this last summer against the potato aphid, using the same strength of sprays; I used a gasoline engine pump, giving about 100 pounds pressure and a rubber trailer, just the ordinary trailer hose. I guided the nozzle by hand and sprayed three or four rows of potatoes on each side of the sprayer. One application directed by hand against the lice cleaned them up in good order.

MR. T. J. HEADLEE: How many gallons to the acre did you use with that apparatus?

MR. H. A. GOSSARD: I used about 200 gallons or something like that on an eighth of an acre.

MR. T. J. HEADLEE: The year before last we used an ordinary sprayer against the false cabbage aphid on turnips which were 12 inches high and had assumed the recumbent habit. We found that by the time the lice were thoroughly wetted we had used 1,500 gallons to the acre, making the cost of the application so large as to render the treatment impracticable. With an engine-driven potato sprayer equipped with a lifting device we were able to cover plants of the same size with a little more than 100 gallons of spray mixture to the acre and to get excellent results in control of the aphid.

MR. W. E. BRITTON: I would like to inquire if this treatment was given for the aphid alone?

MR. H. A. GOSSARD: In most instances the sprays I used were combinations of nicotine, lead arsenate and Bordeaux. I didn't use soap where I used the Bordeaux.

MR. W. E. BRITTON: Did you use the sulphur in the nicotine?

MR. J. S. HOUSER: Most of the experimental work that we did was conducted from the standpoint of aphid control alone and not from the standpoint of developing a combined fungicide and aphicide. We therefore used no copper sulphate or lime sulphur, but employed nicotine sulphate, soap, etc., in various strengths and combinations.

PRESIDENT E. D. BALL: The paper by Mr. R. W. Chapman entitled, "Insects Affecting Wheat Flour and Wheat Flour Substitutes," will be read by Mr. W. A. Riley.

INSECTS IN RELATION TO WHEAT FLOUR AND WHEAT FLOUR SUBSTITUTES¹

By R. N. CHAPMAN, *University of Minnesota.*

The ruling of the Federal Food Administration requiring the purchase of wheat flour substitutes with wheat flour called for the milling

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and marketing of coarse flours in larger amounts than had ever before been attempted. The large flour milling interests of Minnesota predicted insect trouble and later the wholesale Grocers' Association and the Bakers' Association asked for help in protecting their stocks of wheat flour substitutes from insects.

In response to these requests work was carried on along two lines; the first, to meet the existing emergency by devising methods of protection, and the second, a study of the ecological relations of insects and the various flours and cereals. The relative susceptibility of different flours to insects is of prime importance in protecting them from insects, and a knowledge of susceptibility should be the foundation for a knowledge of protection.

The emergency work was mainly concerned with the consumers, for millers adopted measures of rapid transportation calculated to move the products to consumption before the eggs, if any were present, could hatch and cause damage. Circular letters issued through the office of the Federal Food Administration from Minnesota urged dealers to adopt the miller's plan of rapid handling and emphasized the necessity for cleanness in their warehouses.

The consumers did not benefit by the millers' and dealers' methods of rapid handling except in cases where only a few days supply of substitutes was on hand at a time. Where it was necessary to purchase larger supplies, the situation was most serious, for the rapid transportation often brought the eggs to the consumer all ready for hatching.

Housekeepers were advised to heat all their substitutes as soon as they were brought into the home in order to kill any eggs or larvæ which might be present. A method of heating to obtain a temperature fatal to insects and yet prevent the cereal from injury by overheating was devised as a result of a series of experiments. The temperature curves show differences in the different ovens used; but in all cases it was found that when the cereal was less than two inches deep in pans, and heated slowly until the surface temperature reached 85° C., the source of heat could be turned off, in the case of a gas, gasoline, or kerosene stove, or the oven door opened in the case of a coal or wood stove, and in the course of half an hour, the heat would diffuse throughout the cereal until all parts of it had passed well above the fatal temperature for insects.

For obtaining satisfactory results, it is essential that the cereal should be less than two inches deep in the pans, that the heating be done slowly with the fire as low as it will burn well in order to allow for the conduction of heat throughout the cereal, and that the heating be

stopped before a temperature has been reached which will injure the cereal (between 90° and 100° C.).

Since high temperature thermometers are not available for all house-keepers, a mixture of carnauba wax and paraffin has been devised which melts at the proper temperature for the surface of the flour. It is not the exact point at which the wax melts, but the melting of the piece of wax to a grease spot that is taken as the indicator. Therefore the piece of wax measures, not only the temperature attained, but also the time required for a certain amount of heat conduction, until the entire piece of wax has melted. Since temperature and time for heat conduction are the factors concerned in the uniform heating of the cereal, the wax may be even more satisfactory than thermometers, which register temperature only.

In practice, the method has proved to be very satisfactory, and is now being used in several states. When methods of rapid transit are followed systematically by the heating of cereals as soon as they are received by the consuming public, the losses which insects cause to these flours and cereals will be reduced to a minimum.

There are, however, certain difficulties to be contended with in the introduction of this method. The public must be acquainted with the method and impressed with its importance; in this the Federal Food Administration for Minnesota has coöperated. The wax must be made available for all, and in this matter the wholesale grocers co-operated in supplying their trade throughout the state, yet there were frequent complaints from those who were unable to obtain wax. To supply the demand the wax must be manufactured at a reasonable cost and yet conform to the requirements as to melting point and size of pieces. This matter has required constant attention but may now be placed on a more satisfactory basis when industry has returned to conditions of peace.

The bakers have experienced heavy losses and have required special attention and methods. Education in matters of cleanliness and a reform in some matters of handling flour have yielded good results. The exchange or refilling of used sacks has been found to be the source of much trouble. Experiments have shown that when empty sacks are placed in the oven, three or four deep on boards and left for five minutes, all the insects in them are killed at the usual temperature of 232° C. While it is necessary to watch the sacks closely to prevent scorching, this practice has given great relief. All rye proofing boxes and other utensils have likewise been heated in the oven with a result that badly infested bakeries have been entirely freed from insects.

The study of the relative susceptibility of the various flours and

cereals has consisted of experimental work in the laboratory and observational work in storehouses. The experimental work has proceeded on the assumption that other things being equal, susceptibility may be due either to the attraction which a cereal may offer to insects, influencing the number of insects which might invade it in the first place, or to the rate of development of the insects after entrance, which might result in an accumulation of the insects in great numbers.

In the study of the invasion, the various flours were placed in cylindrical jars with removable partitions, which divided each jar into five equal sectors. A different flour was placed in each sector, the partitions were removed, and the insects were placed in a depression in the center of the jar. Being thus surrounded by equal amounts of the different flours, the insects were free to express a choice if they had any.

The experiments were carried on in the dark and extended from a few hours to several days, the length of time making little difference after the first few hours, when the insects were exploring about. When an observation was to be made, the partitions were replaced and the contents of each sector removed, to count the insects contained in it. When one hundred insects were used in the experiment, the number found in a given cereal would be the percentage of relative susceptibility of that cereal as compared with the others used in the experiment.

The relations of *Tribolium confusum* to five grades of wheat flour and various wheat flour substitutes were studied in this way. The results of 25 experiments with adult beetles showed the following percentages: 1st Sizings, 10.6 per cent; 1st Middlings, 11.5 per cent; 1st Low Grade, 12.4 per cent; 1st Tailings, 14.6 per cent; 5th Bran, 52 per cent. The coarseness of these flours varies in the order named from the fine sizings to the bran. The experiments with larvæ did not show a variation greater than 7 or 8 per cent on either side of 20 per cent, the expectation, and consequently show no preference, for an average of about one-fifth of the total number of larvæ were found in each sector.

The results with the wheat flour substitutes showed no percentages constant enough to denote decided choice, either among the various substitutes or as compared with low grade wheat flour, so long as the coarseness remained about equal in all cereals. When the bran from rye meal was introduced into the experiments a decided percentage was noticed. It contained an average of 36 per cent of the beetles and was very constant, while the percentages found in the other portions were small and subject to greater variation. When coarse corn meal was used, no increase in percentage was found.

It seems, therefore, that a coarse, flaky material is more attractive

than a fine or granular material, and that the element of flakiness is, so far as choice is concerned, dominant over nutritive differences, if nutritive differences exist. To check this, some bran was ground to fineness and given an equal exposure to the beetles with the coarse bran. An average of 60 per cent of the beetles were found in the coarse bran and 40 per cent in the fine bran. Again four sections of a jar were filled with fine sawdust and the fifth with coarse sawdust. The sector with the coarse sawdust contained an average of 43.3 per cent of the beetles and the other sections averaged 15.3 per cent, 13.6 per cent, 12.2 per cent and 14.6 per cent respectively. It may therefore be concluded that the factor of coarseness is dominant and the factor of nutritive choice, if measurable, is less significant.

In the study of the relative development of the insects in the various wheat flours and substitutes, it was found that the larval life might be prolonged in certain wheat flour substitutes and that this prolongation took place in the last larval instar. In some cases the life-cycle was twice as long as in other cases. These experiments were all carried on under the same conditions, in an atmosphere of 70 per cent of relative humidity. (The temperature curve on the chart shows a drop of a few degrees near the end of the experiment, with a consequent prolongation of some of the pupal stages.) Further experiments now under way will furnish additional data on relative development.

The data accumulated from examinations of flour in warehouses have not yet reached the proportions which will give significant percentages, but the above results combined with general experience make it seem that coarseness is a factor in susceptibility. The fact that coarse cereals cannot be bolted through fine cloths together with the choice of the insects as shown in the invasion experiments substantiates this contention. The factor of relative development must await further investigations before its importance in influencing susceptibility can be judged.

MR. T. J. HEADLEE: Were any chemical studies made of the effect of heat on the flours, or feeds?

MR. W. A. RILEY: There were a number of experiments carried on, both by the chemists who were interested in the general effect on proteids and also by the home economists of the department, showing that there was no injury at this temperature.

VICE-PRESIDENT W. C. O'KANE: The next paper will be presented by Mr. W. E. Britton.