THE EFFECTIVENESS OF CERTAIN PARAFFIN DERIVATIVES IN ATTRACTING FLIES[1]

By William C. Cook

Assistant Entomologist Montana Agricultural Experiment Station

INTRODUCTION

A survey of the literature concerning substances used to attract insects furnishes very little information regarding the relative attractiveness of different members of the paraffin series. Richardson [2] found amyl alcohol more attractive to flies than ethyl alcohol when used at a concentration of 4 per cent. Speyer [3] tried various pure compounds of this series and concluded that the addition of successive CH_2 groups increased the attractiveness of the compound. He also states that amyl compounds are increasingly attractive in the order in which they are naturally formed during fermentation. Peterson [4] reported that the saturated alcohols were attractive to the adults of the onion maggot in the order iso-propyl, ethyl, butyl, amyl, methyl. He exposed his chemicals in a honey solution at about 1.5 per cent concentration. This concentration is near the optimum for iso-propyl alcohol, but is too weak for ethyl and too strong for butyl and amyl alcohols.

The experiments on which this paper is based were planned for the purpose of determining the relations, if any, between the physical properties of the various compounds and their attractiveness to flies. The results will be presented under four headings: (1) The time factor in bait experiments; (2) the relations of physical properties to the dilution most attractive to flies; (3) the relative attractiveness of the paraffin alcohols and esters; and (4) the relative attractiveness of normal and branched-chain compounds.

EXPERIMENTAL TECHNIQUE

These experiments were conducted at Bozeman in the summer of 1923. Flies were abundant, and a total of 50,000 were captured. About 50 small wire balloon-type flytraps were used, and these were kept in one location during the entire summer. Since preliminary experiments had indicated that the traps could be run quite close together without influencing the results, about four or five were placed 18 inches apart in a circle, and several circles were placed on a line. Figure 1 shows the arrangement of one-half of the series during one experiment. When check traps were used they were placed between the circles, which were then moved farther apart.

The standard or basic bait was 25 c. c. of 10 per cent cane molasses solution. A sufficient quantity of the chemical was added to this to give the desired concentration. Very dilute solutions of a chemical

---

1 Received for publication Mar. 14, 1925; issued February, 1926.

2 RICHARDSON, C. H. THE RESPONSE OF THE HOUSE-FLY TO CERTAIN FOODS AND THEIR FERMENTATION PRODUCTS. Jour. Econ. Ent. 10: 102-109. 1917.

3 SPEYER, E. R. NOTES ON CHEMOTROPISM IN THE HOUSE-FLY. Ann. Appl. Biol. 7: 124-140. 1920.

4 PETERSON, A. SOME CHEMICALS ATTRACTIVE TO ADULTS OF THE ONION MAGGOT (HYLEMYIA ANTIQUA MEIG.) AND THE SEED-CORN MAGGOT (HYLEMYIA CILICRURA ROND.). Jour. Econ. Ent. 17: 87-94. 1924.

were obtained by successive dilutions of a concentrated solution. After the chemical was added the bait solution was absorbed on sufficient bran to make a wet mash. This retarded the evaporation of the solution and greatly facilitated handling.

The chemicals used in the experiments, together with their formulae and boiling points, are given in Table I.

TABLE I.—*Chemicals used in experimental work*

Name and grade	Boiling point (° C.)	Formula
Ethyl alcohol, absolute	78.4	C_2H_5OH.
Ethyl acetate, practical	71 to 74	$CH_3COOC_2H_5$.
Ethyl propionate, technical	85 to 102	$C_2H_5COOC_2H_5$.
Ethyl butyrate, technical	108 to 122	$C_3H_7COOC_2H_5$.
Ethyl n-valerate, c. p	144 to 144.5	$C_4H_9COOC_2H_5$.
Iso-propyl alcohol, 90 to 95 per cent	80 to 81	C_3H_7OH.
Iso-propyl acetate, c. p	87 to 88	$CH_3COOC_3H_7$.
N-propyl n-propionate, c. p	122 to 124.5	$C_2H_5COOC_3H_7$.
N-propyl n-butyrate, c. p	142 to 144.5	$C_3H_7COOC_3H_7$.
N-propyl iso-valerate, technical	150 to 160	$C_4H_9COOC_3H_7$.
Iso-butyl alcohol, c. p	106 to 108	C_4H_9OH.
N-butyl acetate, c. p	124 to 126	$CH_3COOC_4H_9$.
N-butyl propionate, c. p	142 to 144	$C_2H_5COOC_4H_9$.
N-butyl butyrate, technical	155 to 167	$C_3H_7COOC_4H_9$.
N-butyl n-valerate, c. p	183 to 185	$C_4H_9COOC_4H_9$.
Iso-amyl alcohol, c. p	130 to 132	$C_5H_{11}OH$.
Iso-amyl acetate, technical	110 to 140	$CH_3COOC_5H_{11}$.
Iso-amyl propionate, c. p	159 to 161	$C_2H_5COOC_5H_{11}$.
Iso-amyl butyrate, technical	159 to 179	$C_3H_7COOC_5H_{11}$.
Iso-amyl valerate, technical	65 to 80/8 mm	$C_4H_9COOC_5H_{11}$.

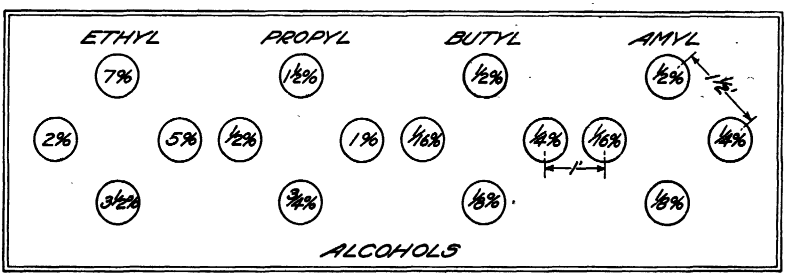

FIG. 1.—Arrangement of part of the trap series in the alcohol experiments

THE TIME FACTOR IN BAIT EXPERIMENTS

In determining the relative attractiveness of two substances which differ in boiling point and probably also in volatility, it is impossible to draw conclusions without considering the time factor. The more volatile compound may be more attractive at first, but will evaporate more quickly, whereas the less volatile compound will remain attractive for a longer time. In order to test this point several experiments were made, in each of which the most attractive concentrations of several compounds were exposed together until only a few flies were attracted. The flies were collected and counted every 24 hours. The combined results of three experiments, each run for 72 hours, are given in Table II.

TABLE II.—*Influence of length of exposure upon relative attractiveness of paraffin alcohols to flies*

Exposure period	Total number of flies captured in each period by use of—			
	Ethyl alcohol (7 per cent)	Propyl alcohol (1 per cent)	Butyl alcohol (¼ per cent)	Amyl alcohol ($\frac{1}{16}$ per cent)
First 24 hours	328	232	108	74
Second 24 hours	168	209	63	92
Third 24 hours	144	222	223	146
Total (72 hours)	640	663	394	312

It will be noted that ethyl alcohol caught the largest number of flies during the first period; iso-propyl alcohol during the second period; and butyl alcohol during the third period. When the captures for the three periods are combined, iso-propyl alcohol is seen to have captured the greatest number.

If it had been possible to continue the experiments for a longer period, the higher alcohols would have caught still more flies. A single experiment, not included in the above table, showed that at the end of five days (120 hours) iso-amyl alcohol had caught a much larger number of flies than ethyl alcohol.

It is evident that a standard exposure period must be used if the results of different experiments are to be comparable. For that reason all the remaining experiments cited in this paper were run for a uniform exposure period of 24 hours.

RELATION OF PHYSICAL PROPERTIES TO THE DILUTION MOST ATTRACTIVE TO FLIES

METHODS

For these experiments the traps were arranged as shown in Figure 1. Several dilutions of a single compound were placed in a circle, and usually four such circles were set out, each containing a different compound. The whole set was duplicated, so that two traps of each dilution of each compound were exposed at once. No control traps were used, since the object of the experiments was to find the most attractive dilution of each chemical, and not the relative attractiveness of the various chemicals.

RESULTS

The work was started on an empirical basis with the four alcohols, and the detailed results for ethyl alcohol are given in Table III.

TABLE III.—*Flies caught on various dilutions of ethyl alcohol*

Per cent solution	Experiment No.								Total
	1	2	12	13	14	23	24	25	
10	[a] 12	16							28
7		41	8	15	30		235	143	472
6			5	10	7				22
5	19	31	7	11	20		273	93	454
4			5	14	21				40
3						103			103
2.5		28							28
2						143	208	99	450
1.5						109			109
1						117	172	161	450
Total	31	116	25	50	78	472	888	496	2,156

[a] Each number represents the total flies caught in two traps in 24 hours.

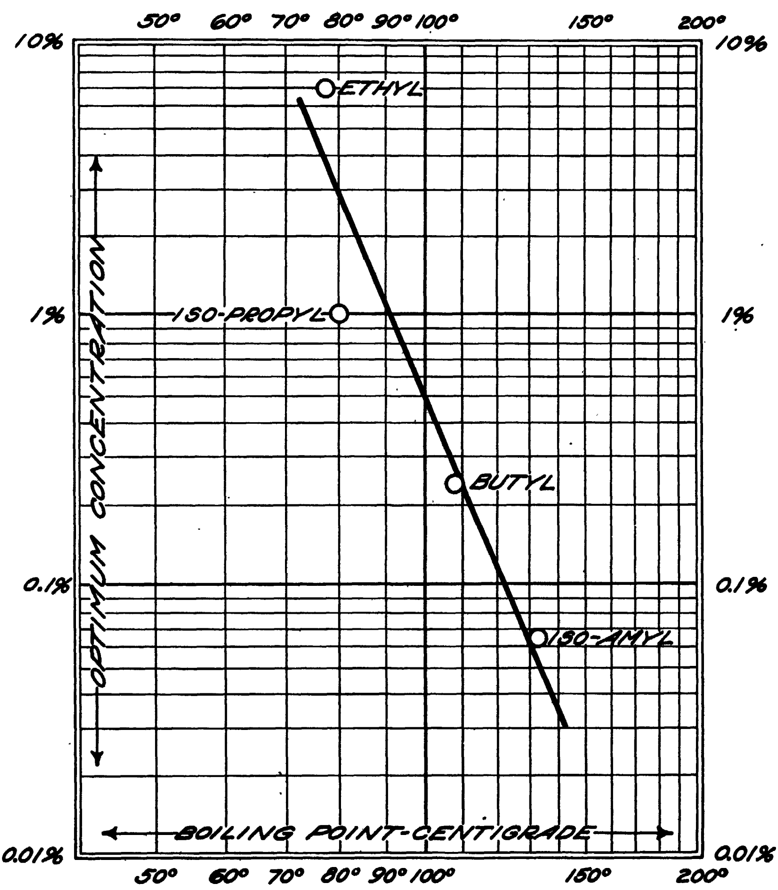

FIG. 2.—Relation of optimum concentrations of alcohols to their boiling points

DISCUSSION

An examination of Table III shows that the 7 per cent ethyl alcohol was the most attractive dilution. The 5 per cent alcohol caught nearly as many flies, but the 7 per cent ranked higher in five of the six experiments in which the two dilutions were exposed together. It is out of the question to present detailed results for all of the compounds in this paper. The complete data are in the files of the entomology department, Montana Experiment Station. The following dilutions of alcohols were found most attractive to flies:

Ethyl alcohol, 7 per cent; boiling point, 78° C.
Iso-propyl alcohol, 1 per cent; boiling point, 80° to 81° C.
N-butyl alcohol, ¼ per cent; boiling point, 106° to 108° C.
Iso-amyl alcohol, $\frac{1}{16}$ per cent; boiling point, 130° to 132° C.

If the logarithms of these concentrations be plotted against the logarithms of the boiling points, the points so found will lie nearly on a straight line (fig. 2).

Using this relation as a working basis, the other compounds were tested in concentrations lying above and below the intersections of their boiling points with this line. In each case the optimum concentration lay fairly close to the line.

The most attractive concentration of each of the 20 compounds used, together with some of the physical constants of each compound, is given in Table IV. The writer is indebted to Jean Timmerman, of the University of Brussels, Belgium, for data on the freezing points of these compounds.

TABLE IV.—*Most attractive dilutions and some physical constants of the paraffin compounds used*

Compound	Molecular weight	Formula	Boiling point (° C.)	Freezing point (° C.)	Most attractive strength
					Per cent
Ethyl alcohol	46	C_2H_5OH	78.4	−114	7.000000
Propyl alcohol (iso)	60	C_3H_7OH	80 to 81	−127	1.000000
N-butyl alcohol	74	C_4H_9OH	116 to 118	−89.8	.250000
Iso-amyl alcohol	88	$C_5H_{11}OH$	130 to 132		.062500
Ethyl acetate	88	$CH_3COOC_2H_5$	71 to 74	−82.4	1.000000
Iso-propyl acetate	102	$CH_3COOC_3H_7$	87 to 88	−73.4	.500000
N-butyl acetate	116	$CH_3COOC_4H_9$	124 to 126	−76.8	.062500
Iso-amyl acetate	130	$CH_3COOC_5H_{11}$	138 to 140		.015625
Ethyl propionate	102	$C_2H_5COOC_2H_5$	85 to 102	−73.9	.250000
N-propyl n-propionate	116	$C_2H_5COOC_3H_7$	122 to 124.5	−75.9	.200000
N-butyl propionate	130	$C_2H_5COOC_4H_9$	142 to 144	−89.2	.100000
Iso-amyl propionate	144	$C_2H_5COOC_5H_{11}$	159 to 161		.025000
Ethyl butyrate	116	$C_3H_7COOC_2H_5$	119 to 121	−93.3	.400000
N-propyl n-butyrate	130	$C_3H_7COOC_3H_7$	142 to 145	−95.2	.037500
N-butyl butyrate	144	$C_3H_7COOC_4H_9$	163 to 166	−97.5	.020000
Iso-amyl butyrate	158	$C_3H_7COOC_5H_{11}$	159 to 179		.007500
Ethyl n-valerate	130	$C_4H_9COOC_2H_5$	144 to 144.5	−89.9	.100000
N-propyl iso-valerate	144	$C_4H_9COOC_3H_7$	150 to 160		.025000
N-butyl n-valerate	158	$C_4H_9COOC_4H_9$	183 to 185		.005000
Iso-amyl valerate	172	$C_4H_9COOC_5H_{11}$	194		.002500

The relation between the boiling points of these paraffin compounds and their most attractive dilutions is shown in Figure 3. This graph is plotted on logarithmic paper on which the horizontal scale is about six times the vertical scale. The figures given for each compound represent the number of flies per trap per day caught in all experiments with each concentration. In this way it is possible to show on one chart the concentrations used and the relation between boiling point and most attractive concentration.

There are some noticeable irregularities in the positions of the points with regard to the line, but the fit is as close as can be expected, for there is necessarily a high experimental error in this work.

Within the limits of error, it may be stated that the most attractive concentration of an alcohol or ester of the paraffin series bears a close relation to the boiling point of the compound. The concentration decreases rapidly with an increase in the boiling point, and when plotted logarithmically a straight line is obtained. The approximate formula of this line is

$$\text{Log. opt. sol.} = 13.78 - 7.1 \text{ log. B. P.}$$

showing that the attractive amount decreases about seven times as rapidly as the log. boiling point increases.

THE RELATIVE ATTRACTIVENESS OF THE PARAFFIN ALCOHOLS AND ESTERS TO FLIES

METHODS

The only important change in these experiments was the introduction between the circles of control traps, baited with 10 per cent molasses absorbed on bran. This afforded a basis for comparing the various experiments.

RESULTS

Three sets of experiments were made. In the first set of three experiments all of the ethyl and propyl compounds were tested at their most attractive concentrations. Four traps of each compound were used in each experiment. In the second set of two experiments four traps of each of the butyl and amyl compounds were used. In the third set of nine experiments two traps of each of the entire series of compounds were used. The results of these three series of tests are given in Tables V, VI, and VII.

TABLE V.—*Number of flies caught on ethyl and propyl compounds*

	Alcohol	Acetate	Propionate	Butyrate	Valerate	Total
Ethyl	2,704	2,564	1,570	967	730	8,535
Propyl	1,403	[a] 1,272 [a] (1,798)	1,844	1,233	373	6,125 [a] (6,651)
Total	4,107	3,836 [a] (4,362)	3,414	2,200	1,103	14,660 [a] (15,186)

Four control traps caught 773 flies.

[a] Iso-propyl acetate was used in only two experiments. The figures in parentheses indicate an interpolated total based on the relative catch in experiments in which it was used.

TABLE VI.—*Number of flies caught on butyl and amyl compounds*

	Alcohol	Acetate	Propionate	Butyrate	Valerate	Total
Butyl	444	441	205	218	355	1,663
Amyl	286	563	333	205	70	1,457
Total	730	1,004	538	423	425	3,120

Four control traps caught 233 flies.

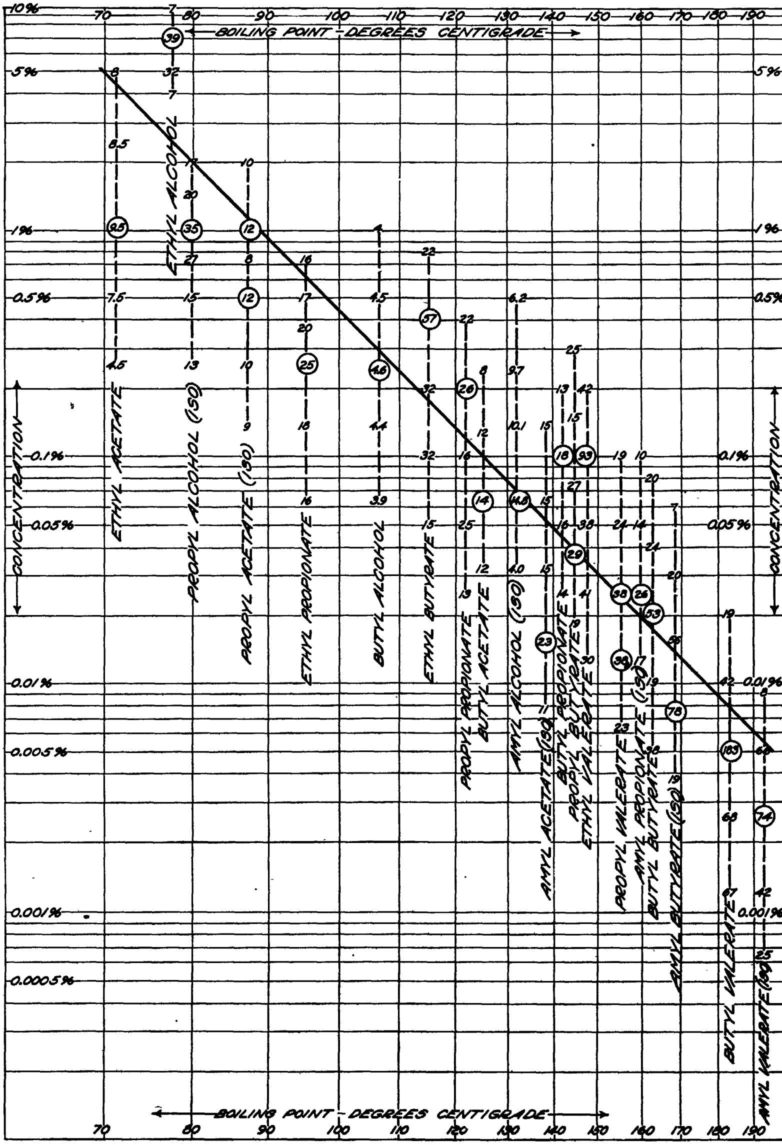

FIG. 3.—Relation between boiling points and optimum concentrations of paraffin compound. Small figures indicate flies per trap per day for each concentration tested. A circle is drawn around the figure for the most attractive concentration

TABLE VII.—*Number of flies caught on 20 paraffin alcohols and esters*

	Alcohol	Acetate	Propionate	Butyrate	Valerate	Total
Ethyl	858	1,202	174	123	226	2,583
Propyl	394	[a] 272 [a] (672)	340	246	49	1,301 [a] (1,701)
Butyl	148	460	446	130	125	1,309
Amyl	177	571	282	166	66	1,262
Total	1,577	2,505 [a] (2,905)	1,242	665	466	6,455 [a] (6,855)

Two control traps caught 165 flies.
[a] Iso-propyl acetate was used only in four experiments. Figures in parentheses indicate calculated values for nine experiments obtained by interpolation.

The data in Tables V, VI, and VII have been carefully studied and plotted. In order that the results of the first two series might be comparable, it was necessary to multiply the figures in Table VI by 3, since the control traps in the first series caught about three times as many flies as those in the second series. The figures in Table VI, multiplied by 3, were added to Tables V and VII. Since the combined results shown in Table VIII differ but slightly from those of the third series (Table VII), they are used as the basis of discussion.

TABLE VIII.—*Combined results of 14 experiments made to determine the relative attractiveness of paraffin compounds to flies*

	Number of flies caught on—					Total
	Alcohol	Acetate	Propionate	Butyrate	Valerate	
Ethyl	3,562	3,766	1,744	1,090	956	11,118
Propyl	1,797	2,470	2,184	1,479	422	8,352
Butyl	1,480	1,783	1,061	784	1,190	6,298
Amyl	1,035	2,260	1,281	781	276	5,633
Total	7,874	10,279	6,270	4,134	2,844	31,401

Control traps caught 1,637 flies.

The only notable difference in the relative position of the compounds in Tables VII and VIII is in the case of butyl valerate. This difference is doubtless due to experimental error. One single trap out of eight in the experiments of Table VI caught 129 flies, whereas the average for the other seven was 32 flies. This difference, multiplied by 3 in forming Table VIII, would account for 291 flies and reduce the total in that table to 899 flies, which would account for the one large discrepancy found in discussing the relative attractiveness of isomeric compounds.

DISCUSSION

If Table VIII is studied in detail several points of interest will be noted. First, there is, in general, a decrease in attractiveness with an increase in boiling point. This is shown by the figures in both columns of totals, and is well illustrated by the alcohols.

The esters constitute a separate group, and will repay further study. As they are located in the table each one differs from its neighbor horizontally or vertically by one CH_2 group. The members of each vertical column differ by one CH_2 group on the alcohol side of the formula, whereas the members of a horizontal row differ by one CH_2 group on the acid side of the formula. Totaling the esters horizontally we get the following results:

Ethyl esters	7, 566
Propyl esters	6, 555
Butyl esters	4, 818
Amyl esters	4, 598

It is seen that the addition of CH_2 groups to the alcohol side of the formula has a slight effect upon the attractiveness.

Totaling the figures for the esters vertically, we get the following results:

Acetates	10, 279
Propionates	6, 270
Butyrates	4, 134
Valerates	2, 844

Here also there is a larger drop from acetates to propionates than is found higher up, but there is a considerable difference between the figures in each case, showing that the addition of a CH_2 group to the acid side of the radical has a relatively large effect upon the attractiveness of the compound to flies.

This is also shown in another way in Table VIII. Omitting the alcohols, the figures in each row decrease regularly from left to right. The one exception, butyl valerate, is probably due to experimental error, as shown above.

Several sets of esters in this group are isomeric; that is, they have the same empirical formula, differing only in the structure of the molecule. One set is that of ethyl propionate ($C_2H_5COOC_2H_5$) and propyl acetate ($CH_3COOC_3H_7$), the empirical formula for each of which is $C_5H_{10}O_2$. Sorting out the five such sets from Table VIII, we obtain the following results:

A	Ethyl propionate	1, 744
	Propyl acetate	2, 470
B	Ethyl butyrate	1, 090
	Propyl propionate	2, 184
	Butyl acetate	1, 783
C	Ethyl valerate	956
	Propyl butyrate	1, 479
	Butyl propionate	1, 061
	Amyl acetate	2, 260
D	Propyl valerate	422
	Butyl butyrate	784
	Amyl propionate	1, 281
E	Butyl valerate	1, 190
	Amyl butyrate	781

There are several irregularities in the table, but in general that member having the lowest acid radical (the lowest of each set as tabulated) is most attractive.

Finally, it will be noted that of 20 compounds studied only 8 were more attractive than the control traps. The remaining compounds were all more or less repellent in action.

The figures given in Table VIII are shown plotted on a logarithmic scale against the boiling points of the compounds in Figure 4. This shows in a more prominent manner the features found in the table.

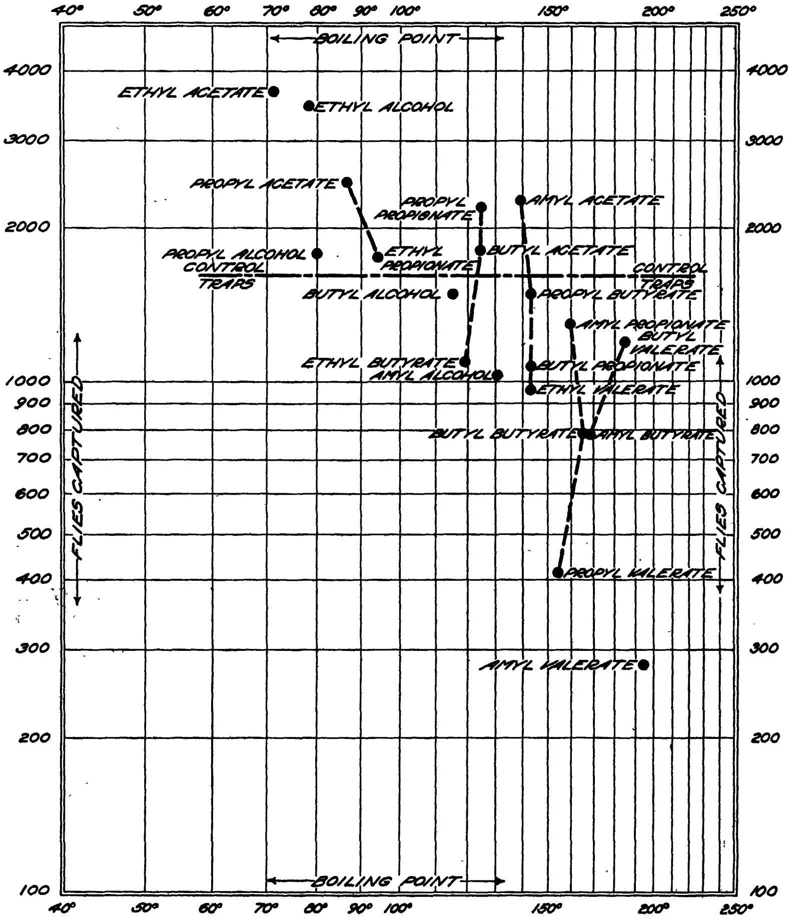

FIG. 4.—Relation between boiling points of paraffin alcohols and esters and their relative attractiveness to flies

RELATIVE ATTRACTIVENESS OF NORMAL AND BRANCHED-CHAIN COMPOUNDS

The final point covered in this investigation is the relative attractiveness of normal and branched-chain compounds. Such compounds as n-propyl alcohol and iso-propyl alcohol are isomeric, having the empirical formula C_3H_7OH. They differ in the arrangement of the atoms in the molecule. Normal propyl alcohol has the structural formula

$$\begin{array}{c} \quad H \quad H \quad H \\ H-C-C-C-OH, \text{ or } CH_3CH_2CH_2OH, \\ \quad H \quad H \quad H \end{array}$$

whereas iso-propyl alcohol has the structural formula

$$\begin{array}{l} \quad\;\; H \\ H-C-H \\ \quad\;\; \vdots \\ H-C-OH, \text{ or } (CH_3)_2\ CHOH. \\ \quad\;\; \vdots \\ H-C-H \\ \quad\;\; H \end{array}$$

The normal compound, as supplied by Eastman, boils at 96° to 98° C., whereas the iso compound boils at 81.5° to 82.1° C., about 15° lower.

RESULTS

Five pairs of such isomeres were studied, four traps of each chemical being exposed to flies at their optimum concentrations for three experiments. The results are given in Table IX.

TABLE IX.—*Relative attractiveness to flies of normal and iso compounds*

Compound	Formula	Boiling point (° C)	Number of flies captured	Ratio (normal=1)
Propyl alcohol:				
Normal	$CH_3CH_2CH_2OH$	96 to 98	243	1
Iso	$(CH_3)_2CHOH$	81.5 to 82.1	260	1.07
Butyl alcohol:				
Normal	$CH_3CH_2CH_2CH_2OH$	114 to 118	61	1
Iso	$(CH_3)_2CH.CH_2OH$	106 to 108	80	1.31
Amyl alcohol:				
Normal	$CH_3(CH_2)_3CH_2OH$	136 to 139	15	1
Iso	$(CH_3)_2CH.CH_2CH_2OH$	130 to 132	48	3.20
Propyl acetate:				
Normal	$CH_3COOCH_2CH_2CH_3$	99 to 102	98	1
Iso	$CH_3COOCH(CH_3)_2$	87 to 88	287	2.93
Butylpropionate:				
Normal	$CH_3CH_2COO(CH_2)_3CH_3$	142 to 144	21	1
Iso	$CH_3CH_2COOCH_2CH(CH_3)_2$	136 to 138	79	3.76

DISCUSSION

In every case the iso compound caught a larger number of flies than the corresponding normal compound. It would be expected that the iso compounds would be slightly more attractive, since their boiling points are lower, but the difference in attractiveness is not proportional to the difference in the boiling point. For example, the two propyl alcohols have the widest difference in boiling point of any pair in the tests, about 15° C., and yet they are the most nearly equal in attractiveness, whereas the two butyl propionates differ by but 6° in boiling point, but the iso compound is more than three times as attractive as the normal compound. The number of flies caught in these experiments is rather small to use in drawing definite conclusions, but it is evident that the iso compounds are more attractive than the normal compounds, and that the difference in attractiveness increases as the boiling points of the compounds increase.

SUMMARY

The experiments herein reported, in which over 50,000 flies were captured, have demonstrated the following points regarding the attraction of flies by organic chemicals of the paraffin series:

(1) There is a definite optimum concentration for each compound studied. This concentration is related to the boiling point of the compound, and becomes smaller as the boiling point rises.

(2) The relative attractiveness of paraffin alcohols and esters is related to the boiling points of the compounds. As the boiling point becomes higher the attractiveness decreases. This relation is somewhat obscured by two other relations: (*a*) The addition of a CH_2 group to the acid radical reduces the attractiveness much more than the addition of a similar group to the alcohol radical. (*b*) This is a corollary of *a*. Of a given set of isomeric compounds, that one is generally most attractive which has the lowest acid radical.

(3) Iso or branched-chain compounds are relatively more attractive than their normal isomeres. The difference in attractiveness increases as the boiling point increases.