STORED PRODUCT MITES DETECTION AND LOSS ASSESSMENT IN ANIMAL FEED.

by
D R Wilkin and B B Thind
Ministry of Agriculture, Fisheries and Food
Slough Laboratory
London Road
Slough
England

Summary:- Mites occur widely in a variety of stored-products, including animal feeding stuffs. However, there are few well defined methods of detection and only a limited number of attempts have been made to quantify the damage and loss caused by mites attaching stored products. The development of a technique capable of extracting and quantifying mites from animal feed has now facilitated work on such infestations. Mites have been shown to occur widely in feed for cows and pigs with Acarus siro L being the most common species and occurring in the greatest numbers. Trials showed that infestations of A. siro reduced the palatability of feed for dairy cows and reduced the growth rate of pigs. Chemical assay of infested feed revealed a reduction in the level of nitrogen in amino acid form compared to uninfested material. The consequences of these results are discussed together with an assessment of the requirements for further work in the field.

Introduction

Mites have probably been associated with stored food for as long as food has been stored. One can speculate that the niche was first created by various animals that stock their nests with supplies of seeds or nuts. Mite species that had adapted to such environments would have found it an easy step to invade larger, man made food stores.

There are a surprisingly large number of early records of infestation of stored food by mites, perhaps because they provided easily obtainable specimens for early microscopists. Generally stored product mites are just sufficiently large to be resolved by the unaided eye but too small to allow details to be made out. Also they were likely to be readily available from a variety of common foodstuffs. OUDEMANS (1926-1937) surveyed the literature published from 1650 to 1850 and found about 400 works on mites taken from staple foods such as cheese and flour. POWER (1664) wrote 'If you besprinkle the object plate upon which you view them with a pretty quantity of oatmeal, you shall see them running and skudding amongst it, under it, over it, and into it like rabbits in their burrows.'

However, none of these early authors seem to have considered the pest potential of mites or damage that could result from mite infestation. Perhaps this can be explained by the low standards of quality

and hygiene applied to foodstuffs and the more obvious losses that must have been occurring due to rodents, and to some extent, insects. Another likely reason for the lack of interest in damage and loss assessment was the difficulty of assessing population densities and determining subsequent losses. This situation persists even today and often limits the assessment of losses attributable to stored product mites.

Two hundred and fifty years after Powers report of mites in oatmeal some serious efforts to quantify damage by mites began to be made. EALES (1917) reported that 2.5 percent of all Stilton cheese was consumed by mites before sale and further financial losses occurred because of the extra labour needed to deal with mites. Interestingly this author also discussed methods of mite control, suggesting that the damage was considered to be of economic significance.

A more detailed appraisal of mite infestation and resultant damage was made by NEWSTEAD and DUVALL (1918) in a series of reports made to a committee investigating losses of food in the United Kingdom during the 1914-18 war. These authors considered that, although the general view of the grain trade was that infestation of mites in grain was a guarantee of good quality, in fact these pests were causing considerable damage. They showed that mites penetrated the epicarp and destroyed the germ as well as consuming some of the endosperm. Another paper (RATHBONE, 1919) presented to the committee, suggested that during the long-term storage of wheat brought about by wartime conditions, mites were a more serious and damaging pest than 'weevils'.

Unfortunately methods of detection were not reported in detail in early papers. Most infestations were only regarded as of economic importance when the mites could be detected as a thick dust or by an objectionable smell. However, NEWSTEAD and DUVALL (1918) did suggest that a sieve may be used to remove dust from grain and that this dust should then be examined with a hand lens for mites.

SOLOMON (1943) carried out an extensive review of the published literature on stored product mites. The number and variety of references quoted, mostly from 1900-1939, indicates that mites in stored products were now regarded as more serious pests. Thirty-one out of the 220 references dealt with control of mites but only seven referred specifically to methods of detection. Quantified measurements of loss were rare, most authors simply offering subjective assessments. Economic losses in stored foods and feeding stuffs resulting from infestation were discussed by HOWE (1965). He pointed out that economic losses were a complex mixture of direct loss and indirect losses caused by rejection or costs of preventative measures. The former were difficult to define but the latter were almost impossible to quantify.

Currently more information is available about the loss or damage caused directly by infestations. A number of excellent laboratory studies have been carried out in which the potential of mites to damage various products have been examined. MLODECKI (1960)

determined some changes in chemical composition of wheat and rye flour infested with mites. The most notable result was a reduction in protein. ZDARKOVA and RESKA (1976) found that a heavy infestation of Tyrophagus putrescentiae Schank caused 44% weight loss in ground nuts compared to a 17% loss caused by an infestation of Acarus siro L. These losses were not, however, related to those occurring under practical conditions.

Estimation of damage and loss caused by stored product mites in the field is still frequently handicapped by difficulties in detecting and enumerating infestations. Development of an effective technique to overcome these problems is an essential part of any investigation and in some cases a new technique may reveal damage and loss that has hitherto gone unnoticed. An example of this is shown by the investigation carried out by the Storage Pests Department of the Slough Laboratory on mites infesting animal feedingstuffs.

Mites in Animal Feed

Infestations of mites in animal feed in the United Kingdom has been reported by WILLIAMS (1960),FREEMAN (1979) and WAYMAN (1969) among others. The feeding stuffs are made up mixtures of ground cereals, proteins and vitamin supplements and may be fed to animals as complete diets or as supplements to other feed. They are often manufactured at a feed mill and supplied to the farm in bulk but some farms may mill and mix their own feed. During manufacture all components are usually ground to a fine meal and the final feed may be used in this form or reconstituted as pellets. The infestations reported by WILLIAMS (1960) and FREEMAN (1979) were detected by simple visual checks and no estimation of the damage or loss were made. Their work did show that infestations were widespread and were giving rise to concern within the industry. This prompted the undertaking of a program of research and development that is still in progress and that is reported, in part in this paper. THIND and GRIFFITHS (1979) developed a flotation technique which extracted mites from the feed and precipitated them on a filter paper, allowing easy counting. This technique enabled at least 70% of the mites to be removed from samples of animal feed. Later modifications to the technique improved recovery to better than 90% (THIND and WALLACE, in press). Having been removed from the feed and precipitated on a filter paper the mites can be readily counted and identified to genus. Selected mites can also be mounted on slides for specific identification.

The development of this technique proved to be a key factor in the investigation and allowed the following surveys and damage and loss assessments to be undertaken.

Assessment of infestations Initially a number of ad hoc investigations were carried out involving the collection and examination of a wide variety of samples of animal feed. Results confirmed the earlier reports and showed that infestations of many thousands of mites per kilogram could be found in feed for cows, pigs and poultry

(Anon, 1969, 1978 and 1981). The investigations also revealed a number of cases where losses were attributed to using mite-infested feed. These included reduction in palatability of the feed, reduced egg production in poultry, reduced milk yield in dairy cattle, reduced growth rate in pigs and many cases of diarrhoea and sickness in a variety of animals. However it proved impossible to establish conclusively that mite infested feed was responsible for the various symptoms. Replacing infested feed with a non-mity equivalent invariably improved the condition of the stock but usually there were so many other variables involved that no conclusions could be drawn. In the light of these results a series of surveys and feedings trials were undertaken to establish the extent and degree of mite infestation in various animal feed and the effects of such feed on the performance of the stock.

Dairy Cattle A survey was carried out to assess the degree of mite infestation in the concentrate feed used on 114 dairy farms situated in the South West of England. The survery was carried out during April- July 1976 and the results are given in Table 1. The feed samples were collected from the discharge point of the feeding system in the milking parlour and were, therefore, representative of the quality of the feed being offered to the cows. For ease of interpretation the results have been arbitarily divided into six levels of infestation.

TABLE 1 Levels of mite infestation in samples of dairy concentrate feed collected from farms in South West England during April-July 1976.

No. of mites/Kg	No. of farms	% of total
0-500	28	24.6
501-2000	14	12.3
2001-10,000	22	19.3
10,001-20,000	8	7.0
20,001-50,000	17	14.9
>50,000	25	21.9

The most heavily infested feed contained more than 500,000 mites/kg and samples from only four farms were completely free from mites. Twenty-two species of mites were recorded during the survey but one species, A.siro, was predominant both in frequency of occurrence (82% of samples) and in numbers found. Glycyphagus destructor (de Geer) was found in 35% of the samples and the predatory mite, Cheyletus eruditus (Shrank) occurred in 26%. Other species occurred in fewer than 20% of the samples and most were found in fewer than 5%.

The causes of the heavy infestations were obscure. Feed was normally stored on farms for 2-4 weeks, but storage period had little effect on mite numbers. Eight feed mills, manufacturing rations for dairy cows were inspected and, although the structure of each and the raw materials used in the manufacturing process were infested, the freshly produced feed contained only low numbers of mites. The most likely explanation for the infestations was the poor storage conditions found on many farms. It was not unusual to find a feed store that had not been cleaned out for more than a decade. The residues which had accummulated over the years must have provided an excellent breeding ground for mites which subsequently spread into the fresh deliveries of rations. The feed stores were often in lofts above the milking parlour and the damp, warm air rising from the parlour would help to create a suitable environment for the development of mites.

In view of the high incidence of infestation a trial was set up to examine some of the effects of infested feed on dairy cattle. The weight of concentrate rations consumed by sixteen pairs of cows was recorded over a 12-week period. For the first 4 and the last 4 weeks all the cows were fed on a standard diet that was free from infestation. During weeks 5 to 8, one member of each pair was fed on feed that had been artificially infested with mites. Prior to use the feed had been inoculated with A. siro and incubated at 20°C and about 75% r.h. until the infestation reached between 50,000 and 150,000 mites per kg. The infested feed was not readily accepted by the cows. Throughout the trial the level of rejection of both groups of cows was about 15% although it fluctuated widely on a day to day basis. The rejection rose to 25% when the infested feed was substituted for the mite-free diet. This is an under estimate of the reduction in feed intake as much of the mitey feed was dropped onto the floor of the parlour by the cows and could not be quantified. The milk yield of the cows was not affected by the reduced feed intake, probably because the cows had access to additional food outside the milking parlour.

Pigs As reported earlier isolated cases of mite infestation in pig feed that were reputed to be causing a variety of disorders ranging from diarrhoea, reduced growth rate and even death were investigated. Although it was impossible to define the role of

mites in causing the disorders, there was a strong suggestion that such infestations were undesirable. A series of trials were therefore carried out during 1979 and 1980 to assess the extent of mite infestation in pig feed used at commercial pig production units and to determine the effects of infested feed on growing pigs.

The incidence of mite infestation in the feed being used on 70 farms distributed throughout England and Wales was investigated. Samples of feed were collected from each farm on three ocassions; December 1979, April and July 1980. As far as possible the feed collected was representative of that offered to the pigs. The results of the mite counts are summarised in Table 2.

TABLE 2 The level of mite infestation found in samples of pig feed collected from farms in England and Wales

No. of mites/kg	% of farms		
	Dec '79	April '80	July '80
0	22	4	8
1 - 1000	39	45	38
1001 - 5000	19	22	19
5001 - 25000	11	15	10
>25000	9	14	25

The number of farms using feed containing more than 25000 mites/kg increased at each sampling, particularly between the April and July visits. By the July visit several farms were using feed containing more than 100,000 mites/kg and three farms were using diets containing more than 1 million mites/kg. The levels of infestation varied widely and only a few farms had consistently high or low numbers of mites. Common factors between farms having consistent infestations were difficult to detect. For example, the type of feed, method of storage, frequency of cleaning and pesticide treatments did not appear to be linked to numbers of mites. However, heavy infestations occurred more often on farms that produced their own feed.

A large range of species were found in the feed but A. siro was the most common species by a large margin and occurred in the largest numbers.

A series of experiments have also been carried out to assess the effects of mite infested feed on the growth rate of pigs. This work was stimulated by problems that occurred during trials with pigs at the National Institute for Research in Dairying, Reading, England. The growth rate of pigs during several experiments was unexpectedly low. No explanation for this poor performance was apparent but, when samples of the feed were examined very large numbers of A. siro were found. In order to establish whether the mite infestation was responsible for the reduced performance of the pigs, feeding trials were carried out using a standard pig diet artificially infested with A. siro. Two batches each of 3,200 kg of pig meal were incubated at 17.5°C and 80% r.h. Before incubation one batch was inoculated with A. siro, the other being left uninfested to act as a control. After 5 weeks some of each batch was removed and fed to pigs. During the following 11 weeks supplies of feed were removed and fed to the pigs as required. The mites continued to breed in the infested batch throughout this period. There was considerable fluctuation in the levels of infestation in samples from individual lots of feed. Some of this variation could be attributed to sampling error but much was caused by variation between the individual lots of feed that made up the large bulk required by this experiment. However, the mean number of mites in the feed rose from about 0.5 million/kg to about 4 million/kg.

Nine littermate pairs of pigs were grown from 20 kg liveweight for a period of 11 weeks; one of each pair was given the control diet and the other fed on infested diet. The growth rate of these pigs is given in Table 3.

TABLE 3 The effects of feed infested with A. siro on the growth rate of pigs

	Control	Infested	% difference between control and infested
Growth rate g/day	556	467	16.0
Feed : Grain	2.76	3.16	14.5

The rate of growth of the pigs on the infested diet was always slower than the control pigs and the difference between the two groups increased as the trial progressed. The pigs were more reluctant to eat the infested feed but did always consume their full daily ration. No clinical symptoms that could be attributed to the infested feed were observed.

Six further pigs were used in an additional trial lasting 6 weeks to assess the amount of nitrogen that was being retained. Each pig received the infested and control diets in alternate 7 day periods and the results are given in Table 4.

Table 4 The difference in nitrogen retention between pigs fed on mite-infested or mite-free feed.

	Control	Infested
Nitrogen retained : Nitrogen intake	0.47	0.38
Nitrogen retained g/d	21.0	17.0

The nitrogen retention of the pigs was about 20% less when fed on diet infested with A. siro. Analysis of the feed showed that mite infestation reduced the percentage of nitrogen in amino acid form from about 80% to about 50%.

After the nitrogen retention trial had been completed the same pigs were used to investigate the effects of live or dead mites on performance. The mites in one batch of infested feed were killed by exposure to -10°C for 7 days and this feed, together with a similar diet containing live mites was fed to the pigs in alternate 7 day periods. No difference in nutrative value between the two diets was detected. A more detailed account of the results of these feeding trials was given by BRAUDE et al (1980).

Further trials using similar experimental techniques have been carried out which demonstrated a linear relationship between the level of mite infestation and nitrogen retention of growing pigs. However, problems associated with experimentation using large animals have prevented proper evaluation of the effects of infestations below 1 million/kg.

Throughout the trials with mite-infested pig feed efforts were made to restrict the growth of microorganisms. Temperatures and relative humidities were kept as low as possible whilst still permitting reasonable rates of increase in the mite population. Samples of feed were assessed for microorganisms before and after the development of mites. There was some growth of bacteria and a large increase in a yeast. The growth of these organisms must have had some effect on the feed but no references could be found to them having been responsible for effecting the performance of pigs or cattle. No growth of toxin producing organisms was detected and no micotoxins were found.

Discussion

The survey and feeding trials reported in this paper show that mites are widespread in animal feed in England and that they have at least the potential to cause serious losses. These infestations were only revealed by the use of a new method of detection, indicating that detection methods and damage and loss assessment are inseparably linked when dealing with stored-product mites.

Enquiries made of pig producers, dairy farmers and suppliers of feed indicates that unexplained losses in performance or reduced palatability of feed are by no means uncommon. In fact, several major feed suppliers considered palatability of dairy rations to be a major problem. Until very recently the possibility that problems with animal production could be attributed to stored product mites had not been considered because all but the most severe infestations in feed escaped detection. The trials with growing pigs showed that infested feed extended the time taken to reach slaughter weight by 2 weeks. Several pig producers included in the survey were using feed that was infested to such a degree that serious loss in performance must have occurred.

A great deal more work remains to be done to quantify all the effects of mites infesting animal feed. Trials with large animals such as pigs or cows require large quantities of feed, often as much as 10 tonnes. Achieving a uniform level of infestation in such large bulks and avoiding contamination by mould or predatory mites presents special difficulties which are not easy to overcome. Variations in the quality of the feed, coupled with the limited numbers of replicate animals and large natural variation, have made it impossible to establish the economic importance of mite infestation below 1 million/kg in pig feed. A different approach such as using small, laboratory mammals as a model or extrapolation from chemical analysis of infested samples, may be required.

Some progress has been made with determining the chemical and physical effect of mites. WILKIN and FAWELL (in press, 1983) showed that very large numbers of A. siro caused a 10% weight loss in samples of pig meal. As reported earlier in this paper, heavy infestations of the same mite reduced the amount of nitrogen in amino acid form in pig meal. However, more detailed studies on the chemical changes in feed caused by mites should be carried out as the results could be used as a guide to mite damage.

Various clinical symptoms have been attributed to mity feed although none were observed during any of the trials reported in this paper. HUNTER (1974) discussed the presence of grain mites in pig feed and concluded that it was likely that they were a contributory cause of scouring and enteric disease of pigs. It is possible that, under field conditions, the mite infestations are often accompanied by the growth of fungi. Microbial toxins could be causing some symptoms that are being wrongly attributed to mites, a conclusion supported by GESZTESSY and NEMESERI (1970 and 1970a). Earlier work (ANON 1954, 1955 and 1956) suggested that mite infested feed checked the growth of rabbits and cockerels, caused degeneration of the liver, kidney, adrenal gland and testicles. However, this work was never reported in full and was contradicted by SZWABOWICZ et al (1958) who found no dilaterious effects in similar trials with pigs and horses. The methods used in both these pieces of work are unlikely to have allowed accurate estimates of mite numbers to be made or the growth of microorganisms to be controled. Therefore, further work coupled with veterinary

support, is needed before the possibility of mites causing clinical symptoms can be ruled out. The role of stored-product mites as allergens in man has been thoroughly investigated. There have been frequent reports of agricultural workers who, after contacting mite-infested feed, develop alergies (WRAITH, et al 1979). It is not unreasonable that similar problems could occur in pigs, cows or poultry but little work has so far been carried out on this subject.

The surveys showed A. siro to be the dominant species in feed used by pig producers and dairy farmers. This species is widely distributed throughout the UK and many other parts of the world (HUGHES 1976). It has been recorded infesting a wide range of stored products but its overwhelming dominance in animal feed stores is unusual and the ecology of bulk feed storage must provide an ideal niche for this mite. Surprisingly, predatory mites rarely occurred in large numbers and did not seem to exert a controlling influence on populations.

Very little research has been carried out on the control of mites infesting animal feed. Ad hoc investigations have shown that thorough cleaning of the feed store and feeding system will usually reduce infestation (ANON,1981a). Contact acaricides seem to show little promise, particularly with finely divided materials. In any case it is prevention rather than control that is required if nutritional damage to feed is to be avoided. Manipulation of the environment could be one method of achieving this. For example mites require relative humidities of 70% or more to reproduce rapidly (CUNNINGTON, (1976). In bulk feed this relative humidity is often largely controlled by the moisture content of the feed. Work is needed to determine the relative humidity/moisture content relationship of animal feed so that moisture content for safe storage can be defined.

The method of detecting and quantifying mites used in the survey and feeding trials reported in this paper worked exceptionally well. However, the technique is time consuming and this limited the number of samples that could be examined. Field and laboratory investigations would be enhanced if a more rapid technique could be developed. Preliminary investigations show that Near Infra Red Reflectance (NIR) can indicate the presence of mites in feed and give some guides to there numbers. Much more development is needed but, in the future this technique could allow for more extensive surveys to be undertaken as samples can be scanned with NIR in 20 seconds rather than the 30 minutes taken to extract mites using the flotation method. The method has additional benefit because it has some potential to detect the nutritional changes brought about by infestation.

The results reported here may help to define the pest status of stored product mites. Ultimately after further work it may be possible to equate numbers of mites in any particular product with a degree of chemical and physical degredation. This, in turn, could be related to the effects on human or animal consumers.

Even limited progress in this direction would allow control strategies to be related to the damage potential of any particular problem. However, the key to progress will always be the availability of an effective and appropriate method of detecting mites.

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