Insect unfriendly packaging design

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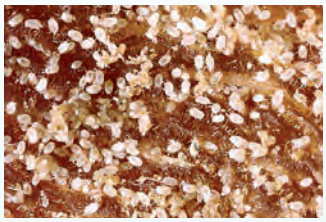
Insect infestations are clearly unacceptable in a food factory, but they are common enough in the industry for us to question whether 'insect free zones' can ever be a practical goal.

A more pragmatic approach would be to develop a system of hygiene and pest monitoring/prevention to cover raw material inputs, manufacturing facilities and finished goods' warehousing, creating a comprehensive strategy to detect, at the earliest signs, any incipient infestation.



Heavy infestation of flour mites on dried apricot.

Any HACCP system must react to new information. When moth larvae and webbing are found in a returned packet, or mites are visible through the cellophane window, or beetles are discovered in the bottom of the sachet, some answers are needed, to reconcile reality with the carefully planned preventative strategy.

The QA manager needs to know where the cause (or blame) lies to prevent it occurring again.

The answers can be many; this article considers in particular one aspect – the influence of packaging on insect and mite infestation, and asks whether packaging alone can provide sufficient protection against product infestation.

Species

Insect and mite pests of dry foods and manufactured products are generally well adapted to life inside buildings: they survive dry conditions and are able to eat hard foods.

To us flour is soft, but from a mite's viewpoint (0.5mm) the particles are tough and jagged. Baked crisp biscuits, grains of wheat, and even malted grains, and dried pasta products at about 5% moisture, are tough, dry and brittle to us, but are favourite foods of many small insects. Understanding the abilities of the pest species helps explain occurrences of infestation in factories, stores and shops.

Life stages

Many adult beetles have strong mandibles; their immature larval stages, though, may be less capable when very young but usually develop stronger mandibles as they grow.

As adults, the common storage moths (Indian meal moth, warehouse moth or mill moth) can not penetrate packaging materials, but they lay eggs, which will develop into larvae many of which will become very effective packaging penetrators.

Mites, though unable to chew through packaging, being less than 0.5mm long even when fully grown, can often find minute gaps in folded packaging. Heat-sealed sachets, nipped in the sealing process, would provide such tiny access holes.

The pest 'profile' therefore involves 'invader' species which cannot chew through tough packaging but by following ever increasing food odour trails they find tiny gaps and imperfections; and 'penetrator' species which, at least during part of the life cycle, can chew through thinner and flexible packaging materials. Some of the invaders are primary SPI – species that are expressly there for the foods/products – whereas others are secondary pests more associated with poor hygiene and dampness, and vice versa for the penetrators. See Table 1 for examples in all categories.

Flour mites (Acarus).

Warehouse moth eggs (enlarged!) – very small and virtually invisible amongst pallets and cartons.

The saw-toothed grain beetle – an invader.

Packaging materials

Packaging materials are chosen for many different reasons, including cost, ease of manufacture, transport stability, market suitability, nature of product and shelf life. We can divide these materials broadly into four categories – paper/card; plastic film; glass; metal.

With careful design, glass and metal are impervious to all insects and mites. Paper and film packaging are not so secure: insects which can chew hard tough foods can often chew through paper, cardboard, waxed card, fibreboard, cellophane, polyethylene and other flexible plastic films, metal and plasticised foils and foil backed paper and card.

Then, the designs of packaging may not always be fully sealed. Some insects and mites are very adept at squirming into very small holes created by imperfectly formed packaging.

Packaging thickness has a bearing on the success of the pest attack, though hard fibreboard and corrugated cardboard and thick plastic sheet may not be as difficult as we may think. Plasticised linings and bags within boxes may also be less

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effective than supposed as insect physical barriers – an insect inside a box may brace its back against the cardboard to begin chewing at a point where the film is creased.

There are newer developments in packaging which could help in this battle – insect repellent treatments can be applied to the base paper or card prior to manufacture, and specially developed 'active packaging' materials which can affect the type and quantity of 'atmosphere' within the packaging.

The latter is more commonly used for fresh foods but may have applications for manufactured foods.

A drawback would be in an infested warehouse, where potential cross infesting insects could damage the special pack from the outside, thus releasing the protective atmosphere.

The repellent type effect is not widely advertised and the active ingredients are not widely approved for use on packaging in direct contact with food materials. This will be a major hurdle for such materials to be incorporated in Europe, though the principle seems sound.

Even traditionally weak jawed flour beetles clearly have significant mandible power, as seen with this hard dry pasta.

However, it is interesting to see such developments, which would only happen if there is a sizeable infestation potential.

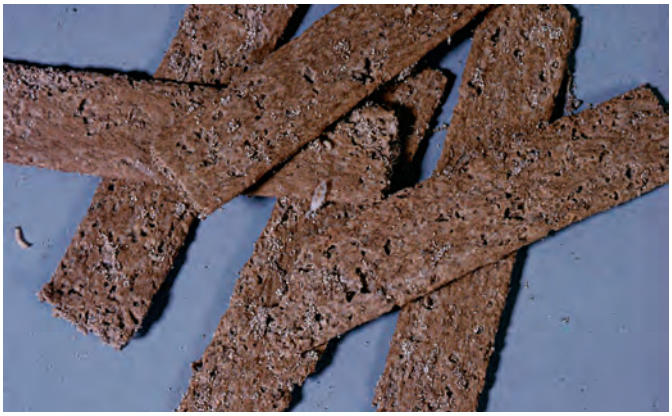
Odour control

A most important feature of packaging is its odour barrier potential. If an insect cannot 'smell' the food, there is probably little reason for it to expend energy trying to penetrate a pack.

It has been shown on a number of occasions that preventing the attractive odours of food products from leaking into an infested store keeps the products free from cross-infestation for extended periods. Thus bag-in-box is sometimes more effective than a plasticised card, which would still depend on perfectly formed comer and flap folds.

Time

Another critical factor is time. The longer a product remains in an infested warehouse the more likely it is to become cross-infested: food odours can emanate, and insects may have time to chew through packaging. Or insects may develop to a stage in their life cycle which can breach packaging. For example, moths flying in a warehouse cannot penetrate cartons. Their eggs will be laid as close as possible to the source (odour) of the larval food (a good mother's instinct), but the tiny emerging larva can only search for gaps. However, once successfully infesting a product, older larvae may easily chew out of one package and into another – their mandibles are then much stronger. But time and temperature work in tandem. All insects and mites are more active at a higher temperature, which explains why sometimes product infestation and damage is greater in retail premises – the time elapsed has been longer and the in-shop temperature is higher compared with many cool/cold warehouses.



Indian meal moth larval damage to pet foods after penetrating packet. Indicator of an infested warehouse.

Small but very destructive Biscuit beetles, perhaps the most successful pentrators of virtually all packaging materials.

Summary

To summarise, insect and mite storage pest species have different abilities to invade and penetrate packaging and they must have a need (a food odour, perhaps), and time.

Some species, packed within the food at the factory, remain with it, being incapable of chewing out, whilst others enter and leave packages almost at will. Some are more interested in dampness, mould and generally poor hygiene, but others are specifically primary food pests.

Packaging choice and design is important but the infestation barrier properties of various packaging materials are not always considered, maybe because infestation is not an everyday problem. The tiny pests are difficult to detect and folded card boxes and bags can be easy targets via comer gaps and imperfect gluing. Perforated liners, for product 'breathing', may also provide a multitude of entry points! Embossed best before codes in foil seals can give insect mandibles the crinkled surface they need to get started.

Time is also important – insects need time to chew through packaging or to develop through to a stage, which can chew through – but time can also be used to our advantage in designing and operating pest monitoring programmes both in factories and warehousing.

The final parts of the puzzle are the 'infest-ability' of the food product – how attractive it is to the local range of species, and in the country where the product will be stored and sold. A highly attractive food sold in warm southern Europe will need all the help it can get from the best packaging design to remain uninfested throughout its shelf life! ■

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Table 1. Critical biological data to understand invertebrate pest risk to products and packaging.

Species	Primary or secondary	Minimum & optimum temp.	Complete life cycle (days) minimum	Max. monthly pop. increase	Body width (mm) adult/larva	Packaging breach adult potential	Packaging breach larval potential
Saw-toothed grain beetle	P	21 - 34	21	50x	1.0 (adult)	invader	invader
Grain weevil	P	15 - 30	28	15x	1.5 (adult)	penetrator	stays in food
Flat grain beetle	P	23 - 35	21	60x	0.8 (adult)	invader	invader
Lesser grain borer	P	23 - 35	28	20x	1.0 (adult)	penetrator	stays in food
Biscuit beetle	P	17 - 28	84	8x	1.3-1.5 (a)	penetrator	penetrator
Confused flour beetle	P	21 - 33	28	60x	1.2 (adult)	invader	invader/ penetrator given time
Australian spider beetle	S	10 - 25	56	4x	1.6 (adult)	penetrator	penetrator
Booklice	S	17 - 30	21	300x	<0.7 (adult)	invader - nymphs and adult	
Indian meal moth	P	18 - 32	56	30x	1.2 (larva)	none (egg-laying)	penetrator
Warehouse moth	P	10 - 25	84	15x	1.0 (larva)	none (egg-laying)	penetrator
White-shouldered house moth	S	10 - 26	56	30x	1.0 (larva)	none (egg-laying)	penetrator
Hide/larder beetles	S	15 - 28	56	?	3.5 (both)	penetrator	penetrator
Mould beetles	S	12 - 25	21	50x	0.8-1.5 (a)	invader	invader
Mites	P/S	5 - 25	10	2,500x	<0.5 (adult)	invader - nymphs and adult	