STUDIES ON THE NUTRITION OF LUMINOUS BACTERIA V. INFLUENCES OF CARBOHYDRATES AND POLYHYDRIC ALCOHOLS ON THE GROWTH AND LUMINESCENCE

BY NOBUSADA OKOTI

SCIENTIFIC RESEARCH INSTITUTE, TOKYO

In 1924 H. Miura (1) isolated 2 strains of luminous bacteria from dead fish. He found that one strain decomposed glucose, maltose, dextrin, galactose, fructose, glycerol and mannitol and could not decompose sucrose, lactose and inuline, but the other strain decomposed only glucose, galactose, fructose and glycerol. In 1932 F. Fuhrmann (2) studied the influence of sugars on luminescence, and obtained the following results: Glucose, fructose and galactose did not increase materially the luminescence; and greater amounts of these hexoses produced acids and consequently inhibited luminescence. Cane sugar was without any material influence on luminescence, while lactose in moderate amounts increased luminescence, but larger amounts inhibited it. In 1935 F. H. Johnson (3) studied the decomposition of carbohydrates and polyhydric alcohol by luminous bacteria. He concluded that it was difficult to find any important correlations between the molecular configuration of the substrate and the ability of the organism to oxidize it, and only those compounds having 3 or 6 carbons were utilized. In 1942 M. Doudoroff (4) studied the anaerobic metabolism of facultatively anaerobic species of luminous bacteria. He observed that a few species of *Photobacterium* and *Achromobacter harveyi* decomposed glucose and produced chiefly formic acid, acetic acid, lactic acid, ethylalcohol, succinic acid and CO_2 , while *Photobacterium phosphoreum* produced hydrogen and occasionally 2, 3-butylene glycol.

The author studied the influence of carbohydrates and polyhydrin alcohol, obtained in hard conditions of post-war time, on growth and luminescence of luminous bacterium "Jidai No. 23".

EXPERIMENTAL

Methods.	Methods similar to those in part III are used.
Media.	Following 18 synthetic media are used.
Medium LII.	
Medium LIII.	Carbohydrate-free. Similar to Medium LII but without glycerol.
Medium LIV.	Glucose medium. Similar to Medium LII but 1.0 g of glucose is added per 100 cc.
Medium LV.	Fructose medium.
Medium LVI.	Mannose medium.
Medium LVII.	Galactose medium.

- Medium LVIII. Sorbose medium.
 Medium LIX. Xylose medium.
 Medium LX. Arabinose medium.
 Medium LXI. Rhamnose medium.
 Medium LXII. Sucrose medium.
 Medium LXIII. Maltose medium.
 Medium LXIV. Lactose medium.
 Medium LXV. Mannitol medium.
 Medium LXVI. Dulcitol medium.
 Medium LXVII. Sorbitol medium.
 Medium LXVIII. Xylitol medium.
 Medium LXIX. Glucose-galactose medium. 0.5 g of glucose and 0.5 g of galactose per 100 cc are added to Medium LIII.
 Results. Results are shown in Tables, 1 to 6.

Table 1. Comparative experiment among glycerol-, carbohydrate-free-, glucose- and fructose-media.

(1) Growth

Time in Hours		0	24	30	36	42
Media						
LII	Glycerol	4.0 r	0.18 mg	0.23 mg	0.38 mg	0.40 mg
LIII	Carbohydrate-free	4.0	0.17	0.29	0.37	0.32
LIV	Glucose	4.0	0.24	0.32	0.37	0.40
LV	Fructose	4.0	—	0.19	0.31	0.28

(2) Luminescence intensity 10^{-7} lux

Time in Hours		18	24	30	36	42
Media						
LII	Glycerol	Luminescence begins.	12.8	114.9	325.0	228.1
LIII	Carbohydrate-free	"	5.9	87.2	108.0	101.4
LIV	Glucose	"	0.2	—	Weak	Weak
LV	Fructose	Dark	Luminescence begins.	Weak	Weak	Dark

(3) Hydrogen ion concentration

Time in Hours		0	24	30	36	42
Media						
LII	Glycerol	pH 7.6	7.4	7.2	7.1	7.2
LIII	Carbohydrate-free	7.6	7.4	7.2	7.2	7.2
LIV	Glucose	7.6	7.2	6.7	6.6	6.2
LV	Fructose	7.5	—	7.0	6.7	6.3

Table 2. Comparative experiment among glycerol-, mannose-, galactose- and sorbose-media.

(1) Growth

Time in Hours		0	24	30	36*	42
Media						
LII	Glycerol	3.0 r	0.20 mg	0.31 mg	—	0.48 mg
LVI	Mannose	3.0	0.30	0.41	—	0.41
LVII	Galactose	3.0	0.10	0.14	—	0.18
LVIII	Sorbose	3.0	—	—	—	—

(2) Luminescence intensity 10^{-7} lux

Time in Hours		18	24	30	36*	42
Media						
LII	Glycerol	Luminescence begins.	5.9	120.1	—	509.4
LVI	Mannose	"	—	0.7	—	—
LVII	Galactose	Dark	Luminescence begins.	—	—	6.3
LVIII	Sorbose	Dark	Dark	Dark	—	Dark

(3) Hydrogen ion concentration

Time in Hours		0	24	30	36*	42
Media						
LII	Glycerol	pH 7.6	7.3	7.3	—	7.2
LVI	Mannose	7.5	7.0	6.6	—	6.1
LVII	Galactose	7.6	—	7.2	—	6.7
LVIII	Sorbose	7.5	—	—	—	—

* Measurements could not be performed by the giving out of the electric power.

Table 3. Comparative experiment among glycerol-, xylose-, arabinose- and rhamnose-media.

(1) Growth

Time in Hours		0	24	30	36	42
Media						
LII	Glycerol	2.2 r	0.20 mg	0.29 mg	0.41 mg	0.45 mg
LIX	Xylose	2.2	—	—	—	—
LX	Arabinose	2.2	—	—	—	—
LXI	Rhamnose	2.2	0.11	0.17	0.24	0.29

(2) Luminescence intensity 10^{-7} lux

Time in Hours Media	18	24	30	36	42
LII Glycerol	Luminescence begins.	—	28.72	158.4	120.1
LIX Xylose	Dark	Dark	Dark	Dark	Luminescence begins.
LX Arabinose	Dark	Dark	Dark	Dark	Dark
LXI Rhamnose	Luminescence begins.	—	75.50	225.7	111.4

(3) Hydrogen ion concentration

Time in Hours Media	0	24	30	36	42
LII Glycerol	pH 8.0	7.8	7.5	7.5	7.5
LIX Xylose	7.8	—	—	—	7.3
LX Arabinose	7.8	—	—	—	7.8
LXI Rhamnose	8.0	7.8	7.5	7.4	7.7

Table 4. Comparative experiment among glycerol-, sucrose-, maltose- and lactose-media.

(1) Growth

Time in Hours Media	0	24	30	36	42
LII Glycerol	4.9 r	0.19 mg	0.19 mg	0.22 mg	0.22 mg
LXII Sucrose	4.9	0.26	0.26	0.26	0.28
LXIII Maltose	4.9	0.24	0.50	0.43	0.43
LXIV Lactose	4.9	0.14	0.21	0.23	0.19

(2) Luminescence intensity 10^{-7} lux

Time in Hours Media	18	24	30	36	42
LII Glycerol	Luminescence begins.	7.1	98.2	118.4	27.9
LXII Sucrose	"	39.1	54.6	57.0	5.5
LXIII Maltose	Dark	Luminescence begins.	Weak	Weak	Weak
LXIV Lactose	Luminescence begins.	17.8	327.8	277.8	156.3

(3) Hydrogen ion concentration

Time in Hours Media	0	24	30	36	42
LII Glycerol	pH 7.5	7.3	7.3	7.2	7.2
LXII Sucrose	7.5	7.2	7.3	7.1	7.2
LXIII Maltose	7.5	7.2	6.7	6.3	6.1
LXIV Lactose	7.5	7.4	7.3	7.2	7.2

Table 5. Comparative experiment among glycerol-, mannitol-, dulcitol-, sorbitol- and xylitol-media.

(1) Growth

Time in Hours		0	24	36	42	48
Media						
LII	Glycerol	1.5 r	0.13 mg	0.33 mg	0.44 mg	0.48 mg
LXV	Mannitol	1.5	0.06	0.16	0.24	0.24
LXVI	Dulcitol	1.5	0.10	0.20	0.25	0.23
LXVII	Sorbitol	1.5	0.06	0.22	0.24	0.23
LXVIII	Xylitol	1.5	0.04	0.11	0.14	0.14

(2) Luminescence intensity 10^{-7} lux

Time in Hours		13	24	36	42	48
Media						
LII	Glycerol	Luminescence begins.	8.7	382.9	81.2	0.7
LXV	Mannitol	"	13.2	263.7	118.4	17.8
LXVI	Dulcitol	"	18.5	138.7	57.0	0.2
LXVII	Sorbitol	"	7.1	199.5	78.3	33.2
LXVIII	Xylitol	"	1.3	38.1	73.3	0.9

(3) Hydrogen ion concentration

Time in Hours		0	24	36	42	48
Media						
LII	Glycerol	pH 7.6	7.5	7.3	7.2	7.2
LXV	Mannitol	7.6	7.5	7.4	7.4	7.4
LXVI	Dulcitol	7.6	7.4	7.4	7.5	7.4
LXVII	Sorbitol	7.6	7.5	7.3	7.4	7.4
LXVIII	Xylitol	7.5	7.5	7.2	7.4	7.4

Table 6. Comparative experiment among glycerol-, lactose- and glucose+lactose-media.

(1) Growth

Time in Hours		0	24	30	36	42
Media						
LII	Glycerol	4.8 r	0.11 mg	0.19 mg	0.32 mg	0.43 mg
LXIV	Lactose	4.8	0.08	0.14	0.20	0.23
LXX	Glucose + Lactose	4.8	0.10	0.21	0.30	0.32

(2) Luminescence intensity 10^7 lux

Time in Hours		18	24	30	36	42
Media						
LII	Glycerol	Luminescence begins.	1.5	73.3	250.7	111.4
LXIV	Lactose	"	0.8	108.0	269.1	118.4
LXX	Glucose + Lactose	Dark	Weak	Weak	Weak	Weak

(3) Hydrogen ion concentration

Time in Hours		0	24	30	36	42
Media						
LII	Glycerol	pH 7.8	7.6	7.3	7.2	7.3
LXIV	Lactose	7.7	7.5	7.4	7.4	7.5
LXX	Glucose + Lactose	7.7	7.3	7.0	6.5	6.2

DISCUSSION AND SUMMARY

"Jidai No. 23" grows considerably in a medium containing inorganic salts, amino acids mixture, vitamin B complex, branchia constituent and nucleic acid without any carbohydrate or polyhydric alcohol; and slight luminescence occurs. Growth is fair in media containing decomposable hexoses such as glucose, fructose and mannose, except galactose as carbohydrate sources, but luminescence is inhibited by large amounts of acids produced. The growth is slightly inhibited by acids towards the end of incubation period. These results are almost similar to those obtained by Fuhrmann (loc. cit.). Sorbose completely inhibits growth and consequently no luminescence occurs.

Arabinose and xylose inhibit growth and luminescence like sorbose, but methylpentose such as rhamnose promotes luminescence as well as glycerol. Maltose is apparently decomposed and growth is promoted, but luminescence is greatly inhibited. Sucrose has no prominent influence upon either growth or luminescence. Lactose greatly promotes luminescence. These results are also similar to those of Fuhrmann. The mixture of two constituents (glucose and galactose) of lactose inhibits luminescence.

Polyhydric alcohol such as mannitol, dulcitol, sorbitol and xylitol considerably inhibit growth and none of these act in place of glycerol.

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