

# Some effects of grain cleaning on mites, insects and fungi

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## Abstract

A 'cleaner-auger' — an auger with the solid tube replaced by a sieve — removed 0.2% by weight of particulate matter from two 19 t bins of wheat at 16% m.c. Subsequently half as many *Acarus* mites developed in the cleaned bins as in two control bins. Conveying then destroyed 90% of the mites when the grain was cleaned again. Half as many mites then developed in grain that had been cleaned twice than on grain that had never been cleaned. A similar order of difference was observed in laboratory tests in which mite populations developing on sieved, 'auger-cleaned' and uncleaned grain, were compared. In further laboratory tests, the number of mites developing increased with the increasing proportion of dust.

A cleaner auger used to empty a bin of grain infested with insects removed 0.3% by weight of dust and 98% of adult *Oryzaeophilus surinamensis* and *Cryptolestes ferrugineus*. However, in a second test, only 0.16% of dust and 43% of *Sitophilus granarius* were removed.

Whole, sieved grain had 4–25% the count of fungal colony forming units as found on broken grains or on the finer dust.

An aspirated sieve used for seed cleaning removed all *O. surinamensis* and *C. ferrugineus* and over 95% of *S. granarius*. While only 1/10 samples from an infestation of 200 adult insect/kg were pest-free, 6/10 were free of insects when the infestation was 30 kg. The performance of the aspirated sieve in removing insects varied with sieve sizes. A 1 mm sieve produced 1/10 pest-free samples while a 2 mm sieve produced 8/10 pest-free samples.

## Introduction

Grain is usually cleaned to meet EU Intervention and commercial standards, including the required purity for seed use, but little attention has been paid to cleaning as a means of reducing or removing pests. The cost of removing the impurities is sometimes considered excessive but the advantages are many and in the light of the current demand for reduced insecticide use this attitude may have to be reconsidered.

There are a number of advantages of removing extraneous matter from grains in terms of pest control. The rate of airflow through chaff is reduced (Henderson 1943, 1944; Kelly 1940) which could permit pest outbreaks in these slow cooled or dried areas. The efficacy of fumigants such as ethylene dichloride and carbon tetrachloride is reduced by extraneous matter in grain (Walkden and Schwitzgebel 1951). Insecticides are absorbed preferentially by the particulate matter in grain (Anderegg and Madisen 1983), thus interfering with the calculated dose. This also raises the possibility that cleaning would be able to reduce the chemical residue of grain samples.

The productivity of *Oryzaeophilus surinamensis* increases on cracked grain (Turney 1957; Fleming 1988) while *Tribolium castaneum* accumulates and is more productive in wheat with dockage (McGregor 1964). In contrast, Mathlein (1961) found that *C. ferrugineus* propagated better on whole than ground grain possibly due to cannibalism. Ground kernels are more susceptible than whole to *Penicillium* and *Aspergillus* (Tuite et al. 1985). Solomon (1969) found that mites could survive in shrivelled or broken grains, extraneous plant material but not sound grains or dust. The removal of ground grain during cleaning would therefore probably enhance storability.

Burrell and Havers (1973, 1975) compared mite populations in cooled uncleaned barley with 2.7% dust with cleaned barley with 0.4% dust. After two months the uncleaned grain had 46 times the number of mites that occurred in the cleaned. This difference was not maintained and after eight months there were no differences. However, the differences they reported may have been due to a 1.5% reduction in moisture content that occurred in the cleaned, but not the uncleaned grain and a greater ratio of the predator, *Cheyletus* to prey, in the cleaned grain.

In addition to these biological disadvantages, dusts in air are undesirable due to the risk of explosions (Palmer 1973) and can cause allergies and respiratory disease in workers handling dusty grain (Lacey 1991).

There are thus a number of very good reasons for cleaning grain: to achieve market standards of purity, to prevent the dusts causing disease, allergies and explosions and to limit biological deterioration during storage. The experiments compiled in this account investigate the latter, least-known benefit of cleaning. They examine the use of a cleaner auger on the development of mite infestation in cleaned grain on a farm scale, and the effect of the proportion of dust in samples of grain on the subsequent development of mites on a laboratory scale. There is a brief comparison of the mould count of whole grain, broken grain and dust. Descriptions of experiments on the effect of cleaner augers on removing insects from grain are followed by an examination of the efficacy of a laboratory-scale aspirated sieve cleaner in removing insects from grain.

## Development of Mite Populations in Cleaned and Uncleaned Grain

### Farm scale experiment on the effect of a cleaner auger

#### Method

Seventy-five tonnes of freshly-harvested grain at 70% e.r.h. (16% moisture content) was divided between two bins using two augers, one conventional, the other a 'cleaner auger' in which a part of the auger tube was made up of perforations. The cleaner auger had a perforated area of 200 × 36 cm, with 36% of this area being taken up with 3 mm diameter round perforations. When this pair of bins was filled, the contents were conveyed into a pair of adjacent bins and the original pair of bins were refilled in the aforementioned manner and then

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conveyed again into a further pair of bins. Thus there were two replicate bins each of cleaned and uncleaned grain.

The amount of dust removed was weighed, to estimate the proportion removed, thoroughly mixed and some was stored at -20°C, for further laboratory tests. During conveying, 20 grain samples, each of 1 kg, were taken from each bin and 20 were taken from the grain before it was divided between the two augers. These were sieved using woven-meshes of 2.0 mm and 1.0 mm to determine the efficiency of cleaning. These mesh sizes were chosen to match the Intervention Board (IBAP) standards for miscellaneous impurities.

The temperature of the grain was monitored using a central row of thermocouples in each bin, at the surface and at 0.5 m intervals to the base. The mite populations were determined monthly by taking twenty 0.2 kg samples from each bin from five columns and four rows. Mites were extracted by sieving through a 0.7 mm mesh and numbers of the different genera counted under a low-power microscope. Where numbers were high, a disc divided into areas (Solomon 1962) was used. The moisture content of these samples was then determined gravimetrically by drying in an oven at 130°C for 2 hours (BS 412).

Observations were carried out between December and July and then the grain was turned out of the bins by pneumatic conveyer and divided between the cleaner and conventional augers once more to see if removal of the mites would inhibit their build-up. The two bins of uncleaned grain were divided between two bins in this fashion so that one bin contained uncleaned grain and one contained grain that had been cleaned once. The two bins of cleaned grain were similarly divided so that one contained grain that had been cleaned twice and one contained grain that had been cleaned just once. Thus, one bin contained grain that had not been cleaned, one contained grain that had been cleaned twice and two contained grain that had been cleaned once. The cleanings were collected and weighed and mite populations assessed immediately afterward to determine the effect of cleaning. Monthly observations were then carried out between September and February.

### Results

The cleaner auger removed 88 kg of dust from 37 t of grain, about 0.2% by weight. Sieving the 1 kg samples showed it removed 53% of material passing through a 2 mm sieve, termed 'shrivelled grain' and 78% of material passing through a 1 mm sieve, termed 'extraneous matter'.

The grain in all the bins was initially 16% ± 0.5% moisture content, with no difference between cleaned and uncleaned bins. This did not change throughout the experiment, except at the surface where atmospheric absorption raised the moisture content, to nearly 18%. Throughout the test, the temperature of grain in the replicate bins was very similar and within ±1°C. The temperature of the grain started at 11°C in December, fell to 4°C in February and then rose to 13°C before the grain was cleaned for the second time. Thereafter, the temperature peaked at 17°C in September, before declining to 8°C at the end of the test in February.

There was no consistent difference in the mean number of *Glycyphagus* spp. occurring in cleaned and uncleaned bins but

numbers were very low and only exceeded 100/kg. on the last sampling occasion before the second cleaning. By far the majority of mites were *Acarus* spp. and mean numbers of this species were lower in the cleaned bin of each pair on every sampling occasion but the difference was usually only by a factor of 2 (Fig. 1).

When the grain was moved in the second storage season, the cleaner auger removed 54.2 kg (0.29%) from the previously uncleaned grain and 33.8 kg (0.18%) from the previously cleaned grain. The conveying reduced the mite numbers by about 90% but the cleaning process did not apparently enhance this (Table 1).

There were no differences between the average numbers of *Acarus* in the cleaned and uncleaned bin of each pair but the numbers in the bin that was cleaned twice were consistently lower than those in the bin that had never been cleaned (Fig. 2).

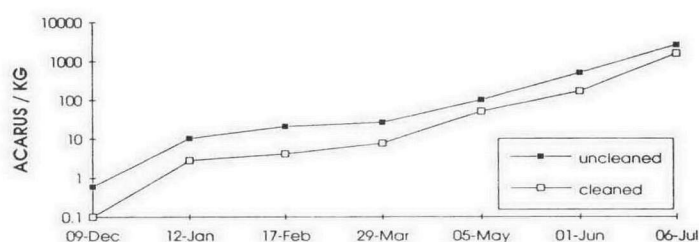


Fig. 1. Comparison of the average number of *Acarus*/kg in 2 pairs of cleaned and uncleaned bins of wheat (n=25).

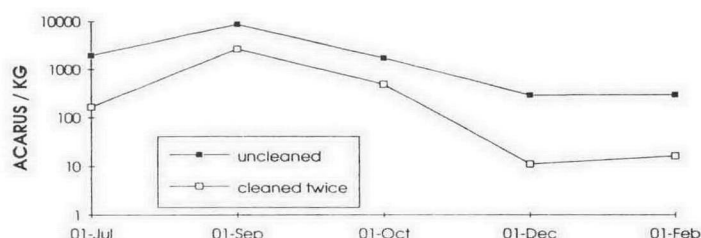


Fig. 2. Comparison of the average number of *Acarus*/kg in an uncleaned and a twice cleaned bin in a second storage season (n=25).

### Laboratory tests

#### Methods

Three separate grain fractions in different states of cleanliness were prepared. These were:

- grain which had been sieved thoroughly using 2 mm mesh to remove most of the broken grains, chaff, seeds and fine dust.
- grain which had been passed through the cleaner auger.
- uncleaned grain to which material from the cleaner auger was added at 0.1 g/5g.

Table 1. Comparison of the removal of mites from two pairs of bins during conveying by a cleaner-auger and a conventional auger (n=25)

	<i>Acarus siro</i>			<i>Glycyphagus destructor</i>		
	Before	After	Removed (%)	Before	After	Removed (%)
Cleaned	2547	337	87	112	8.5	97
Uncleaned	2547	195	92	112	2.6	98
Cleaned	1527	165	89	192	3.5	99
Uncleaned	1527	464	70	192	3.5	98

All grain and its components were at 75% e.r.h. and had been stored, prior to use, in a freezer at -20°C for several weeks.

Twenty replicates of each grain fraction were prepared and placed in 7.5 × 2.5 cm glass-necked vials with close sealing tops containing fine gauze inserts to permit ventilation but prevent mite escape. Five pairs of *Glycyphagus destructor* were placed in each tube and all 60 tubes placed in a desiccator over KOH providing an r.h. of 75% in an incubator at 20°C±0.5°C. The process was repeated using *Acarus siro* in a further 60 tubes. Mite numbers were estimated as described above, after what was estimated to be one generation under these conditions (18 days).

A similar test was set up to compare mite populations in grain containing 0.2%, 2% and 20% dust and the mites were enumerated after 18 and 50 days.

### Results

In the first experiment, after 18 days there were significant differences (students' t test  $p < 0.05$ ) between *Acarus* populations in all treatments, with highest numbers of over 600 being found in the uncleaned grain and lowest (about 200) in the clean grain (Table 2). Only the differences between the *Glycyphagus* populations in the uncleaned grain, at over 200, and the sieved grain (less than 100) were significant (students' t test  $p < 0.05$ ).

In the second experiment, there were significant differences (students' t test  $p < 0.05$ ) between numbers of *A. siro* in all the different dust fractions on both sampling occasions, with dirtiest grain having the highest populations (Table 3). After 50 days, there were over 450 mites in the grain with 20% dust, four times that in the fraction with only 0.2% dust. Differences between populations of *G. destructor* in the samples of grain with increasing dust proportions were only significant after 50 days (students' t test  $p < 0.05$ ). The grain with 20% dust had over 300 mites in 5 g, more than five times that of the cleanest grain.

## Mould Populations of Grain and its Sieved Fractions

### Method

The fungal flora of 10, 1 g samples of dust, broken grain and whole wheat were compared using a dilution plate technique and incubated for 7–10 days. Two media were used: a) 20 g/L malt extract agar with 20 international units (i.u.) of penicillin and 40 i.u. streptomycin/mL to inhibit bacterial growth; and b) 20 g/L malt extract agar with 100 g/L sodium chloride, to provide a lowered equilibrium relative humidity. Moulds were identified and grouped into field and storage fungal groups (Christensen and Kaufman 1969).

### Results

Whole grains had a significantly lower count of field and storage fungi than broken grains which in turn had a lower count than the dust (Table 4). The difference between the count of storage fungi on broken grain and dust was not significant, all other differences were significant. The storage fungi enumerated were mainly members of the *Aspergillus glaucus* and *A. candidus* groups, *Penicillium* spp. and *Wallemia sebi*. The field species found were *Cladosporium*, *Alternaria* and *Cephalosporium*.

## The Effect of Cleaning on Insect Populations

### Use of a cleaner auger

#### Method

While dismantling a badly infested 'control' bin in October 1975, a cleaner auger was used to prepare the grain before sale and the opportunity was taken to examine its efficiency in removing dust and the insects therein. The auger was inclined at about 60° and moved about 5–10 t/hour, 2.4 m of the casing

**Table 2.** Comparison of the number of mites in 5 g of sieved, uncleaned and 'auger-cleaned' grain (n=10).

		<i>A. siro</i>			<i>G. destructor</i>		
		Sieved	Auger-cleaned	Uncleaned	Sieved	Auger-cleaned	Uncleaned
18 days	mean	219	304	627	96	172	257
	s.d.	87	67	220	47	91	99

**Table 3.** Comparison of the number of two species of mites in 5 g of grain with three levels of dust (n=10)

		<i>A. siro</i>			<i>G. destructor</i>		
		0.2	2.0	20.0	0.2	2.0	20.0
18 days	mean	38.9	58.5	80.4	85.5	96.5	117.7
	s.d.	14.8	20.6	19.9	34.5	31.3	60.4
50 days	mean	114.7	161.4	472.3	56.6	73.3	312.7
	s.d.	44.9	73.1	134.3	26.1	31.5	161.1

**Table 4.** A comparison of fungal numbers in colony forming units per g on whole wheat, broken wheat and fine dust (n=10).

		Whole	Broken	Dust
		Storage	mean	1225
	s.e.	786	10966	5991
Field	mean	8346	31539	180048
	s.e.	2012	5356	31477

was perforated with 1/8 in round holes. (Comely et al. 1961). Ten samples each of 1.36 kg were taken before being passed through the cleaner auger and 10 afterwards. The samples were sieved through a 2 mm mesh, the sievings weighed and the number of insects in the sievings counted.

A second, more thorough test was carried out in October 1992. A 25 t bin of wheat was found to be infested with *S. granarius* and the original infestation was estimated by taking 250 g gravity spear samples from nine columns and three rows: at the surface, and at 1 m and 2 m, making a total of 27 samples. The area of heaviest infestation was further sampled using the same grid. These samples were sieved through a 2 mm mesh and the live and dead insects removed and counted.

The contents of the bin were then augered onto a belt conveyer which discharged to an elevator and thence, at about 15–20 t/hour, through the same cleaner auger that was used in the mite tests, inclined at about 20°. The grain was returned to a second bin using a further auger. Nineteen samples, each of 1 kg, were taken from each end of the cleaner auger and sieved through a 2 mm mesh to determine the number of insects and quantity of dust therein. The cleanings were collected, weighed and mixed and six samples of 0.2 kg removed. The number of live and dead insects therein was counted, to estimate the number removed and the proportion alive.

**Results**

Before cleaning, the grain in the first test contained 39.7 g of dust, 0.3% by weight and 1269 live adult insects in 13.6 kg (93.3/kg) and very high but unquantified numbers of larvae of *O. surinamensis* and *C. ferrugineus* (Table 5). After cleaning, the grain contained 4.5 g of dust, 0.03% by weight and only 25 adults in 13.6 kg (1.8/kg) and no larval insects. The cleaner auger thus removed 89% of the dust, 98% of the adult and all the larval insects.

In the second test, the in-bin sampling suggested the infestation to be about 7.8 *S. granarius* /kg, with about 40% dead. Before cleaning, the grain contained 0.32% dust and 669 *S. granarius* in 19.4 kg (34.6/kg) (Table 5). After cleaning, the proportion of dust was 0.15% and the infestation was reduced to 440 *S. granarius* in 22.4 kg (19.6/kg.), an apparent reduction of 15/kg. The cleaner auger thus removed 43.4% of the weevils and 53% of the dust. Forty kilograms of dust were removed from the 25 t of wheat (0.16%) and the dust was estimated to contain 429 000 insects (17.2/kg) , of which 27% were dead.

**Use of an aspirated sieve**

*Method*

The apparatus used for these experiments passed grain samples through a de-awner, two aspirated slide sections, through a top sieve comprising 3.5 mm elongated slots, through a bottom sieve of 1.0 mm slots and finally through a rotary drum (principally for rubble separation). The material removed by the aspirated section could not be examined as the air was voided from the building in which the machine was housed.

*Effect of population density.* Thirty live adults of three species; *O. surinamensis*, *S. granarius* and *C. ferrugineus* were placed into each of 10 polythene bags containing 1 kg of wheat at 70% e.r.h. A further 10 bags were prepared which were infested with 200 of each species.

These were left for about 20 days at 25°C, long enough for the infestation to become established, but not long enough to allow a further generation to emerge ( Eastham and Seagrove 1947). The bags were then placed at –20°C to kill the insects, before they were put through the cleaner, 23 days later, after defrosting.

The cleanings resulting from the process were collected and the insects (or insect heads) in it counted. The cleaned grain was also collected, sieved and the insects that had evaded the cleaning process were counted.

*Effect of mesh size.* In this experiment, twenty, 1 kg bags of wheat were each infested with 100 of the three insect species. Ten of these were put through the cleaner with the 1 mm bottom sieve in place while for the remainder, a 2 mm sieve was substituted to see if more insects would be removed. The insects were not killed before being placed in the cleaner and so the numbers of live and dead insects in the cleaner were counted, to give an estimate of the proportion killed by the process.

**Results**

*Effect of population density.* Less than one-third of the introduced *O. surinamensis* and *C. ferrugineus* were found in the cleanings but over two-thirds of the *S. granarius* were recovered (Table 6). Only the latter species was found in the cleaned grain and even then, a very small proportion (less than 5%) of those introduced were discovered. A higher proportion of all three species was retrieved from the lower than the

**Table 5.** The infestation density and dust content of grain before and after passage through a cleaner auger, and the estimated efficiency in removing dust and insects.

Test		Before	After	% Efficiency	Removed	% Efficiency
1 *	Insects/kg	93.3	1.8	98	–	–
	Dust %	0.30	0.03	89	0.47	157
2 +	Insects/g	34.6	19.6	43	17.0	49

\**O. surinamensis* and *C. ferrugineus*.  
+*S. granarius*.

**Table 6.** Comparison of the proportion of dead insects of three species at two population densities removed by an aspirated sieve cleaner and remaining in the cleaned grain (n=10).

Insects/g		Insects (%)			Pest -free samples
		<i>S. granarius</i>	<i>O. surinamensis</i>	<i>C. ferrugineus</i>	
30	mean	82	26	16	6/10
	range	70–93	10–43	7–30	
200	mean	58	9	11	0/10
	range	60-74	7-12	8-15	

higher infestation density. After cleaning, none of the samples infested with 200 insects/kg were pest-free, but 6/10 initially infested at 30/kg were uninfested.

*Effect of mesh size.* Slightly fewer *S. granarius* escaped cleaning when the larger, 2 mm mesh sieve was used and 8/10 samples cleaned using the latter sieve were pest-free, compared with only 1/10 processed using the smaller, 1 mm mesh (Table 7). There was no difference between the numbers of insects found in the sievings from the different mesh sizes or in the proportion of insects alive which was usually less than 10%.

### Discussion

The reductions in mite population development brought about by cleaning and the increase in mite population with increasing dust content were significant but as they were only of the order of a factor of 2, are not of practical importance, when viewed in isolation.

The reduction in mould count of cleaned grain and the removal of insect infestation by cleaners, both simple 'cleaner-augers' and aspirated sieve-cleaners, were both significant and practically useful. It suggests that it may be possible to remove insects from heavily infested grain where chemical treatments are not permissible and that mould counts of grain may be similarly lowered. The efficiency of cleaning may vary with infestation density but the work described here suggests that manipulating sieve size may be a means of increasing cleaning efficiency. The two-thirds of the introduced *O. surinamensis* and *C. ferrugineus* that were not recovered from the cleanings or from the cleaned grain, were presumably lost during aspiration.

The disparity between the results of the two tests using 'cleaner-augers' against insects may have been due to a variety of factors including insect species (*S. granarius* may be more difficult to remove than the smaller species), auger loading (an auger working at full capacity may remove fewer insects than one that is not), auger angle and finally, mesh used in the cleaner section of the auger. Further research may suggest how to improve the latter. The cleaner auger used in the test against mites and the test using *S. granarius* should have achieved over 99% purity (Comely et al. 1961). In the second test there was reasonable agreement between the two methods of estimating the proportion of dust and insects removed; sampling the dust and sampling the grain before and after passing through the auger. The low proportion of the *S. granarius* infestation killed by augering conflicts with the estimates in the review by Banks (1988).

Prickett (1989) found in the U.K. that from a sample of 742, 15% of small farms, 28% of medium farms and 59% of large farms used some form of grain cleaner. Prickett and

Muggleton (1991) found that 59% of 169 commercial sites used a cleaner and of those, 79% used an aspirated sieve. There is thus an ability to clean on most commercial sites and a sizeable minority of farm stores and also scope for a greater uptake of the method.

It should be noted that the sieves used in these experiments to remove and quantify extraneous matter were of woven mesh while Intervention Board, British and International Standards (BS 410, ISO 3310/2) require long, slotted perforations. The proportion of extraneous matter described here may therefore differ from that determined by the standard method.

The cost of cleaning must include up to 0.3% of weight loss in dust removed which would be 30p/t (at £110/t) if it was not re-united with the grain on sale. McClean (1989) has estimated costs of 50p-£3/t respectively for throughputs of 15000-1000 t/season. However, use of 'cleaner augers' would incur much lower costs and would be of practical use to smaller-scale farmers including those in developing countries.

Further benefits not examined by these tests include the possibility of lowering chemical residues in samples and the labour saved in sampling the cleanings, rather than the entire store, for infestation during inloading or outloading. It follows that routine cleaning during loading would reduce the founding infestation and cleaning during outloading could ensure that market standards of freedom from pests were achieved at sale.

Further work is required to determine the effect of cleaning on hidden stages of insect (such as *S. granarius*) larvae, and on the effect of aspirated sieve seed cleaners on disinfecting mite-infested grain. Fuller data on the effect of auger cleaners on insect infestations would also be advantageous.

### Acknowledgments

Norman Burrell contributed the information on the cleaner auger performance against *O. surinamensis* and *C. ferrugineus*; Chris Duckett was responsible for the test with *S. granarius*; and Paul Hart and Lee Dixon carried out the laboratory mite tests. The work was funded by the Pesticide Safety Directorate, MAFF.

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**Table 7.** Comparison of the proportion of insects of three species removed and killed by an aspirated sieve using two sieve sizes (n=10).

		Insects (%)			Pest-free samples	
		In cleanings			After cleaning	
		<i>S. granarius</i>	<i>O. surinamensis</i>	<i>C. ferrugineus</i>	<i>S. granarius</i>	
1 mm	mean	78 (88)	22 (95)	21 (97)	6 (80)	1/10
	range	57-93 (71-94)	12-32 (60-95)	12-26 (75-96)	0-10 (70-100)	
2 mm	mean	79 (88)	20 (76)	18 (89)	0.2	9/10
	range	62-85 (73-96)	13-33 (71-85)	8-24 (63-100)	2 (100)	

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