to prevent blood clotting and containing 0.3 gram sodium fluoride to prevent enzymatic glycolysis. Every collection of blood samples was followed by a injection of similar amount of sodium citrate solution as the volume of blood drawn out.

The blood samples were centrifuged as soon as possible to preventa possible glycolysis. The plasma solutions were collected in small tubes, which were placed in a freezer (−20°C). The glucose content was measured by Hultman's method after deproteinization. The count rate was determined through glucose pentaacetate.

The specific activity of plasma glucose were divided by the injected pure dose per kg body weight. The pure dose in present experiment was 11.64 nCi which was 82.7% of 14.2 nCi. The latter was multiplied by 10 and converted to logarithmic value, which was called logarithmic standard specific activity. These values were plotted against the time on which the blood samples were taken. The regression equation was obtained.

Theortically, the rate of decline in the specific activity of blood glucose-U-C^{14} is described by the following differential equation (Cook, 1966):

$$\frac{dx}{dt}=ax \qquad (1)$$

where, x=Specific activity of glucose

t=Time after injection

a=Const=reciprocal of turnover time.

Integration of (1) and evaluation of the constant of integration at $t=0$,

where $x=x_0$, the zero time specific acivity gives the equation

$$x=x_0e^{-at} \qquad (2)$$

Taking the natural logarithm of (2) and substituting b for ln x_0 gives the equation:

$$\ln x=-at+b \qquad (3)$$

A plot of ln x against time gives a straight line with slope of-a and ordinate intercept of b. The body pool size of glucose is then the value of injected does/anti ln b. The utilization rate of glucose is the pool size times the slope of the curve.

Practically, the regression line was obtained in 10-base logarithmic system. The values on the regression line, therefore, should be multiplied by 2.303 to gain natural logarithmic values. The slope times 2.303 shows the turnover rate.

RESUITS AND DISCUSSION

1. Glucose concentration in plasma.

It was known that the glucose concentration in half a ml of the supernatant solution from plasma samples decreased gradually following the time after injection, even though there was some zigzag in the later part of this experiment. The reason for this decrease might be the taking the blood and the injection of sodium citrate solution which was glucose-free.

To estimate the glucose concentration in plasma, the amount of supernatant solution was observed after centrifugation. From 6ml of mixed solution about 4.5ml of supernatant was obtained. Since half a ml of this solution had 0.119mg glucose for the sample taken at 5 minutes after injection, it was estimated that 4.5ml had 1.071 mg of glucose which was corresponding to 0.5ml plasma solution, and that the concentration of

glucose in plasma would be 214.2mg per 100ml (Table 1).

Riis (1967) published that the concentration of plasma glucose was 220mg, averagely, for the hens normally fed until before the trial. Sturkie (1954) cited that Thompson and Carr observed the glucose concentration of chickens plasma; 213.2mg per 100ml.

2. Metabolism of glucose

The logarithmic standard specific activity of plasma glucose was plotted against the time on which the blood samples were taken (Figure 1). The regression equation was obtained:

$$y=1.27-0.0106x \qquad (1)$$

Where Y is the logarithmic standard specific activity multiplied by 10 and x is the time on which the blood samples were taken.

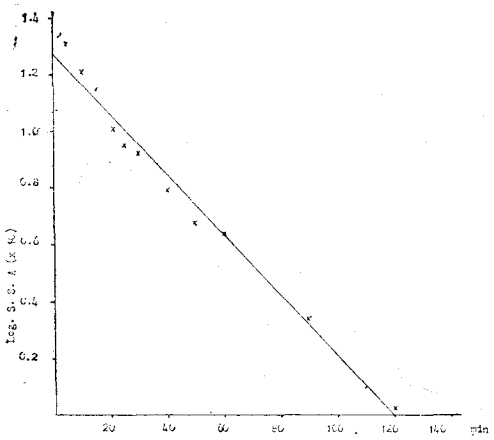

Fig. 1. The semilogarithmic plot of the disappearance for plasma glucose activity after injection of uniformly labeled glucose for 120 minutes.

Although there were no significant deviation from the straight line, the first and last part of plots lay above the line. In order to get other possible information the regression line for 10 to 50 minutes was drawn on Figure 2. The regression equation (2) was obtained:

$$y=1.32-0.0132x \qquad (2)$$

The pool size was expressed as the value per unit body weight. From equation (1) the pool size was measured as 1.065g per kg body weight. However, the value from equation (2) 0.957g was derived. The plasma glucose concentration, turnover rate, turnover time, and glucose utilization were shown on table 1.

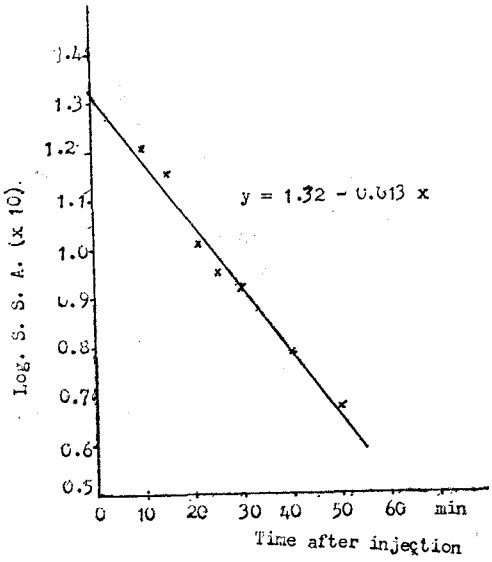

Fig. 2. The semilogarithmic plot of the disappearance for the plasma glucose activity after injection of uniformly labeled glucose for 50 minutes.

Table 1. Comparison of results obtained from this experiment and Riis's

Experiment	Plasma glucose concentration mg/100ml	Glucose pool			Glucose utillized mg/min
		Size g	Turnover rate /min	Turnover time min	
This experiment					
(1) For 5-120 min	214	1.065	0.024	41	26
(2) For 10-50 min	214	0.957	0.030	33	29
Studies of Riis					
(1) Non-fasted	220	1.18	0.015	62	19
(2) Fasted for 16 hours	265	0.95	0.028	38	26

Glucose pool size obtained from overall smples is little more than that from 10-50 minutes samples, because the slope value of the straight line in Figure 1 is less and the intercept is, also, lower than those in Figure 2. Kronfeld (1964) and While (1961) measured glucose space dividing the pool size by the plasma glucose concentration and by the metabolic body weight. This term approximates the extracellular fluid volume per kg body weight. From this experiment the glucose space was determined as 25.3 and 22.8 per cent for overall samples and for 10-50 minutes samples, respectively.

In order to compare the glucose spaces between feeding conditions and between animal species, Table 2 has been established.

Viewing from both results for 5-120 minutes and 10-50 minutes, there were not much difference. Hence either results for long or short period could be used for the determination of turnover of glucose.

Table 2. Comparison of glucose concentrations, pool sizes, and spaces as affected by feeding conditions and by animal apecies.

Species	Body weight (kg)	Feeding (Fasted hour)	Plasma glu. content (mg %)	Glucose pool (g)	Glucose space (% body wt)
Chiken(5-120min)	1.98	1	214.2	1.065	25.3
Chiken(10-50min)	1.98	1	214.2	0.957	22.6
Sheep*(Single I)	36.6	24	76	5.01	18
Sheep(Continous)	33.5	24	59	3.75	23
Cow**(Normal)	527	1	43	89	32
Cow**(Insulin)	525	1	40	92	44
Cow**(Fed)	554	1	61	95	28
Cow**(Fasted)	503	96	51	72	28

* Kronfeld and Simesen (1961)
** Kronfeld and Raggi (1964)

According to the increasing body weight, plasma glucose concentration decreased and glucose pool size increased, but the glucose space, i.e., extracellular fluid was generally similar.

Kleiber(1965)[8] described that the concept of

Table 3. Comparison of utilization rates.

Species	Experiment (Single inj.)	Body wt. kg	Fasting hour	Utilization rate g/hr/kg b.w. 3/4
Chicken	5-120 min.,	1.98	1	0.83
Chicken	10-50 min.,	1.98	1	1.04
Chicken*	5-100 min.,	1.8	14-18	1.08
Sheep**	40-160 min.,	49	16	0.34
Sheep**	40-160 min.,	44	96	0.19
Sheep**	40-160 min.,	44	1	0.28
Cows***	40-150 min.,	465	48-120	0.30
Cows****	30-180 min.,	575	24	0.35

* Riis and Herstad (1967)
** Kronfeld and Simesen (1961)
*** Kronfeld and Raggi (1964)
**** Head et al. (1964)

isokinetic bahabior could be used in intermediary metabloism. Isometrically built animals have metabolic proportional to their body weight and have rates of intermediary transfer proportional to the metabolic size or the 3/4 power of body weight.

Trasfer rate=pool content×turnover rate.

Kronfeld and Raggi(1964) used "entry rate" instead of "transfer rate". Annison and White (1961) used "utilized rate" for these term, and Riis and Herstad (1969) also used the term "utilization". On this report the term "utilization rate" was used. For interspecies comparison, it is convennient to relate metabolic parameters to the metabolic body size. The units on the column of Table 1 were arranged to the g/hour and the values were divided by $1.98^{3/4}$.

要　　約

單一注射方法에 依하여 正常產卵鷄의 포도당代謝에 關聯되는 血漿포도당의 代謝풀(pool)크기, 代謝回轉速度, 代謝回轉時間, 其他 關係되는 項目들을 調査하였다,

날개의 靜脈을 通하여 正常的으로 飼養된 產卵鷄에 11.6μCi의 純粹포도당—C^{14}를 注入하였으며 注射 5分後에 採取한 血液의 遠心分離에 依하여 얻어진 血漿의 포도당 濃度는 100ml當 214mg이였다. 血漿포도당의 標準比放射能의 對數를, 注射後 血液을 採取한 時間(5分부타 120分까지)에 對하여 그린 曲線과 그의 回歸方程式에 依하여 여러가지 代謝狀態를 測定하였다. 포도당代謝의 풀(pool)크기는 1.07g이었고 代謝回轉速度는 1分間 0.024이었으며 代謝回轉時間은 41分이었다. 포도당의 利用速度는 1分間 26mg이였으며(0.75乘한, 即 代謝體重 kg當) 1時間當 0.83g이었다. 포도당 空間(細胞外 體液의 容量)은 體重의 25.3이었다. 注謝後 10分부터 50分까지 採取한 試料로부터 얻은 結果도 上記의 5分부터 120分까지의 試料에서 얻은 成績과 比等하였다.

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