A STUDY OF THE

PHYSICAL FACTORS INVOLVED
IN THE SWIFT STABILITY TEST
FOR FATS

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O F THE many test proposed for determining the susceptibility of fats and oils to oxidation, or in a more practical sense, of predicting the keeping quality, the one sometimes referred to as the Swift Test appears to be gaining fairly wide acceptance, and bids fair to become a sort of standard method. It has many good features and has been the subject of cooperative study by a committee of this Society. There is no need to describe the test again, but very briefly it consists in bubbling air through three portions of the sample, which are started at different times, until the one started first yields a rancid odor. Then the peroxide numbers of the test portions are plotted against time, and the stability is expressed as the number of hours that the fat maintains a peroxide number below some arbitrary value. Since the success of this sort of test so frequently depends upon a rigid adherence to the particular set of conditions chosen, the authors of the original publication emphatically cautioned against departing from these. The temperature is 208° F. (97.8° C.), the rate of air flow 2.33 cc./sec., and 20 cc. of fat are treated in 1-in. test tubes in the dark.

The writer's first efforts to use this test produced some erratic results, and since he had departed somewhat from the exact conditions specified in the original paper, it appeared desirable to study the method carefully with respect to these conditions, partly with the object of determining the magnitude of error that might result from any variations in them, and partly to ascertain if some modification might not yield results in a shorter time. This seemed especially important, since the duration of the test for very stable fats of the all hydrogenated type might be in the neighborhood of 100 hours, or four days. This circumstance not only limits the capacity of the apparatus, but renders the test practically useless for control purposes and makes it a slow tool for experimental testing. This was recognized by the stability test committee, the report of which in 1932 indicated its intention to examine the possibility of using metals to further accelerate the onset of the end point.

In the course of the work being reported here certain slight modifications of the apparatus were made which are believed to be improvements in certain respects and are presented for the benefit of those who wish to make their own apparatus at an appreciable saving in cost.

The Apparatus

There are two principal changes.

(1) The substitution of oil color tubes for the 1-in. test tube, and

(2) the elimination of the oil bath. The oil color tubes are more durable than test tubes; they are much cheaper, require less sulphuric acid-chromate solution for cleaning, and are more easily handled during cleaning in quantity. Also a smaller sample is required for the test. When it was found that these would, with a few individual exceptions, fit snugly into 1-in. standard copper pipe (7/8-in. I. D.), a heating apparatus not requiring oil suggested itself. Five inch lengths of the pipe, closed at the lower end, are soldered at the upper end into the cover of a rust resisting closed container in which water is boiled and retained by refluxing. This apparatus may be made quite compact, and requires only a single 500 watt heater to maintain boiling. In the case of the writer's, a cover was soldered on a cheap, drum shaped refrigerator drip pan 14 inches in diameter. For studying the effect of light on the test this shape was required so that all the tubes would be equidistant from the light source. It is heated by an electric iron costing $1.50. The temperature of the fat in the tubes is 99.5° C. (211° F.). This difference of 3° F. from the temperature of the Swift test required the determination of the temperature coefficient of the test results to obtain a correction to apply, making the writer's results comparable to others. The use of smaller tube and less fat necessitated changing the rate of flow so that the rate of flow of air per cc. of fat would be the same as in the Swift test. Fourteen cc. of fat permits the air delivery tube to be 2 inches below the surface, and 1.63 cc./sec. gives the correct flow.

Effect of Modified Flow Conditions on the Results and the Reproducibility of Results

It was suspected that the use of a smaller delivery tube might make for a shorter test time because such produces smaller air bubbles, with consequent considerable increase of contact area between gas and fat (since the area of a spherical bubble varies with the square of the radius). In order to test this and...
to check the validity of the assumption of the compensating effect of a smaller air flow rate with a smaller amount of fat, the following experiment was made: A sample was tested in strict accordance with the Swift method. At the same time the sample was run according to the conditions just described. Also a repeat run was made on another sample which had been stored in the ice box a day or so between tests. The results are shown in Figure 1. It is evident that the method is capable of very good precision and that the writer's modification yields results in line with others. These results are summed up in the following table:

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>Present</th>
<th>Swift Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of fat</td>
<td>20</td>
<td>14 cc</td>
</tr>
<tr>
<td>Rate of air flow</td>
<td>2.33</td>
<td>1.63 cc/sec</td>
</tr>
<tr>
<td>Diameter of inlet tube</td>
<td>0.40</td>
<td>0.25 cm</td>
</tr>
<tr>
<td>Test time</td>
<td>34</td>
<td>34 hrs.</td>
</tr>
</tbody>
</table>

Now careful consideration of the factors involved in a reaction between a gas and a liquid, through which the gas is bubbled, leads to the obvious conclusion that the dimensional elements that would be expected to influence the rate is the area of gas bubble surface contacting unit quantity of liquid in unit time. By this standard the flow conditions just tabulated are not the same, for, as suggested above, the gas inlet tube in the writer's apparatus, being smaller, releases a given amount of air in a given time in the form of more bubbles, and these have a greater total surface. Since, however, the same keeping test was obtained in the two cases, the implication is that the value of the rate of air flow might not be of much consequence to the results.

Although this conclusion was checked and verified by direct test, as will be reported, the magnitude of the differences in surface just mentioned were calculated after making a rough determination of the rate of bubble formation from different sized tubes. The equations used and data for the two conditions are given in Table Ia, as well as two equations relating the number of bubbles formed and the total bubble surface to the size of the tube. That is, within the error of these measurements, the volume of the bubbles, for a given flow, is proportional to the square of the diameter of the delivery tube. Or the area of the bubbles is proportional to the 4/3 power of the diameter of the tube, which may be shown to follow from the above relations.

Thus, increasing the reacting surface by 33% of the regular value had no measurable effect on the results. This suggested that a lot of time might have been wasted in careful calibration of capillary flow tubes. To verify this conclusion by actually using different rates of flow in the same apparatus the data in Table II were obtained. Their reliability is indicated by curves and in Figure I. These coincide almost exactly in Test I.

Therefore, changing the rate of flow by 100% produces no difference in the test results, at least for the particular samples studied. It is realized that these experiments ought to be made on other types of fats and oils before drawing final conclusions regarding this effect, but the following theoretical considerations are in support of the results just presented.

In the case of reactions of the third order, the reaction rates follow the law for monomolecular reactions when two of the reactants are present in great excess relative to the third. The hydrogenation of oils is a typical example. Here, in the general case, the oil and catalyst occur in such high excess over the hydrogen at the points of reaction that the concentration of the latter alone governs the rate. If we can picture a reacting system in which oil is dissolved in extremely dilute solution in some solvent through which hydrogen is bubbled in great excess, then we would expect that the rate, assuming also an abundance of catalyst, would depend on the oil concentration. Or if the catalyst, instead of the oil, were present in extremely small amounts, its concentration would govern the rate. This last is analogous to the state we have in the stability test. The oxidation of the fat is essentially catalytic, the catalyst or catalysts being some compounds resulting from the breakdown of the original reaction products, or the