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Comparison Between the Reducing Action of Monosaccharide Sugars and Their Efficacy in Supporting the Life of Lucilia Sericata Meig

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A COMPARISON BETWEEN THE REDUCING ACTION OF MONOSACCHARIDE SUGARS AND THEIR EFFICACY IN SUPPORTING THE LIFE OF LUCILIA SERICATA MEIG.

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Neither the materials nor the techniques presented in this paper are wholly original. Only the method of comparison and the exact chemical methods can make any claim to originality: the results, and the conclusions one may draw from them, might well have been predicted from results obtained by many students in various ways, as will appear from the brief outline which follows.

In 1927, Bertolf reared honey bee larvae on pure sugars. He found that, so far as the monosaccharide hexoses are concerned, fructose, glucose, and galactose support life in the order given. Fraenkel (1936) found that the adults of **Calliphora erythrocephala** survive equally well on all three of the sugars named and several others also: a situation which certainly does not obtain in the case of **Lucilia sericata.** Loefer (1935) found that the protozoan, **Chlorogonium euchlorum,** exhibits an acceleration of growth in the presence of both fructose and galactose but for some reason glucose has less effect.

Much evidence indicates that fructose is a highly efficient nutrient for many animals. Thus Rowe, McManus, and Plummer (1935) found that, as concerns the ovarian function in young women, there is a much greater tolerance for fructose than for galactose. This is in line with the clinical use of fructose for diabetics.

Weinbach and Calvin (1935) found that the relative reducing power of the monosaccharides is fructose, glucose, galactose, in the order given, and Watchporn and Holmes (1931) had previously demonstrated that fructose is effective in reducing the production of urea by embryonic kidneys, although the effect of galactose in this respect, is irregular, and xylose has no inhibiting effect. Apparently the effect of glucose was not tested.

This outline is by no means a complete account of this most interesting problem. For such a review the reader is referred to Traeger's (1941) excellent discussion, and to the more recent texts on biochemistry.

The adult "greenbottle" fly, **Lucilia sericata** is incapable of surviving upon pure proteins, and evidently depends upon those ingested in the larval state. The chief function of protein ingested by adult flies is the formation of eggs: without it, eggs do not develop. On the other hand, **Lucilia** survives for varying periods of time on pure carbohydrates, especially sugars. The sugar most effective in prolongling life is fructose, which, in pure form, enables 70% of the flies to survive 33 days. On a diet of concentrated glucose flies live about 29 days; while galactose supports life no more than 14 days at most. I cannot agree with Crow (1932) who maintains that this species may live from 6 to 8 days on water alone: repeated experiments under widely varying conditions always brought 100% mortality no later than the fifth day.

When fed sugars in molar dilutions, the time of survival depends in part, of course, upon the dilution of the sugar, but it is also a function of the species of sugar; so that if the same molar concentration of two different sugars is employed in feeding two different groups of flies, there is still a divergence between them as concerns the duration of life. Moreover this divergence

becomes greater as the molar concentration increases, as is illustrated in Table I.

Table I Survival of Lucilia on Monosaccharides

Molar Conc.	Days Surviving On:		
	Fructose	Glucose	Galactose
1/64	7.0	6.0	6.0
1/48	7.5	7.0	6.5
1/32	10.5	9.5	7.5
1/24	14.0	13.0	9.0
1/16	20.0	18.5	11.0
1/8	29.0	27.0	14.0

Since fructose, glucose, and galactose all reduce alkaline cupric sulphate solutions, one would naturally expect them to have a similar effect upon respiratory enzymes and pigments, and upon any substance which has the properties of such enzymes and pigments. Methylene blue, an efficient hydrogen acceptor, is one such substance. It oxidizes fructose very rapidly, glucose somewhat more slowly, while galactose requires a considerable time for oxidation. The reactions are more or less reversible, especially in the presence of free oxygen. Nearly four times as much glucose (20.08 mgs.) as fructose (5.94 mgs.) is required to reduce equivalent quantities of methylene blue in a given time.

In order to obtain a reliable comparison of the reducing action of the three sugars, a given unit of methylene blue solution was mixed with a measured quantity of sugar of known concentration, and the time required for reduction at constant temperature carefully recorded. This was repeated with each sugar, and in order to make the comparison more complete, several "standard" concentrations of the sugars were used. Preliminary tests indicated that the most desirable concentrations were molar dilutions: .02, .04, .06, .08, and .10. In practice, 5 ml. of each was added to five marked test tubes. To each tube 10 ml. of the dye was then quickly added, and the tubes simultaneously immersed in a water bath of 40°C.

The stock solution used in the tests was made by dissolving 0.00047 gms. of the dye in 500 ml. of water to which 1.0 gm. of sodium hydroxide had been added. Methylene blue is reduced only in alkaline solution. It is usually comparatively easy to time the reduction of methylene blue because the color disappears rapidly and completely. The results of the tests are given in the following table.

Table II Reduction of Methylene Blue by Monosaccharides

Molar Conc.	Time Of Reduction In Minutes By:		
	Fructose	Glucose	Galactose
0.02	8.0	13.0	18.0
0.04	6.0	8.0	12.0
0.06	5.0	6.0	9.0
0.08	4.5	5.0	7.0
0.10	4.0	4.0	6.0

One should notice that difference in reduction time for different sugars is much greater at very low concentrations than it is in solutions containing the sugar in more concentrated form. The significance of this is not entirely evident, but it seems to be characteristic, because it appears consistently, even when substances other than methylene blue are used. This is indicated on Table III, which consists of data relative to the reduction of haemoglobin.

Table III Reduction of Haemoglobin by Monosaccharides

Molar Conc.	Time Of Reduction In Minutes By:		
	Fructose	Glucose	Galactose
0.02	14.0	16.0	20.0
0.04	9.0	10.0	12.0
0.06	7.0	7.5	9.0
0.08	6.0	6.5	7.0
0.10	5.0	5.0	6.0

The hoemoglobin solution was prepared by dissolving in 500 ml. of water 1.0 gm. of dry, powdered haemoglobin and 1.0 gm. of sodium hydroxide. The preparation was filtered before use. The reduction of haemoglobin is more difficult to observe because the change in color is from a yellow amber to a cherry red, and the change is often so gradual that it is diffucult to determine the time at which reduction begins and whether or not it has been completed. Only by repeating the experiments many times could reliable conclusions be made as to the reduction time.

Peptone, gelatine and egg albumin did not reduce either methylene blue or haemoglobin, even when the solutions were heated to the boiling point and then allowed to stand for twenty-four hours.

All of the evidence presented seems to indicate that there is a close relationship between the ease with which a carbohydrate is oxidized in the animal body and its ability to support the life of the organism. That this is likewise related to the fact that proteins are not oxidized readily seems probable. Of course the only way one could finally determine whether or not the oxidation of carbohydrates "spares protein" in proportion to the ease with which a given carbohydrate is oxidized would be to run nitrogen determinations on flies fed specific sugars. Apparently this has not been done. Evidently **Lucilia** lacks the chemical machinery for converting ingested proteins into materials which are easily oxidized.

One conclusion seems inevitable: there is no direct relationship between the ease with which a sugar is oxidized and its chemical relationship to other sugars. Glucose and galactose are stereoisomeric aldoses, yet they are not oxidized with anything like equal speed, either in vitro or in the animal body. On the other hand fructose, which is a ketose sugar, is oxidized more easily than either of them.

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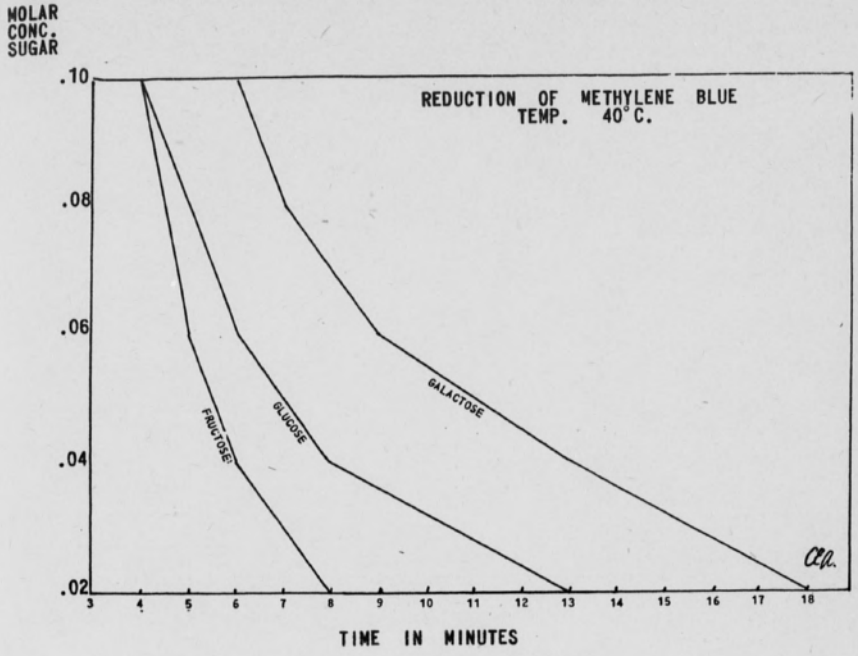
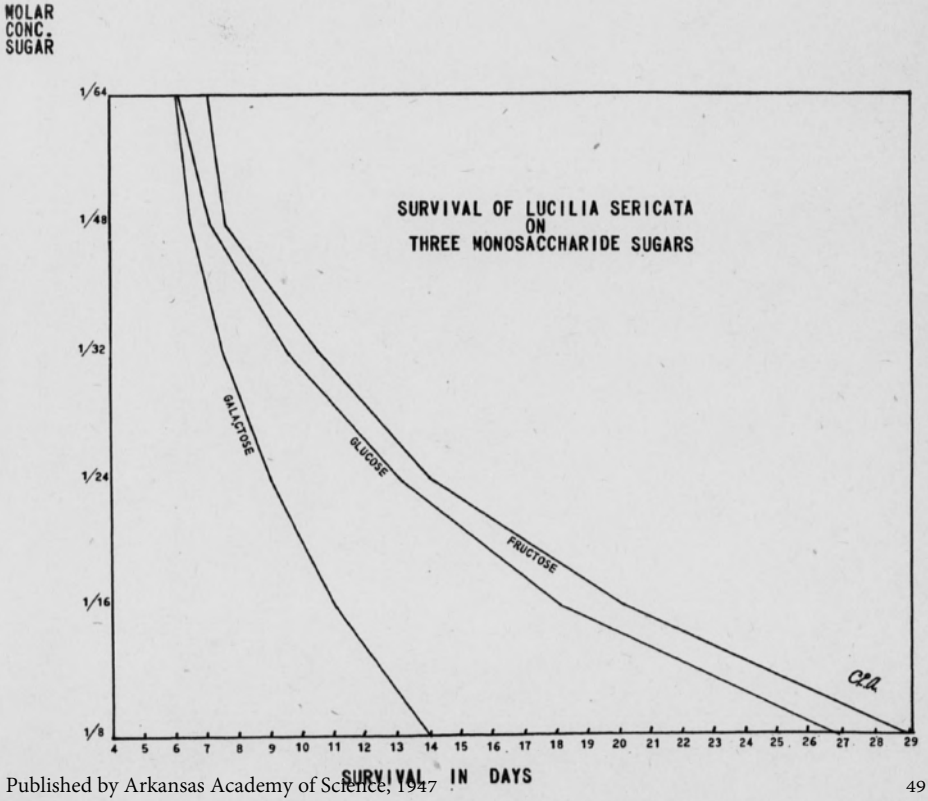

MOLAR
CONC.
SUGAR
.10
.08
.06
.04
.02
REDUCTION OF METHYLENE BLUE
TEMP. 40° C.
GALACTOSE
GLUCOSE
FRUCTOSE
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
TIME IN MINUTES


MOLAR
CONC.
SUGAR
1/64
1/48
1/32
1/24
1/16
1/8
SURVIVAL OF LUCILIA SERICATA
ON
THREE MONOSACCHARIDE SUGARS
GALACTOSE
GLUCOSE
FRUCTOSE
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
SURVIVAL IN DAYS