Observations on the heating of grain caused by insects

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Summary

1. The heat output by the insects, *Oryzaephilus surinamensis*, *Tribolium confusum*, *Sitophilus zeamais* and *Sitophilus granarius*, was investigated by reading the temperature of the inside of the grain in which the insects were developing in 2 lb or 7 lb jars incubated at 25°C and 70 % R.H.

2. All the insects tested increase the temperature of grain, but the amount of heat produced by insects varies with the species of and the developmental stages of the insects.

3. It was found that all the temperature peaks correspond with the peak in number of the fourth instar larvae and the period in which the insects start to cause the heating corresponds to its 1 st and 2 nd instar larvae.

4. *Sitophilus* spp. whose larvae live in the endosperm of the wheat produced more heat than *Tribolium confusum* and *Oryzaephilus surinamensis* whose larvae live on the grain.

5. Among the four species of insects, *Sitophilus zeamais* produces the highest heat, followed by *Sitophilus granarius*, *Tribolium confusum* and *Oryzaephilus surinamensis*.

6. It is considered from the above results that the heat produced by insects seems to depend upon the species, the number and the age structure of population, and its surroundings.

7. It is suggested therefore that when comparing the rate of development of insects kept at different densities, the effects caused by heating at the higher densities must be considered.

Introduction

The phenomenon of heating of grain stored in bulk or in sack has been known for long time. If the heating starts at some points which makes a "hot spot" in the grain and causes the movement of moisture in grain from the centre to the top of the grain, or towards a cooler part of the stack. Here the moisture content of grain becomes very high and it may be favour to the growth of mould or bacteria and cake. Therefore a knowledge of the heating of grain is essential if it is hoped to study the problem encountered in storage of grain. It has been realized that this heating may occur in the grain of either insect infestation or too damp.

In spite of the heating in relation with insects, the possible substantial increase in temperature in culture jar with developmental stages of the insects is not widely recognized. If the insects in the culture raise the temperature of the grain over 2°C above the room temperature, the development of insects may be affected. This aspect is important when comparing the rate of development of insects kept at different densities.

It was aimed, therefore, in this investigation to determine the possible effects of different insect activity on the rise in temperature in grain.

Experimental method

The insects used were *Oryzaephilus surinamensis*, *Tribolium confusum*, *Sitophilus zeamais* and *Sitophilus granarius*, obtained from stock culture bred in an insectary maintained at 25°C and 70 % R.H. A certain number of each insect was put into the jar containing the culture media as shown in Table 1 and a thermometer was inserted into the culture media before it was covered with black filter paper and stuck on with paraffin wax. To prevent the mite and psocid. infestations. The thermometer could be read without disturbing the culture media. Another jar containing the same culture media and a thermometer was prepared for the control. The thermometer was only supported by the filter paper and the paraffin wax. All the jars were incubated at 25°C and 70% R.H. during the experiments. Daily observations on temperature commenced from the day after incubation. All the parent of each insect were sieved out 20 days after incubation and the adults of the first generation(F_1) were sieved out at intervals thereafter and counted. The heat produced by insects was taken by obtaining the differences in temperature between the jar containing insects and the control.

Table 1. The culture media and number of insects used in this experiment.

Insect	No. adult insect	Size of jar	Culture media	Parts by weight
O. surinamensis	100	7 lb	Wheatfeed, rooled oats, yeast	5 : 5 : 1
T. confusum	50	2 lb	Wholemeal flour, yeast	6 : 0 : 5
S. zeamais	50	2 lb	Wheat	8
S. granarius	50	2 lb	Wheat	8

Results

All the results obtained are shown in Table 2 and the heat produced by insects is plotted daily(except for weekends) and the approximate lengths of developmental stages of the insect are marked with arrows in Fig. 1(The developmental periods for *Tribolium* are my own observations and those for the other species are taken from previous work by Dr. R.W. Howe. The actual sequences of the life stages might be quite different). From Fig. 1 it is possible to compare the relation from Howe's data as shown in gradual decline of heat production between the heat output and the age of the insects at the point of pupation.

Oryzaephilus surinamensis : There is no temperature peak throughout the incubation but the rise in temperature of 0.2°C is shown from the 21 st days to 31 st days, corresponding probably to the fourth instar larvae, in considering that the first generation adults have emerged from the 41 st days.

Sitophilus zeamais : The temperature peak is noted at 28 th days, corresponding probably to the peak of number of the fourth instar larvae. To reach the rise in temperature of 2 or 2.5°C which lasted for 11 days, 28 days are needed, but the rise in temperature by insects are significantly noticeable from 13 th day to the end of the observation.

Table 2. Daily record of the rise in temperature caused by insects and the number of emerging adults in the first generation sieved out.

Days after incubation	*Oryzaephilus surinamensis*		*Sitophilus zeamais*		*Sitophilus granarius*		*Tribolium confusum*	
	Amount of heating (°C)	Adults sieved out	Amount of heating (°C)	Adults sieved out	Amount of heating (°C)	Adults sieved out	Amount of heating (°C)	Adults sieved out
13	—	—	0.1	—	—	—	—	—
14	—	—	0.1	—	—	—	—	—
15	—	—	0.2	—	—	—	—	—
16	—	—	0.5	—	—	—	—	—
17	—	—	0.7	—	0.3	—	—	—
20	0.2	—	1.4	—	0.8	—	—	—
21	0.2	—	1.5	—	1.1	—	0.2	—
22	0.2	—	2.0	—	1.1	—	0.2	—
23	0.1	—	2.3	—	1.5	—	0.2	—
25	0.2	—	2.3	—	1.7	—	0.2	—
28	0.1	—	2.5	—	1.8	—	0.6	—
29	0.2	—	2.1	—	1.7	—	0.5	—
30	0.0	—	2.0	—	1.9	—	0.4	—

31	0.2	—	1.9	61	2.0	—	0.7	—
32	—	—	2.0	—	1.8	—	1.4	—
34	—	—	2.0	227	1.9	—	1.5	—
35	—	—	1.9	182	2.0	35	1.2	—
36	—	—	1.8	102	1.9	65	1.0	—
37	—	—	1.6	112	1.6	85	1.7	—
38	—	—	1.3	113	1.4	83	1.5	—
41	—	114	1.0	331	0.8	176	0.9	—
42	—	—	0.9	—	0.5	—	1.0	—
43	—	—	0.8	—	0.5	—	0.8	—
44	—	131	0.8	315	0.5	235	0.9	—
45	—	—	0.6	—	0.5	—	0.7	—
48	—	—	0.8	333	0.7	250	0.5	—
49	—	150	0.5	—	0.5	—	0.4	—
50	—	—	0.4	—	0.9	—	0.4	—
51	—	—	0.4	224	0.6	241	0.2	—
52	—	175	0.3	—	0.5	—	0.1	1039
55	—	—	0.1	144	0.5	236	—	449
56	—	—	0.1	—	0.2	—	—	—
57	—	—	0.1	—	0.2	—	—	—
58	—	—	0.1	63	0.2	124	—	1237
Total	—	470	—	2207	—	1530	—	2725

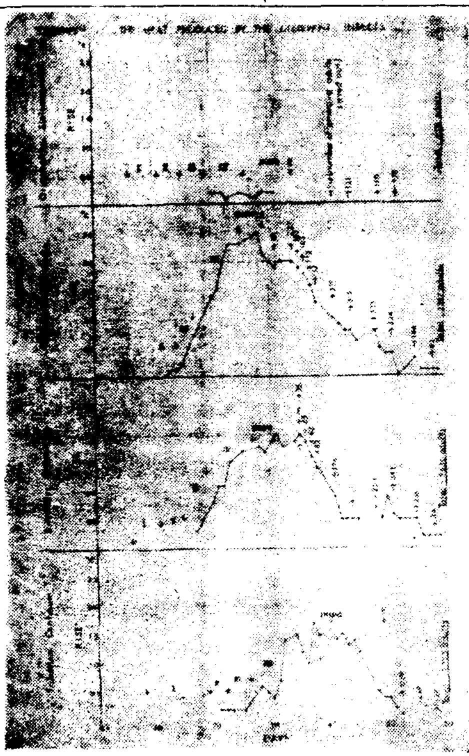

Fig. 1. The heat produced by the different insects.

There is a slight temperature peak, 0.15°C, around 48 th days which might be affected by the presence of adults because in this period about 300 adults were sieved out each time at 3 days interval, while 100 or 200 adults were sieved out every day before this period.

Sitophilus granarius : The rise in temperature was recognized from the 17 th days to the end of the observation, and the temperature peak is noted at 31 st days and 35 days, corresponding mostly to the fourth instar larvae. To reach the rise in temperature of 1.5 or 2.0°C which lasted for 15 days, 26 days are needed. As shown in the case of *Sitophilus zeamais*, the slight temperature peak is shown around 50 th days on which period comparatively larger number of adults were sieved out at 3 day intervals than before.

Tribolium confusum : The rise in temperature is recognized from the 21 st days to 55 th days and the temperature peak is noted at 37 th days, corresponding probably to the fourth instar larvae, and this peak is much lower than that of *Sitophilus* species even though largest number of insects were sieved out throughout the observation and to reach the rise in temperature of 1.5 or 1.7°C which lasted for 9 days, 34 days were needed.

Discussion and conclusion

Some of the thermometer supported by filter paper and paraffin wax moved in the foods during the time at which temperatures were recorded. The bulk of these touched the bottom of the jar and at sieving, the thermometers were removed and replaced in variable position, and this could affect the temperature reading.

However, in any case, the presence of insects in grain cause considerably the rise in temperature in grain, but it varies depending upon the species of insects.

Of four insects tested, *Sitophilus zeamais* seems produce the largest heat, followed by *Sitophilus granarius*, *Tribolium confusum* and *Oryzaephilus surinamensis*.

According to Fig. 1 the trend of heat produced by both *Sitophilus zeamais* and *Sitophilus granarius* whose larvae live in the endosperm of the wheat is generally quite similar each other, but *Sitophilus granarius* show lower heat peak and slower rise in temperature than former which might be resulted from its smaller number of first generation.

In considering the *Tribolium confusum* and *Oryzaephilus surinamensis* whose larvae live on the grain, *Tribolium confusum* produced comparatively less heat than *Sitophilus* sp., although *Tribolium confusum* had the largest number in the first generation. Its smaller size of body, difference in its activity and difference in heat conductivity of wheatmeal flour might have some relation with the degree of heat production.

The heat produced by *Oryzaephilus surinamensis* was the least compared with that of the others. The reason for this possibly due to the larger jar used and the rolled oats as food which has larger surface area from which the heat can be lost more easily than from wholewheat and wheatmeal flour. Also they are the smallest in size and in the population of first generation.

In spite of diversity in amount of heat produced by various insects, all the temperature peaks seem to correspond probably to the peak number of fourth instars larvae and the period on which the insects start to cause the heating corresponds to their 1 st nd 2 nd instar larvae.

It is not clear from this work whether or not a large number of emerging adult affects on the temperature of the culture. This is an aspect which would be investigated.

It may be concluded that the heating caused by insects in grain depends on the species of insect, the number and the age structure of population, the size and the shape of grain and its surrounding. And, therefore, it is suggested that when comparing the rate of development of insects kept at different densities, the effects caused by heating at the higher densities must be considered.

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摘　　要

1. 穀物中의 害蟲이 發熱에 미치는 影響을 調査하기 爲하여 *Oryzaephilus surinamensis*, *Triborium confusum*, *Sitophilus zeamais* 및 *Sitophilus granarius*의 重要害蟲을 供試로 이들의 각각을 25°C 및 70 %의 飼育室에서 2~7 파운드의 飼育瓶에 飼育하면서 溫度의 變化를 調査하였다.

2. 供試된 害蟲은 모두 發熱에 影響을 미치고 있었으나 그 程度는 害蟲에 따라 差異가 顯著하였다.

3. 그러나 4種의 害蟲은 共히 發熱의 始期는 各害蟲의 幼蟲 1~2齡期에 該當하였으며 發熱量의 頂點은 幼蟲 4齡期와 一致하였다.

4. 發熱量을 比較해 보면 *Sitophilus* spp. 와 같이 幼蟲期를 種子內에서 經過하는 害蟲이 穀物 表面에 棲息하는 *Triborium* sp. 및 *Oryzaephilus* sp. 보다 大體的으로 發熱量이 많았다.

5. 供試된 害蟲 중에서 *Sitophilus zeamais*가 發熱量이 제일 높고 다음이 *Sitophilus granarius*, *Tribolium confusum* 및 *Oryzaephilus surinamensis*의 順序였다.

6. 以上의 結果를 보면 害蟲으로 因한 發熱은 害蟲의 種類, 齡期 및 이의 密度, 穀物의 크기 및 形態, 그리고

環境에 따라 影響을 받는다고 하겠다.

7. 害蟲으로 因한 發熱關係는 많은 數의 昆蟲을 使用하여 이의 生活史를 試驗할 때는 必히 檢討되어야 한다고 믿어진다.

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