MILLING LOSSES CAUSED BY INSECT INFESTATION OF WHEAT[1]

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ABSTRACT

Wheat infested at a level of 41 internal forms per 100 g. of dirty wheat lost 1.1% of its weight due to insect feeding during a storage period of 11 weeks. The Entoleter-scourer aspirator used in the cleaning of infested wheat prior to milling reduced the number of insect-infested kernels by 40%. Insect fragment counts and ash levels increased as flour grade was lowered. Milling a straight grade flour of 0.48% ash from wheat infested with 41 internal forms per 100 g. of dirty wheat resulted in 4.5 lbs. less flour per 100 lbs. of wheat than was obtained from comparable noninfested wheat.

A low insect fragment count in flour for food is one of the production requirements that must be met by United States millers. The Food and Drug Administration, realizing that it is not possible to buy wheat consistently that is 100% free from infestation, has set no hard and fast sanitary requirements. It states that the dividing line between flour that is grossly contaminated with insect fragments and that which is passable is a broad band which cannot be sharply defined, nor can fragment tolerances be established (4).

Internal insect infestation in wheat is common in the warmer regions of North America. Potential flour recovery is largely determined by the amount of endosperm present in the wheat kernel. Insects which spend a considerable portion of their life cycle within the wheat kernel reduce the amount of endosperm thus reducing the amount of flour which can be obtained from infested wheat.

Unpublished data have shown that if a mill is free of insect infestation and dead insects, the presence of insect fragments in the flour produced is due to the insect infestation present in the wheat when it is received by the mill. Live insects present at the head end of a mill will, over a period of time, be reduced to fragment size, many of which will pass through rebolters with the finished flour at the tail end of the mill.

Notable progress has been made in the development of cleaning machinery designed to remove kernels that have been damaged by insects. The Entoleter-scourer aspirator[2] is used in the cleaning process

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[2]Safety Car Heating & Lighting Co. Inc., Entoleter Division, New Haven, Conn.

before the wheat enters the first break rolls. It is widely used in the U.S. and Canada. The Kice aspirator[3] can be used to help extract insect fragments after the wheat has passed through the first break rolls. Experiments were carried out to determine the efficiency of these machines in removing insect contamination, and to determine the effect of insect-infested kernels on flour yield, ash, protein, and insect fragment counts.

Materials and Methods

A 60-bushel lot of wheat was taken from each of 2 railroad cars containing "weevily" wheat. Weevily wheat is defined as wheat which is infested with live weevils or other insects injurious to stored grain (6). The 2 lots which were designated A and B were fumigated with methyl bromide and stored at 60°F. and 30% relative humidity to prevent development of possible survivors. Two other 60-bushel lots were drawn from noninfested wheat of the same quality. One of these lots was held as a control. It was fumigated and placed in storage with lots A and B. The other 60-bushel lot designated the artificially infested lot, was divided into 6 equal portions and placed in portable wooden bins of 10 bushels capacity.

Approximately 2500 adults each of the rice weevil, *Sitophilus oryzae* (L.), granary weevil, *Sitophilus granarius* (L.), lesser grain borer, *Rhizopertha dominica* (F.), flat grain beetle, *Cryptolestes* spp., confused flour beetle, *Tribolium confusum* Duv., and saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) were placed in each of the 6 bins. The bins were stored at 80°F. and 70% relative humidity. Five samples from each bin were X-rayed each week for 11 weeks to note the progress of internal infestation (5). The wheat was fumigated when the average internal insect infestation of the artificially infested portions reached the level found in the weevily lots (A and B). The contents of the 6 bins were then thoroughly mixed together. Finally, each of the 4 lots was cleaned and milled on a large experimental mill.

The weevily lots were assumed to be comparable for milling purposes. The Entoleter-scourer aspirator was used in the cleaning of the first weevily lot (A), and was omitted from the cleaning of the second weevily lot (B). The latter lot was run through the Kice aspirator after the stock had passed through the first break rolls. Five 2-lb. samples each of uncleaned wheat, cleaned wheat, wheat in the grinding bin and screenings removed during the cleaning process were collected from each lot. Five 100-g. portions of each of these samples were

[3] Kice Aspirator Co., Wichita, Kansas, U.S.A.

examined for insect contamination by the methods outlined in the A.O.A.C. Journal (1).

Duplicate samples of 2 lbs. each were obtained from all mill streams of the 4 wheat lots. Three 50-g. portions of each of these samples were examined for insect fragments using the A.O.A.C. method for flour analysis (3).

Protein and ash determinations (1) were made on 3 samples of each of the mill streams, the results being reported as averages.

The weight, in grams, of each mill stream produced in a 15-minute period was determined. From these data were calculated the percentage of each stream recovered based on total weight of clean wheat.

The total weight of flour and feed produced was determined at the end of the mill run for each wheat lot.

Results and Discussion

The storage period of 11 weeks had a different effect on the control and artificially infested lots as shown in Fig. 1.

The moisture content in the control lot was reduced by 2.3% while the moisture supplied by the insects in the artificially infested lot held the moisture loss to 1.7%. The reduced moisture loss in the presence of insects can be accounted for by the water given off by the insects in their metabolic processes and thereafter picked up by the wheat.

The protein content increased by 0.3% in the artificially infested lot and by 0.7% in the control lot. These differences, due partly to the larger decrease in moisture content of the latter lot and partly to the reduction in endosperm of the infested lot, were not significantly different.

The test weight per bushel was reduced by 0.8 lbs. in the control lot and by 1.1 lbs. in the artificially infested lot. Student's *t*-test showed an insignificant difference between the test weights. The insects consumed a portion of the endosperm, however, and based on 41 internal forms per 100 g. of dirty wheat a storage period of 11 weeks resulted in a weight loss due to insect feeding of 1.1%. Burquest (2) indicated a 2% loss due to insect feeding in wheat infested with 7-12 internal forms per 100 g. of dirty wheat. The author was present when this study was undertaken (2), and it is suggested that the 2% included losses resulting from rodent-cut bags and spillage in handling as well as insect feeding. Because of the difficulties encountered by Burquest through inadequate storage and handling facilities, the wheat used in the present experiments was placed in proper containers and not removed until it was spouted directly to the mill.

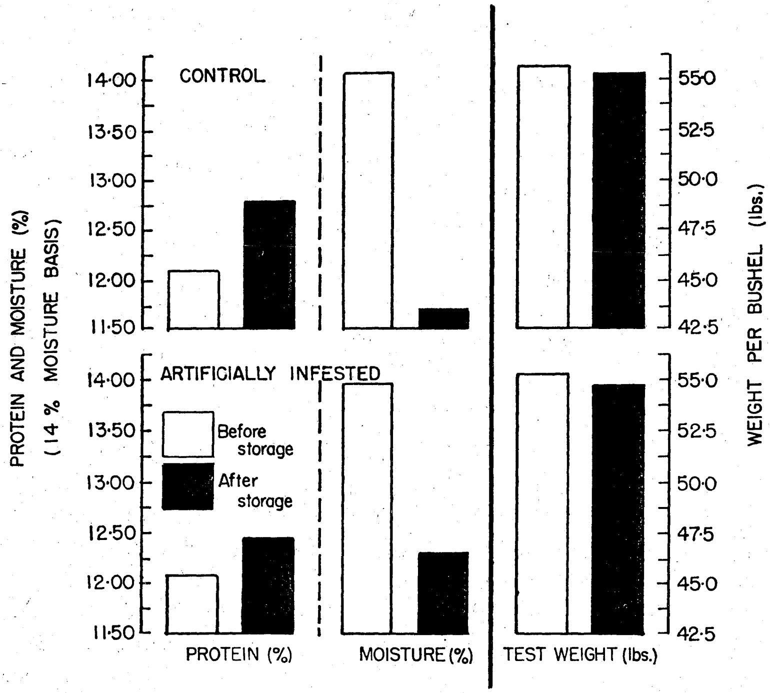

Fig. 1. Effect of 11 week storage period on protein, moisture, and test weight of infested and noninfested wheat.

X-ray plates showed that lot A and the artificially infested lot contained 42 and 41 infested kernels per 100 g. of wheat, respectively, before being put through the Entoleter-scourer aspirator.

The efficiency of the Entoleter-scourer aspirator in reducing internal infestation is evidenced in Table I by a 40.4% reduction of infested kernels in lot A and a 36.6% reduction in the artificially infested lot. In lot B where the Entoleter was by-passed the infestation was reduced by only 0.9%, an insignificant reduction. Similar reductions in the number of infested kernels by identical cleaning of the artificially infested lot and lot A also indicated that commercially graded "weevily" wheat could be duplicated for test purposes in the laboratory.

There are a number of factors which affect the efficiency of the Entoleter-scourer aspirator in removing insect infestation. Whether the wheat to be passed through the machine is infested or noninfested,

TABLE I

THE VALUE OF THE ENTOLETER-SCOURER ASPIRATOR IN REDUCING INTERNAL INSECT INFESTATION
(Average values of five replicates)

WHEAT LOT	NUMBER OF INFESTED KERNELS PER 100 GRAMS OF WHEAT						MEAN REDUCTION
	BEFORE ENTOLETER-SCOURER ASPIRATOR		AFTER ENTOLETER-SCOURER ASPIRATOR		KICE ASPIRATOR		
	Mean	S.D.[a]	Mean	S.D.	Mean	S.D.	
							%
A	42	3.42	25	2.55	..	...	40.4**
B	46	3.00	..	...	42	3.39	0.9
Artificially infested	41	2.46	26	2.34	..	...	36.6**

[a] Standard deviation.

losses can be substantial if the aspiration is set so that many light kernels are removed. This reduces the amount of wheat available for grinding into flour. If the wheat is infested, the predominant stage of the internal insects and their average size becomes important. Small larvae which have not had time to consume much endosperm will not have reduced the weight of the kernels to any extent. Large larvae will have consumed larger portions of the endosperm and reduced the weight of the kernels appreciably. Kernels containing pupae will be mere shells and very light. If the level of aspiration is such that sound but light kernels are not removed, the kernels infested with large larvae or pupae will have been weakened to the point where the Entoleter would crack them open and the internal insects would be aspirated off. Kernels infested with small larvae would not have been sufficiently weakened to be cracked open, consequently they would not be removed from the wheat lot unless the level of aspiration was increased. The number of internal insects present in wheat going to the grinding rolls governs the number of fragments present in the resulting flour. To properly use the Entoleter-scourer aspirator the miller must know the level of infestation, the predominant stage of the insect present and the test weight of the wheat to arrive at a balance between the removal of too few infested kernels and little sound wheat, or the removal of most of the infested kernels and a larger percentage of sound kernels.

Insect fragment counts recovered in the 3 grades of flour are shown in Table II. Student's t-test showed the fragment count in patent flour was lower than that in the first clear grade ($P < 0.01$); also, the fragment count of the first clear grade was lower than that of the second clear grade ($P < 0.01$).

TABLE II

MEAN NUMBERS OF INSECT FRAGMENTS RECOVERED PER 50 GRAMS OF FLOUR FOR EACH GRADE
(Average values of 3 replicates)

FLOUR GRADE	"WEEVILY WHEAT"			ARTIFICIALLY INFESTED	CONTROL
	Entoleted (Lot A)	Not Entoleted (Lot B)	Difference (Lot B — A)		
Patent	375	479	122**	258	0.6
1st Clear	509	667	158**	643	3.6
2nd Clear	803	1004	201**	786	8.0

Burquest (2) stated "the Entoleter-scourer aspirator is a valuable addition to wheat cleaning equipment in removal of internal infestation from wheat during the normal cleaning process." To prove that the removal of infested kernels in the cleaning process resulted in significantly reduced insect fragment counts in flour, the present data were analyzed statistically. Internal insect infestation levels in lots A and B were within sampling error limits. A *t*-test applied to the fragmentation data for each grade of flour produced in these 2 lots verified the value of the Entoleter in the cleaning process as stated above (2) by showing that the absence of this machine would result in significantly higher numbers of insect fragments in the flour.

The fragment count of lot B (Table II) would have been higher if the Kice aspirator had not been used. This machine removed over 3,500 insect fragments per 50 g. of aspirator stock. From the fragmentation data in Table II it is evident that the Kice aspirator did not take the place of the Entoleter in reducing fragment counts in flour, but a still greater reduction could be obtained if the Entoleter and the Kice aspirator had both been used when milling the insect-infested wheat.

Mill streams are diverted to patent, first clear or second clear grade flour primarily on the basis of ash content. The actual limits for each grade depend on the per cent ash desired in the finished flour. Flour is usually manufactured at 1 or 2 ash levels, a low one of 0.39% and a high one of 0.48%. Ash content of flour is determined by burning a known weight of flour until nothing but ash remains. Insect fragments present in the flour would likewise be reduced to ash.

It has been estimated that the ash content of insect fragments is 10-20%. Due to the small size and weight of insect fragments, an increase in ash content due solely to ash from insect fragments would be small enough to be within the experimental error of ash determinations.

It is the bran portion of the kernel which has the highest ash content. Insect infestation reduces the amount of endosperm available for grinding into flour thus altering the bran to endosperm ratio. This not only results in a larger proportion of bran to endosperm, but due to the weakened structure of the infested kernel the ability of the mill to pulverize the bran or high ash portion of the kernel is increased. To maintain the same ash specifications in a finished flour milled from insect-infested wheat, some of the high ash streams would have to be directed to a lower grade flour resulting in reduced yield of patent flour (Fig. 2). For a straight grade flour (0.48% ash) the control lot would yield 4.5 lbs. more flour per 100 lbs. of wheat milled than would the artificially infested lot.

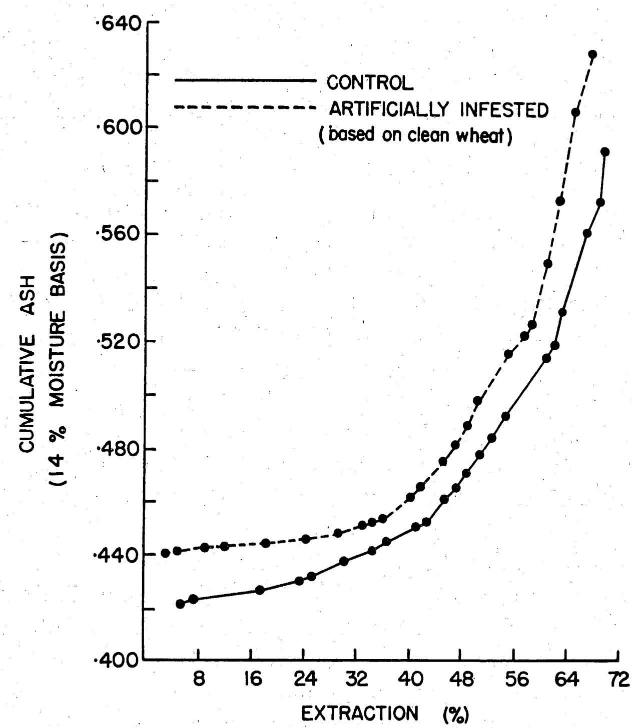

Fig. 2. Relationship between extraction and ash content of artificially infested and control lots.

The insect fragment count of each mill stream of the 4 wheat lots was determined. The relationship between cumulative numbers of insect fragments and flour yield of lot A is shown in Fig. 3. These data indicate that after flour yield passes 45%, cumulative insect fragment count rises rapidly, and particularly so beyond 60%.

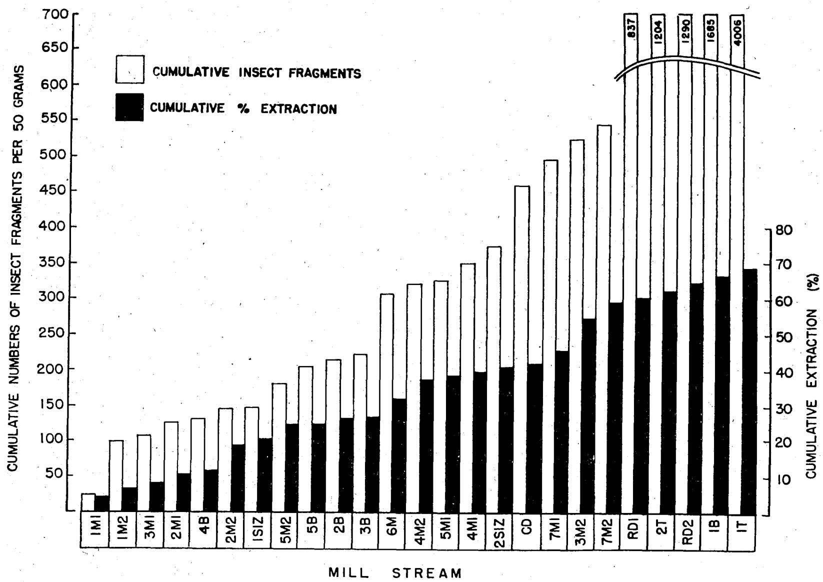

Fig. 3. The effect of each mill stream from wheat of lot A on cumulative flour extraction and cumulative numbers of insect fragments.

Burquest (2) recorded a rapid increase in cumulative numbers of insect fragments when flour yield passed 48%. His data were based on 12 internal forms per 100 g. of dirty wheat while the present results are based on 42 internal forms per 100 g. Although insect fragment counts were a great deal higher in the present study due to a higher level of internal insect infestation, the results indicate that fragment count increases considerably when flour extraction reaches 45-50% regardless of the level of internal infestation.

Figure 3 indicates that streams 1 break, 1 tailings, 2 tailings, and 1st reduction add 7.98% of the flour yield and 54.16% of the total insect fragments. Of these 4 streams, the 1 break and the 1st reduction are directed to patent flour. Collectively they add 3.26% of the flour yield and 17.66% of the total insect fragments. The removal of these 2 streams would cause little reduction in the amount of patent flour obtained, but the fragment count would be reduced by almost 20%.

The data presented in Figs. 2 and 3 show that internal insect infestation raises ash content which reduces patent flour recovery. It would therefore be more costly to mill flour from infested wheat than non-infested wheat. Although actual cost per cwt. of flour was determined for both the control lot and the artificially infested lot, it was felt that such figures would vary from year to year and place to place. On the basis of a straight grade flour (0.48% ash) noninfested wheat would yield 4.5 lbs. more flour per 100 lbs. of wheat than would wheat infested at the level of 41 internal forms per 100 g. of dirty wheat. Burquest (2) based his calculations on a 0.39% ash flour. He found that wheat infested with 12 internal forms per 100 g. of dirty wheat resulted in a loss of 1.5 lbs. of patent flour per 100 lbs. of wheat milled. A reduction of less than 1.5 lbs. would result in the case of a 0.48% ash flour based on the same level of internal infestation. These data indicate that the level of internal infestation and patent flour recovery are related; an increase in internal infestation resulting in a corresponding reduction in patent flour recovery.

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