NUTRITIVE VALUES AND TASTE SENSITIVITY TO CARBOHYDRATES FOR MOSQUITOES

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The stimulating effect of carbohydrates on the mosquito *Aedes aegypti* was previously investigated by Salama (1966). The present study is an attempt to correlate the taste sensitivity to carbohydrates and their nutritive values for the mosquito *Culiseta inornata* Will. as compared with *Aedes aegypti* L.

MATERIAL AND METHODS. Experimental individuals were taken from standard cultures fed on 5 percent sucrose solution. The stimulating effectiveness (acceptability) of 39 sugars and related compounds was tested as previously described by Salama (1966). Different concentrations of tested sugars were presented in fine capillary tubes, 1.5–2.5 mm in internal diameter which fitted over the whole proboscis. The acceptability of a sugar was judged from the abdominal distension and the flow of the solution through the food canal. In another series of experiments, the utilization (nutritive value) of 27 of the tested sugars was determined. Groups of 20 females on the day of emergence were transferred to screened glass cages, 10 in each cage. The tested compound was presented as 5 percent concentrated solution in a small tube 6 x 2 cm, in which was a cotton pad to serve as a feeding substratum for the insects. The solution was changed every three days and experiments were run at 23–25° C. Totalling the daily survival percentages from the day of emergence to the day of 50 percent mortality gives the survival score (Hassett *et al.*, 1950). The utilization of different compounds was compared with sucrose as a standard diet.

RESULTS AND DISCUSSION. *C. inornata* showed the same response to carbohydrates as *A. aegypti* with a few exceptions (Table 1). In the disaccharides, lactose and melibiose are non-stimulating to *Culiseta*, but stimulating (acceptable) to *Aedes*. Both inositol and sorbitol among the polyhydric alcohols are stimulating to *Culiseta* while in *Aedes* only inositol is stimulating. The results generally showed that most pentoses, hexoses, di- and trisaccharides were acceptable stimuli. Compounds with α-linkage were superior stimuli.

From the data on the utilization of sugars (Table 1), it is clear that *C. inornata* can survive well on a limited number of sugars. The control individuals lived on a water diet only, for 4–5 days and for 2–4 days without water. According to the survival scores, the tested compounds can be arbitrarily classified into three nutritive groups:

a—Substances with a high nutritive value and on which the mosquitoes can survive well, with survival scores above 1500. These compounds in the order of decreasing utilization are as follows: melezitose, D-maltose, sucrose, D-fructose, D-glucose, mannitol.

b—Substances which are moderately well utilized and on which the mosquitoes can survive for a few days longer than those receiving water diets alone (9–17 days till 50 percent mortality), with survival scores from 750 to 1500. These include D-mannose, sorbitol, melibiose, D-xylose and raffinose and all were found to be stimulating to the mosquito. Since the control individuals lived for 2–4 days without any food or water, it is presumed that all these sugars were ingested. The failure in promoting long survival compared with su-

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crose and other utilized sugars may be related to the inability of the mosquito to break down or to absorb these materials.

c—Substances with no nutritive value and with survival scores close to that of water (less than 750). These substances when used at high molar concentrations (1M) still showed low survival scores and therefore may be considered as toxic or rejected.

Of these compounds, D-arabinose, sorbose, galactose, xylan, inositol, α-D-methyl glucoside and glucosamine hydrochloride are stimulating to either *Culiseta* or *Aedes*. In a series of experiments, *Aedes aegypti* were offered cotton pads soaked in 5 percent solutions of these sugars colored with methylene blue and they ingested the solutions as shown by

TABLE 1.—Nutritive values and taste sensitivity to carbohydrates for *C. inornata.*

Compound	Days to 50% mortality	Survival scores (daily survival percentages)	Stimulating effectiveness	Stimulating effectiveness in *Aedes* (from Salama, 1966)
Water	4	340	..	..
D-L-glyceraldehyde	3	240	−	−
D-arabinose	4	245	+	+
*L-arabinose	..	....	+	+
D-xylose	9	820	+	+
*L-xylose	..	....	+	+
*L-fucose	..	....	+	+
*D-erythrose	..	....	−	−
D-ribose	3	220	−	−
D-fructose	28	2410	+	+
D-glucose	24	2140	+	+
L-sorbose	3	230	+	+
D-galactose	5	440	+	+
D-mannose	15	1360	+	+
*L-rhamnose	..	....	−	−
*D-α-glucoheptose	..	....	−	−
Sucrose	30	2510	+	+
D-maltose	30	2640	+	+
Cellobiose	4	340	−	−
Lactose	4	320	−	+
Melibiose	13	1170	−	+
*Turanose	..	....	+	+
Melizitose	41	3550	+	+
Raffinose	9	780	+	+
Xylan	4	310	+	+
Glycogen	4	300	−	−
Inositol	5	490	+	+
Sorbitol	16	1310	+	−
Dulcitol	4	330	−	−
Mannitol	18	1970	−	−
Glycerol	3	230	−	−
α-D-methyl glucoside	4	310	+	+
*β-D-methyl glucoside	..	....	+	+
Sucrose octoacetate	2	145	−	−
Gulonic lactone	2	150	−	−
Glucosamine hydrochloride	4	320	+	+
*Glucose-6-phosphate (magnesuim)	..	....	+	+
*α-D-fructose, 1-6-diphosphate (magnesium)	..	....	+	+
*Glucose-1-phosphate dipotassium	..	....	−	−
*Diacetone glucose	..	....	−	−

+ = Stimulating (acceptable), − = non stimulating (non acceptable).
Sugars marked by * are tested only for their stimulating effect, but not for utilization.

dissection. Ribose, cellobiose, lactose, glycogen, glyceraldehyde, dulcitol, glycerol and gulonic lactone, on the other hand, are non stimulating sugars to both *Aedes* and *Culiseta* (with the exception of lactose which is stimulating to *Aedes*). These proved also to be ingested as they were inseparable from the only source of water to the insect. The ingestion of these solutions, however, was in very small quantities, judged by the grade of abdominal distension and by the traces only of the colored solutions in the alimentary tract. It can be assumed therefore that the low survival scores obtained with these compounds may be due either to their toxic effects or to the lack of proper hydrolytic enzymes. Galun and Fraenkel (1957) pointed out that there are enzymes in *A. aegypti* for sucrose, maltose, trehalose and raffinose, but not for lactose and melibiose. To single out the toxic compounds to *Culiseta* in this group, representatives were mixed with sucrose in equal quantities to render the mixture more nutritive and palatable. The non-significant change in survival score of *Culiseta* as compared to the tested compound itself, is observed with ribose, xylan, glycogen, glucosamine hydrochloride and gulonic lactone and this may indicate their toxic effects. The survival scores of arabinose, sorbose, and galactose increased significantly after mixing with sucrose, though remaining less than the survival on sucrose alone. The possibility of competitive inhibition of these sugars in their mixtures with sucrose may be a factor reducing the volume intake and so the survival. Dethier *et al.* (1956) found that the volume intake of mixed sugars by the blowfly is influenced by inhibition.

From these results, no good correlation could be found between the nutritive value and the stimulating effectiveness of the compounds tested. Inositol, for instance, is stimulating but without nutritive value, while mannitol is non-stimulating, but well utilized by the mosquitoes. Mannose is stimulating at a higher median threshold than other sugars, yet has greater nutritive value. Galun and Fraenkel (1957) found that glucose, sucrose, maltose, raffinose, melezitose, and sorbitol are the only compounds *A. aegypti* can utilize well. In correlating their results with my data for stimulating effectiveness of sugars (1966), it shows that sorbitol is non-stimulating to *Aedes,* but well utilized, in contrast to inositol which is stimulating and without nutritive value. The main differences between the species show that raffinose is stimulating, but well utilized by *Aedes* and not by *Culiseta.* Mannose is stimulating to both species, but is more utilized by *Culiseta.* It is clear that with few exceptions the sugars which have nutritive values are tasted, while those without nutritive value may be tasted or not. Previous studies on the honey bee (Vogel, 1931; von Frisch, 1934) and the fleshfly (Haslinger, 1935) showed that the non-nutritive substances are tasteless, but those with nutritive value may be tasted or not. Hassett *et al.* (1950) found no good correlation between the nutritive value of carbohydrates and their acceptability to the blowfly.

Summary. The response of *Culiseta inornata* to carbohydrates showed a few differences from that of *Aedes aegypti.* Lactose and melibiose are non-stimulating and both inositol and sorbitol among the polyhydric alcohols are stimulating. *Culiseta* survives well on a number of sugars which are mostly stimulating. These sugars in the order of decreasing nutritive values are: melezitose, D-maltose, sucrose, D-fructose, D-glucose, mannitol. Other compounds proved to be either toxic or unusable. No good correlation between the nutritive values of sugars and their stimulating effectiveness in *Aedes* or *Culiseta* could be found. Most of the utilized sugars are tasted, while the non-utilized sugars may be tasted or not.

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A CHECK LIST OF THE MOSQUITOES OF THE GREATER ANTILLES AND THE BAHAMA AND VIRGIN ISLANDS

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This compilation is the result of efforts to consolidate the available literature dealing with the mosquitoes reported from the Greater Antilles of the West Indies and the Bahama and Virgin Islands. It is presented in an attempt to authenticate distribution records for the mosquitoes from this area.

The Greater Antilles, for the purpose of this text, include the following major islands and such smaller nearby islands as come within the administrative boundaries of these: Cuba, Hispaniola (including both the Dominican Republic and Haiti), Jamaica and Puerto Rico. The Virgin Islands include those islands immediately to the east of Puerto Rico. The Bahama Islands refer to the chain of British West Indian islands to the south and east of Florida and north of Cuba and Hispaniola.

The selection of this area of limited scope was deemed most practical in our concern over the species of mosquitoes which could accidentally be introduced into the United States by means of aircraft and ships. Every day, in one way or another, man is probably responsible for the transportation and establishment of insects and/or other organisms from one area to another. Many ship and airline traffic routes from South America have made use of these larger islands of the Caribbean for intermediate stops. In addition, the attractiveness of some of these areas as tourist resorts increases the traffic flow to and from the islands and the United States. Current defense and security measures in this area have added to this flow of traffic.

Within the area of the Greater Antilles and the Bahama and Virgin Islands have occurred in the recent past—or occur now—many of the familiar mosquito-borne diseases. These diseases and the primary vectors from the Caribbean area are: malaria, *Anopheles albimanus;* dengue fever, *Aedes aegypti;* eastern equine and St. Louis encephalitis, *Culex* spp., probably *nigripalpus* and *quinquefasciatus* which are known vectors of these maladies in Florida. *Wuchereria bancrofti* as transmitted by *Culex quinquefasciatus* has created at times a filariasis problem in St. Croix, Virgin Islands and in Puerto Rico. Yellow fever transmitted by *Aedes aegypti* has not occurred in the area of the Greater

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