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Alternatives to Methyl Bromide; IPM in three typical danish flour mills

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Contents

Abstract

Methyl bromide prohibited
In the past the Danish flour mills have relied on a pest control strategy, which includes fumigation with methyl bromide, typically once a year, in order to prevent problems with various insect pest species. In Denmark the use of methyl bromide as a pesticide was banned on the 1st January 1998.

New system - IPM
The fact that methyl bromide was prohibited in Denmark has forced the Danish mills to improve their pest management systems. The IPM concept is considered to be a way to manage pest problems in flour mills without fumigation, previous works have pointed out that practical experience was limited. The public does not want to find insects in the flour, at the same time there is also a strong public wish for the production of food without a reliance on insecticides. IPM could be a way of fulfilling both of these expectations, although the removal of methyl bromide could lead to an increasing use of residual insecticides.

This project has dealt with the control of insect pests in three Danish flour mills. The purpose was to increase our knowledge of technically and environmentally acceptable prevention and control methods on these insect pests, at an acceptable price level.

Increased sanitation
The present investigation shows that the flour mills in Denmark have replaced fumigation's using methyl bromide with increased efforts in sanitation. By implementing more comprehensive cleaning practises combined with surface treatments using residual insecticides, during regular shutdowns in production, they have been able to manage to a degree pest problems. For the time being they are learning and gathering experience regarding how to operate without methyl bromide.

Missing documentation
Creating useful documentation on the efficacy of the insect pest control was found to be difficult, this could be an important objection against the present IPM systems. A possible way to improve the IPM systems, could be the establishment of a team of relevant experts, in order that a co-ordinated strategy be applied to pest control.

Main pest species
The two main pest species in the mills are the Mediterranean flour moth *Ephestia kuehniella* Z. and the confused flour beetle *Tribolium confusum* Duval. Other pest species cause only local or minor problems, although these problems will sometimes be of economic importance. This report forms the framework for further improvement of the IPM systems, without the reliance on fumigation with methyl bromide.

1 Introduction

Definition of IPM
IPM (**I**ntegrated **P**est **M**anagement) in the area of stored products can be defined as a system which comprises of hygiene, technical, technological and bio-technical methods, physical control, biological control, and chemical control. These methods should be combined in such a way that highest priority is given to the protection of the human health as well as the environment. Moreover, commercial policy is a possible further element of IPM (Reichmuth, 1996). IPM is a dynamic system that should be harmonised with local conditions in order to use the most promising elements with regard to the environment and economy.

IPM in stored products
The use of IPM in the area of stored product protection is at a stage which can be characterised as a 'learning to understand and assimilate the technology' (Schöller et al., 1997). The most detailed scientific experience has been gained in grain stores (Hagstrum & Flinn, 1996), where it is possible to sample the insect population, and thereby follow the pest population level in detail. Knowledge of the IPM concept is limited at consumer level (Platt et al., 1998).

In the past the majority of Danish flour mills have relied on a pest control strategy, which included fumigation with methyl bromide, typically once a year, in order to prevent problems with insect pest species. This situation changed on the 1st of January 1998, when the use of methyl bromide was banned in Denmark.

History
The phase out of methyl bromide in Danish flour mills was supported by the Danish government through financial support to two projects dealing with IPM in mills. A preliminary project (Skadedyrcentralen Danmark A/S, 1997), which condensed and improved the present experience with IPM into a general guideline including theoretical options of using alternative methods of pest control in mills, concluded that there are alternatives, which - when combined in a joint strategy (IPM) - can replace fumigation's. This first report (Skadedyrcentralen Danmark A/S, 1997) also concluded that practical experience is limited in the milling industry. It was therefore found relevant that further practical experience under Danish conditions should be obtained in order to support the development of effective IPM programmes against insect pests. During 1998 the second project (reported here) was initiated and this project has dealt with the insect pest control situation in three Danish flour mills. The purpose was to increase the knowledge of technically and environmentally acceptable prevention and control methods on insect pests in flour mills, at an acceptable price level.

Several reports (Hallas et al., 1993; UNEP, 1994; Hansen & Mourier, 1995) have concluded that it is technically possible to manage pest control without fumigation with methyl bromide, also that the theoretical contents of IPM in mills exist (Mills & Pedersen, 1992; Skadedyrcentralen Danmark A/S, 1997; MBIGWG, 1998). The work in the second project originated from the recommendations given in the earlier works, and it was also connected with the project "Investigation on the possibilities of using the IPM concept for pest control in Scandinavian flour mills", affiliated to the Nordic Council of

Ministers, in which the present use and limitations of IPM in one of the Danish mills are compared with a mill in Norway.

The project was supported by “Council for recycling and cleaner technology”, which is affiliated to The Danish Environmental Protection Agency, and who paid 47% of the costs. The project was carried out by Per Sejerø Nielsen, Danish Pest Infestation Laboratory together with the staff at the flour mills and the PCO’s.
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Michael Høst Rasmussen and Anders Hasselager, Danish EPA (Chair)
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2 Materials and methods

2.1 **Contents of the project**

The project has been carried out between the Danish Pest Infestation Laboratory, the mills and their pest control operators (PCOs). The work has primarily taken place in the form of discussion meetings and investigations in the mills. Most of the work has been concentrated on a description of the actual system and discussions on the actual possibilities of improving the systems in the mills.

Another aspect of the work has been a discussion of relevant methods for determining the level of pest control, which could be used in the evaluation of the effectiveness of the IPM system. On one hand the mills have a clear impression of resources used in pest control, but on the other hand an analytical tool which could be used to express the value of increased efforts in pest control does not exist.

In 1998 the relationship between the Danish mills and their PCOs has been problematic, due to sale of companies etc. This has had the consequence that for the most part the PCO work at the mills has consisted of trap inspections only. This unacceptable situation was first solved during 1998. This, together with the actual length of the project (5 months) limited the content. Therefore relevant investigation of new methods in the actual IPM programs was not possible.

The project has dealt with the insect pest control situation in three Danish flour mills, which were considered representative of Danish mills. The project analysed the situation , and recommendations were made on improvements of the actual IPM systems. Further, education of the staff is a recommended element of IPM, and therefore short courses in IPM were carried out in each of the mills.

3 Results

3.1 **IPM in mills**

Although accepted as a common method (Mills & Pedersen, 1992; Kenkel et al., 1994), IPM in a flour mill is quite complicated. IPM, in the strictest sense of the term, includes the establishment of thresholds, at least the economic injury level. This is difficult to establish in a flour mill as it has neither been possible to measure the size of the pest population nor to decide the economic damage caused by an actual population size. This means that IPM strategies in flour mills may, to a much higher degree than in other stored product areas, be dependent on a strategy, which includes a number of preventive elements.

Implementation of IPM
Application of IPM strategies in flour mills will differ from country to country; methyl bromide is used as a fumigant in most parts of the world, and current IPM practices in flour mills also include a reliance on fumigants, especially methyl bromide (Kenkel et al., 1994). Nevertheless when the use of methyl bromide is phased out, it will be necessary to implement IPM strategies without its use. These strategies have to become much more detailed and effective, compared to previous ones, in order to constitute a pest control system that can function without any reliance on methyl bromide.

Traps
The population sizes of the pest species are a central question in all IPM programmes. In a flour mill it is not possible today to make a common sampling of the pest species, and other indirect measurements must be used. Concerning the two main pest species. The Mediterranean flour moth *Ephestia kuehniella* Z. can be caught in pheromone traps whereas the confused flour beetle *Tribolium confusum* Duval. is normally counted during inspections as sticky traps for this species are not normally are used in Denmark. Both methods are indirect measurements of the population size, and the measures are heavily dependent on many factors, e.g. temperature.

Complaints
In mills it is very difficult to estimate the economic damage caused by the insects. The actions taken against insects are normally on a preventive basis and are based upon previous experience. One measurement of damage is the number of complaints, this can be considered the most important measure for the mills. Generally complaints from larger customers, bread factories etc. do not occur because of the general quality assurance systems and the fast rate of product usage in these systems. Complaints to mills tend to come from domestic consumers who have found insects in a small bag of flour produced several months earlier. This has the consequence that an increase in numbers of complaints can be related to circumstances at the mills in the past or to circumstances at the consumer, and therefore this measure can be difficult to use, especially if pest control procedures have been altered. As the economic injury level is at present difficult to establish in flour mills, it makes further demands on the evaluation of the IPM systems.

At present one way to manage insect pest infestations in flour mills without reliance on fumigants will be to establish management systems which are designed to continuously suppress the development of pests where and when problems are encountered. At the same time it is also necessary that the system works on a preventive scale. Further the actual control procedures must be as detailed as possible to prevent any problems from escalating, this being the most essential demand, which can be made on the IPM system.

IPM is not a static system; new pest problems will arise, buildings and machinery are changed, and procedures are changed in order to improve the IPM system. The description of the IPM system in the following is how the systems were carried out at the mills in 1998.

3.2 General comments on the situation in Denmark

The actual use of the different elements in IPM, will be a reflection on the conditions at the mills and demands and expectations put on by the surrounding community. It seems that the public in Denmark are very concerned about residues of pesticides in food, and the interest in food produced by the organic concept has increased very fast in recent years. As the number of pests in the final product can be a reflection of the amount of pesticide used in the mills, there seem to be two conflicting expectations in the public. IPM could be a way to comply with both of these expectations, although the removal of methyl bromide could increase the use of residual insecticides.

As in many other countries most Danish mills are situated in older buildings, which partly explains some of the pest problems, timber structures and wooden floors with several layers and cracks, are perfect harbourages for insects, and are very difficult to clean. In Denmark the milling companies operate in a very pressurised market with low flour prices. In 1998 the price for 100 kg of flour in bulk transport would be around 190 DKK. This has the consequence that the construction of new mills is not under consideration, and further that expensive elements of IPM only are accepted if they are considered of major importance.

The mills in Denmark have used pheromone traps since they became commercially available. The mills are familiar with the use of these traps and have experience in using the trap data for analysis.

Chemical treatment
In Denmark chemical treatment against pests in flour mills consist of general surface treatments with deltamethrine or chlorpyrifos. Pyrethrine is used against moths, and local fogging units with pyrethrine are used in areas where special problems exist. All quoted prices are in DKK. Around 15 % of the amount paid to the PCO's is expenses for insecticides.

For the time being neither heat treatments or freeze-out during winter are used in Danish flour mills as IPM components.

3.3 The mills

3.3.1 **Mill 1**
It has a capacity of handling 100,000 tonnes of grain per year. In 1997/98 the mill was rebuilt and most of the milling equipment was replaced. During

the period 1993-97 the mill has only been partly fumigated once. Only a small fraction of the production is sold in consumer packaging.

	1993	1994	1995	1996	1997
No. of fumigation's	0	0	0	0	0
No. of spot-fumigation's	0	1	0	0	0
Cost of fumigation's	0	9,800	0	0	0
Cost of PCO (Inspections, insecticides etc.)	40,000*	40,000*	40,000*	40,000*	40,000*
Cost of cleaning (staff)	366,000	371,000	376,000	380,000	386,000
Other costs	43,000	44,000	49,000	48,000	47,000
Total cost of pest control	449,000	464,800	465,000	468,000	473,000

Table 1. Five years' statistics on economics (DKK) of insect pest control in mill 1. *) Estimate.

Pest species
The main pest species in this mill is *T. confusum*. Minor pest problems occur with *E. kuehniella*. *Tenebrio molitor, Sitophilus granarius* and psocoids can be found near the grain storage and near the grain intake at the mill.

The mill is certified by the ISO 9002 system. The pest control situation has been managed by increased efforts in identifying infestation places and dealing with them. Shutdowns in production are normally for 4 hours once a week.

PCO
The pest control situation is placed in charge of a private PCO. The contribution from the PCO consists of eight annual inspections, during the summer time at least once a month. Further the PCO will always be consulted when pest problems are encountered. During these visits the traps are emptied, and the whole mill is inspected thoroughly. A total of 43 pheromone moth traps is used, more traps are used now and then to locate an infestation. All the relevant windows at the mill are secured with insect-proof nets. The collaboration between the PCO and the mill production manager is very detailed and can be characterised by a quick response.

Sanitation
The cleaning is divided into daily, weekly, monthly and quarterly cleaning procedures, these procedures are documented and to some extent also controlled. If special problems occur, hired cleaning personnel are used. If necessary the machinery is stopped for 4 hours each week dismantled and cleaned inside.

Grain storage
The mill has a storage capacity of 10,000 tonnes of grain. The grain store, which is situated 1 km away from the mill, is not monitored continuously. As a rule the grain inside each cell is moved every 6 weeks. The grain will be stored for at least 2 weeks, and the storage time varies greatly - up to 1 year - depending on the actual production.

Flour silos
The flour silos at the mill have a total capacity of 3,000 tonnes of flour, this means that the storage time in silo is very short, about a week or less. The flour silos are normally emptied and inspected once a month. The mill has had problems with flour accumulation on the sides of the silos. In order to find a solution to this problem they are altering the structure of the bottom of the silos.

Final sieving
The wheat flour is sieved through mesh size 280µm when leaving the mill unit. The flour meant for bags is further sieved through mesh size 280µm before it enters the packing machinery. The material from the sifters is not transported directly back to the mill machinery, it is drawn off in sacks and inspected for presence of insect pests. The control on the material from the sifters is not registered and cannot be used in an analytical way.

The mill has the policy that complaints are not normally accepted. Only very rarely does the mill get complaints on its products. The mill is favoured by the small amount sold in consumer package.

In one place a local fogging unit with pyrethrum is used at regular intervals, to alleviate moth problems.

3.3.2 **Mill 2**
This mill is the smallest of the three mills, it handles 85,000 tonnes of grain per year. It does not produce flour in domestic consumer packaging.

	1993	1994	1995	1996	1997
No. of fumigation's	2	1	1	1	0
No. of spot-fumigation's	0	0	0	0	1
Cost of fumigation's	117,000	59,000	60,000	82,000	51,000
Cost of PCO (Inspections, insecticides etc.)	40,000*	40,000*	40,000*	43,000	45,000
Cost of cleaning (staff)	600,000	624,000	648,000	960,000	1,000,000
Other costs	3,775	5,665	7,550	9,437	10,570
Total cost of pest control	760,775	728,665	755,550	1,094,437	1,106,570

Table 2. Five years' statistics on economics (DKK) of insect pest control in mill 2. *) Estimate.

Pest species
The main pest species in this mill are *T. confusum* and *E. kuehniella*. In a small area of the mill there is an occurrence of *Tenebrioides mauritanicus*, and until now it has not been possible to eradicate this pest. Outside the milling area there is occurrence of *Tenebrio molitor*. The mill does not normally run in the weekends. In the mill buildings some old wooden silos not in use sometimes cause problems with insect pests.

The IPM system is a combination of rules and procedures, some of which have been established during the quality assurance system ISO 9002. The pest control has been managed by increased cleaning efforts, including stops in production. These shutdowns in production, in which the main part of the

running machinery in the mill is cleaned inside, are carried out 3-4 times annually.

PCO
The pest control is placed in the charge of a private PCO. The contribution from the PCO consists of eight annual inspections, plus presence at the four annual cleaning operations. During these visits the traps are emptied, and the whole mill is inspected thoroughly. A total of 47 pheromone moth traps is used. Most of the relevant windows at the mill are secured with insect-proof nets. During 1998 the mill have introduced a notice board where the staff can register any observation of pests, in order to improve the information supplied to the PCO at the time of inspection.

Sanitation
The cleaning routine consists mainly of cleaning on a full-time basis performed by two persons. The 3-4 annual cleaning procedures are done in 30-48 hours requiring around 150 man-hours.

Grain storage
The mill has a storage capacity of 10,000 tonnes of grain, separated in a number of cells, in which the largest cells are monitored continuously. The temperature reaches around 5°C during the wintertime.

Flour silos
The flour silos at the mill have a total capacity of 1,400 tonnes of flour, the daily storage being less, this means that the storage time is very short (about 2-3 days). The flour silos are emptied once a year, but the mill can increase the frequency of this routine.

Final sieving
The wheat flour is sieved through mesh size 340 µm when leaving the mill unit. The wheat flour, which is bagged in sacks, is sieved through 280 µm before entering the final silos. The material from the final sifters is tapped in sacks and inspected for insect pests.

The mill will accept less than 1 complaint per 300,000 produced units. Over the years the mill has only received very few complaints, probably because it does not produce flour in consumer packaging.

3.3.3 **Mill 3**
It is a large modern roller-mill, handling 150,000 tonnes of grain per year. In 1998 the mills were provided with newer machinery, and a central vacuum cleaning system was also established. The last time the mill was fumigated with methyl bromide was in 1996.

The main alternative to the use of methyl bromide, has been an improvement in the sanitation procedures. More resources have been allocated to sanitation procedures during recent years (Table 3). According to the mill, the expenses for pest control have further increased in 1998. During the period 1993-97, production has decreased by around 10%.

	1993	1994	1995	1996	1997
No. of fumigation's	1	1	1	1	0
No. of spot-fumigation's	0	0	0	0	0
Cost of fumigation's	86,000	88,000	90,000	126,000	0
Cost of PCO (Inspections, insecticides etc.)	40,000*	40,000*	40,000*	50,000	53,000
Cost of cleaning (staff)	350,000	350,000	350,000	510,000	550,000
Other costs	12,000	12,000	13,000	19,000	26,000
Total cost of pest control	488,000	490,000	493,000	705,000	629,000

Table 3. Five years' statistics on economics (DKK) of insect pest control in mill 3. *) Estimate.

The mill is situated in old buildings containing wooden floors and old timber structures. A few old wooden flour/bran silos are also present. This creates well-known problems in many places, areas that are difficult to clean, and also a number of places, which are inaccessible, thereby causing hidden infestation of pests.

Pest species
The Mediterranean flour moth *Ephestia kuehniella* and the confused flour beetle *Tribolium confusum* are the two main pest species; only minor and local problems occur with other pest species, including *Tribolium destructor*, *Plodia interpunctella* and *Tenebrio molitor.*

The IPM system is a combination of rules and procedures, some of which are established during the quality assurance system ISO 9002. The mill is also approved by the environmental management system ISO 14.001. The pest control has been managed by increased efforts in cleaning, including stops in the production. The shutdowns in production, in which the main part of the running machinery in the mill is cleaned inside, were planned to take place four times annually, but this goal was not obtained in 1998.

PCO
The pest control situation is managed by a private PCO. The contribution from the PCO consists of eight annual inspections, plus assistance at the four annual cleaning operations. During these visits the traps are emptied, and the whole mill is inspected thoroughly. A total of 84 pheromone moth traps is used. There are normally 1-2 traps in each room, depending on the size and equipment. All the relevant windows at the mill are secured with insect-proof nets. The catches of *E.kuehniella* together with the number of observations of *T. confusum* are evaluated against former years' catches and observations.

Sanitation
The cleaning efforts consist mainly of one person who takes care of the cleaning full-time. More personnel are used when needed, especially in the four annual cleaning procedures, where hired cleaning personnel are also used.

Grain storage
The mill has a storage capacity of 25,000 tonnes of grain. The temperature of some of the grain silos can be monitored continuously, but more importantly, competent personnel perform the supervision of the grain stores. Heavily infested grain is rejected and the few kilograms of grain,

which are inspected, possibly will not show a light infestation. In Denmark the mills do not encounter problems with insect pests in incoming grain. The grain is stored for at least 2 weeks, and the storage time is very variable - up to 1 year - depending on the actual production. Imported American wheat is the grain type, which is kept in store for the longest period.

Flour silos
Final sieving
The flour silos at the mill have a total capacity of 2,700 tonnes of flour, this means that the storage time will be very short (a week or less). The wheat flour is sieved through mesh size 112/250 µm when leaving the mill unit. The material from the sifters is not continuously investigated for the presence of insect pest, and the material is transported directly back to the mill machinery. The wheat flour is further sieved through 224/355µm before entering the final silos. It is the goal that 100% of the wheat flour is sieved through 224µm at this stage. For the moment there are no procedures for cleaning or inspecting the flour silos, but the mill will be investigating how an effective control can take place.

The mill accepts less than 1 complaint per 300,000 produced units. Flour moths in consumer products cause almost all of the complaints to the mill.

In one area containing bran silos, a local fogging unit with pyrethrum is used at daily intervals, because of an inexpedient building structure causing moth problems. In the area with packing machinery a fogging unit with pyrethrum has also been used during a period with moth problems. With success the mill has tried to fill up dead ends in machinery with food grade chalk in 1998.

3.4 **Possibilities of evaluating IPM programmes**

As it is not possible at present to establish the economic injury level for pest species in flourmills, there is a need for investigating how the effectiveness of IPM programmes can be evaluated in a sound way. With the actual procedures in the mills, the possibilities are rather limited. Within the present IPM system four parameters could be used to evaluate the effectiveness over the years. These four parameters are:

Pests
1) Estimation of pest populations
This estimate would be very valuable as the amount of resources allocated to pest control could be evaluated against the number of pests recorded. Considering the two main pest species, the possibility of doing this seems minimal. The best estimate is achieved through *E. kuehniella*, where the male moths can be caught in pheromone traps. Pheromone traps are a perfect tool in locating areas of infestation, but used as a population estimate the measure is more problematic due to its indirect nature. With regard to *T.confusum* the situation is even worse. The infestation by this species often occurs inside the machinery or in inaccessible places, and the numbers are normally estimated by trap catches or counts of living specimens during inspections. The commercially available traps are not considered effective in Danish mills, and the numbers counted during inspections will always be a very subjective measure.

Complaints
2) Number of complaints

This parameter is essential to the mills as all actions against pests are carried out in order to keep the number of complaints as low as possible. The main limitation is that the measure is related to circumstances in the past. Further, the mills agree that it is impossible to put a value on a complaint. Unfortunately the measure will also be dependent on conditions outside the mills.

Insecticides
3) Amount of insecticides used
If not used in a preventive way, this estimate will tell something about the demand each year for a chemical solution to pest problems. It is not a perfect measure as its size is very dependent upon the use of non-chemical solutions, and furthermore the action of the various insecticides is variable and not comparable.

Amount of resources
4) Amount of resources allocated to pest control
This parameter will first of all estimate on how much is considered necessary to spend on pest management in order to maintain the quality level. As it cannot be related to pest population size, it cannot be used in an analytical way.

None of the objectives seems perfect, and this might be one of the most important factors objecting to the present IPM systems. The success of using IPM in flourmills will depend on the overall effectiveness in keeping pest numbers at acceptable levels. In order to achieve this, the mills are forced to increase the efforts in a continuous improvement of the different components of the IPM systems. Although the present estimations of pest populations are not perfect, they have to be used when evaluating the effectiveness of new initiatives.

3.5 **Comparison of the mills**

Differences between mills
The three mills in the present investigation are believed to be representative for Danish flour mills. Although flour mills, seem identical, differences will always be found in both production and design of the interior of the mills. Apart from their size the most pronounced difference between the three mills is that mill 3 has a much larger part of the production in consumer packaging (Table 4) and that its grain storage capacity is higher. Nearly half of the production at mill 2 consists of rye products and special flours. Further mill 2 does not make use of its full production capacity, having the effect that this mill has a much better opportunity to plan shutdowns in production. Mill 2 is also the one mill, which uses the largest amount of resources in pest control.

	Mill 1	Mill 2	Mill 3
Size - tonnes of grain / year	100,000	85,000	150,000
Part of production being wheat flour	75 %	50 %	80 %
Part of production sold in consumer´s package	<10 %	0 %	33 %
Part of production sold in sacks	25 %	22.5 %	0 %

Part of production sold as bulk	65 %	77.5 %	77 %
Capacity of grain silos (tonnes)	10,000	10,000	25,000
In % of yearly production	10 %	12 %	17 %
Capacity of flour silos (tonnes)	3,000	1,440	2,700
In % of yearly production	3 %	2 %	2 %

Table 4. Overall comparison of three Danish flour mills.

During the period 1993-97 Table 1 to 3 yield an impression of the overall cost of insect pest control in the three mills - the value of production stops is not included in this estimation. Around 5-10% of the total amount spent on insect pest control has been used on fumigation.

Differences in success

The mills have not managed the ban against methyl bromide equally successfully. In one of the mills (Mill 1) methyl bromide has only been used once for a spot-fumigation since 1993, so for a long time the mill has managed its pest control without reliance on methyl bromide. This mill has always had a very close collaboration with its PCO, and is also the mill with the fastest response to increasing pest populations. The reconstruction of the mill in 1997/98 has further removed some inexpedient building structures, which had caused problems in the past. Mill 2 has managed removal of methyl bromide very well. It has primarily improved its sanitation programme, and until now the mill has been able to manage its pest problems in this way. One of the mills (Mill 3) has serious problems with its building structure, and so far it has not found a way to manage these problems. In table 5 selected components of the IPM systems are compared.

	Mill 1	Mill 2	Mill 3
Grain storage:			
Incoming grain investigated	Yes	Yes	Yes
Sufficient investigation	?	?	?
Incubation of samples	No	No	No
Temp. investigation is silos	No	Partly	No
Final sifters	280/280µm	340/280µm	224/355µm
Material from final sifters	Controlled	Controlled	Not controlled
Flour silos inspection	12 times / year	1 time / year	No procedure
Mean residence time for flour in silos	1 week	2-3 days	1 week
Insect-proofing of windows	Yes	Yes	Yes
Cleaning	Scheduled	Partly scheduled	Not scheduled
Reporting on cleaning	Partly	No	No
Production stops	4 hours / week	3-4 stops / year	3-4 stops / year
Full use of production capacity	Yes	No	Yes
Problems with complaints	No	No	Partly

Number of PCO visits / year	8 times	12 times	12 times
Main insect pests	Flour moth Flour beetle	Flour moth Flour beetle	Flour moth Flour beetle
No. of moth pheromone traps	43	47	84
Evaluation of trap data	Yes	Yes	Yes
Use of trap data to locate infestation	Yes	Yes	Yes
Use of local fogging units	Yes	Yes	Yes

Table 5. Selected element of IPM systems in Danish flour mills.

4 Discussion

4.1 **IPM in mills**

IPM is useful in mills
The actual investigation supports the view that the IPM concept is very useful in the milling industry as an alternative to fumigation's with methyl bromide. The use of the different elements recommended for an effective IPM programme will always be dependent on their relevance as experienced by the mill. Careful control of incoming grain is a procedure that is recommended in IPM programmes, but as Danish mills do not encounter problems with insect pests in grain storage, they show reluctance to increase their efforts in this area. This fact is also applicable to other components of IPM in mills.

Shutdown
The purpose of shut downs of the production in the mills, together with cleaning procedures, is most relevant. The experience from the Danish mills shows that the mills manage the ban against methyl bromide primarily by increasing their sanitation programmes.

HACCP
The HACCP (Hazard Analysis Critical Control Points) concept was developed in order to manage contamination of food, especially microbiological contamination, through the establishment of hazard analysis and critical control points. It yields a logical and cost-effective basis for a better decision-making with respect to product safety (Leaper, 1997). Although it seems extremely difficult to establish a full HACCP investigation on insect pests in mills, it could form a relevant framework for further improvement of the IPM system. By operating with a team of experts, who continually try to improve the methods used in prevention and control of pests, a system that can effectively react to changes in pest population is created. Similar co-ordinated strategy has proven successful in other food plants (Stanbridge, 1998).

It has been argued that a zero level of insect tolerance ought to be a demand before IPM is implemented (Hellekant, 1995). Although certainly an advantage, the situation in the Danish mills show that a zero level is not needed, before the mills can operate with and benefit from the introduction of IPM systems.

4.2 **Weaknesses in the actual programmes**

The most pronounced weakness in the actual programmes is the inability to make a proper evaluation of the effectiveness of the IPM systems. Due to its nature and the lack of accurate monitoring of *T. confusum*, this species is considered to be the most problematic pest species in the three mills.

The monitoring and control of pests in Danish flour mills is left in the hands of a PCO. The collaboration between the mills and the PCO is a critical point and constituted during part of the trial period a bottleneck in the actual systems. It is a clear condition of a well-acting IPM system that the co-

operation between the two partners is perfect and that the expectations of one another are well defined. The relationship between the mills and the PCO was later improved, and it must always be an aim to ensure that this relationship be further is improved.

Further the pest control needs to be more targeted towards preventative measures and conscious alertness on well defined action levels. The results from inspections and trap catches are now to some extent used as a measure, which indicates if pest populations have increased in the past. The systems could be improved if the mills tried to introduce action levels and further decided what to do when these levels are exceeded. Although not a perfect way, such a step could be a way to improve the actual systems.

None of the mills is carrying out a detailed control for insect pests on the tailings from the final sifters. Therefore an internal infection in the milling machinery can increase gradually and first be noticed when the pests enter the production area.

4.3 **Recommendations to the mills**

Control on sifters
The following recommendations can together with the general recommendations in section 4.4 be given to the mills. It seems essential that the mills establish permanent and detailed control on materials from the sifters. The sifters are the most relevant control points in the mills. This will yield a good measure of the degree of infestation inside the machinery. This control must include establishment of thresholds and a decision on what to do if these thresholds are exceeded.

Collaboration
The collaboration between the mills and their PCOs needs to be improved. Situations where the PCO together with the staff at the mill are making a detailed investigation on a specific pest problem always seem to produce valuable results.

Internal procedures
It can be recommended that the internal procedures be tightened. Many procedures against insect pests are in use but every now and then these procedures fail, e.g. when sacks with material are left in the mill, inspection and cleaning are postponed etc. Further there is a need to establish control on the flour silos in mill 3.

Building structure
The building structure is now and then important for the pest problem. It is essential that personnel with pest experience are include at an early stage when new building structures or alterations are planned.

4.4 **General recommendation on IPM in mills**

On behalf of the two Danish projects (Part 1 & 2) the following main recommendations can be made.

Inspection frequency
The mills need to decide in advance what to do when an increase in the catch of *E. kuehniella* is occurring. The actual systems are designed in such

a way that the traps will be inspected every month but in a situation where trap catches increase rapidly and counter steps are needed, a quicker response could be valuable. This would require that either the PCOs increase the inspection numbers when necessary or that the mills train their personnel to do the job.

Cleaning inside machinery
Shutdown in production together with cleaning can be recommended. Very satisfactory results are obtained from mill 1 (4-hour suspension each week) and also from mill 2 (2-day suspension three to four times a year). The experience from the largest mill (3-4-day suspension three to four times a year) is less positive, the separation and assembling of the sifters turned out to be more difficult and time-consuming than expected. From a theoretical point of view it seems that three to four annual shutdowns together with cleaning of the whole mill would be sufficient for a break in the build-up of pest populations under the climatic conditions present in Danish flour mills.

Relationship between pest and complaints
It can be recommended that a detailed investigation on the relationships between pest occurrence and complaints be carried out in order to analyse the effect of the steps taken against the pests.

Tribolium
At a more superior level it seems relevant to point out the need for more scientific research on the possibilities of monitoring *Tribolium* species in mills. The commercial traps for *T.confusum* are not effective in Danish flour mills, and the monitoring success during inspection is also variable, and finally an inspection requires time in order to be successful in the identification of breeding size.

5 Conclusions

Increased sanitation's
The use of methyl bromide as a pesticide was banned in Denmark by the 1st of January 1998. Danish flour mills, of which the majority in the past have based their pest control on this fumigant, have handled this new situation by adopting IPM strategies. The Danish mills have primarily increased their efforts in sanitation together with shutdowns in production and surface treatments with insecticides, these initiatives have managed problems with insect pests.

Old mills with a construction that supports hidden infestations of pests seem to be the ones that have the biggest problems with the removal using methyl bromide as a fast and highly penetrating fumigation method.

Documentation's
Creation of a useful documentation on the efficacy of the insect pest control was found to be difficult. The next main step forward could be the adoption of the working methods known from the HACCP-principles. In this way a team of relevant persons secures that a co-ordinated strategy is applied to the pest control.

The IPM systems can be improved
Without any doubt, the actual IPM systems in the three mills can be improved and several recommendations are made on behalf of the project. These improvements are believed to be of major importance. But with the low price of flour, in Denmark, there will be an upper economic limit for the cost of insect pest control. This might have the consequence, that other improvements, which can be recommended on the basis of a sound IPM system, will not be accepted by the mill if the output is believed to be of minor importance.

The fact that methyl bromide was prohibited in Denmark has forced the Danish mills to improve their pest management systems, and for the time being they gather experience on how to operate without fumigation's with methyl bromide.

The mills need to have better tools for monitoring the populations of *T.confusum*. It is to be hoped that science will improve its efforts in developing more efficient monitoring systems against this cosmopolitan pest species of flourmills.

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