INTEGRATED PEST CONTROL IN MIXED FEED PRODUCTION AND APPLICATION IN TROPICAL COUNTRIES

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Abstract
An important factor of increasing the animal production is the application of industrially produced mixed feed. This technological process guarantees promt introduction of new scientific knowledge in animal nutrition into the pratice. For this reason the use of mixed feeding stuffs is increasing permanently in tropical and subtropical countries. From the viewpoint of store protection some problems have to be solved. Analysing the entire process, we found out that the elaboration of an integrated method for control of store pests is possible. The following components have to be taken into consideration:
A) The favourable ecological conditions for mass propagation require to minimize the population density of pests during storage. The best measure for maintaining all quality parameters is the cooling of bulk feeding stuffs. Temperatures between 10°C and 15°C are the limit for insect development.
B) By using hammer mills and pellet power presses most of pests (except mites) or all pests, respectively, are killed (share 98.5 to 99.9 %).
C) The final pest-free product is also an attractive nutritive substrate for store pests.
D) Mixed feeding stuffs should therefore be stored so brief as possible and in pest-proof store-rooms. By this way an optimal reduction of losses can be reached with a minimized application of post-harvest chemicals.

Introduction

An important factor of increasing animal production is the utilization of new scientif knowledge in the practice of animal nutrition and animal feeding. By using the mixed feed technology a rapid, safer and controllable introduction of modern results of animal nutrition research into the practical work of animal production farms is best possible (Ruttloff, 1981; Becker, et., 1983).

Also the necessary degree of mechanization and automation for breeding large animal stocks is only possible by using industrially produced feed-stuffs.
From the viewpoint of store protection the complete process of mixed feed production and their utilization in farms includes a number of problems which are closely connected with the technological process as a whole. The resolution of these problems plays an important role for keeping the animal stocks in a good state of health and securing the production of quality products.
Due to the permanently increasing importance of the modern technology of mixed feed also for tropical and subtropical countries we have examined together with other research institutions of mixed feed industry the nexus of related problems to make up an integrated pest control programme in warm climates.

Material and methods
The insects and mites were from stock cultures of the Department of Plant and Store Protection, Institute of Tropical Agriculture. They were reared at 26 + 1°C and 65-75 % r.h. Adults of mixed age and 1st instar larvae (max. 4 days) were used.
Samples of raw materials, milled and pelleted mixed feed were collected at the "Mischfutterwerk Leipzig". In the first group (a) of experiments the infestation level of raw material was determined, and the samples incubated for 4 weeks at 26°C (raw material and mixed feed) and searched again.
In the second group (b) the pests were added to the nutritive substrate, processed by hammer mill, searched and incubated for 4 weeks at 26°C. In comparative experiments 50 g of wheat in 100 ml beaker was used as level. The other subtrates were filled to the some volume. The effect of the subtrates on the postembryonic development (1st. instar larvae to adults) and the population density (50 unsexed adults, 10 weeks of rearing) was tested.

Results
Analysing the production process "mixed feed" concerning its problems which are relevant for store protection and integrated measures, we have to lay special emphasis on:

- storage of raw material
- processing and
- storage and distribution of final products.

The storage of raw material is the complicative part. The great number of raw nutritive substrates used, their different origin and the necessary shelf-live offer favourbale ecological preconditions for the appearance of a broad spectrum of post-harvest pests which compared to other branches of the agricultural production, are not to be found elsewhere. A survey of used raw material groups is indicated in table I.

Table I: Raw material share in the production of mixed feeds (according to Röhnich, 1986)

Group of raw material	Share in the final product (%)
Raw material containing carbohydrates (cereals, tapioca, by-products of sugar industry etc...)	46.0 - 60.0
Milling products (fodder meal, bran etc...)	9.3 - 24.0
Residues of oil manufacture (oil cake. oil meal, expeller etc...)	14.9 - 29.0
Feedstuffs of animal origin	5.0 - 7.0
Dry green fodder	0.7 - 2.0
Mineral mixtures	2.7 - 4.1

The given data reflected the high significance of vegetal components. This refers mainly to the source of carbohydrates but also the fatty and protein containing raw materials.
About the situation of pest infestation, pathogen spectrum and loss problems there are numerous publications (Bahr, 1980; Prevett, 1975; Weidner, 1981; Stein, 1986). The results show that due to the mentioned range of raw material, representatives of nearly all animals known as store pests occur in the stores of raw material. Owing to the discontinuity of agricultural output and striving for importing raw material for possibly low prices, extremly long storage periods for the several components occur in mixed feed industry. The kind and extent of losses are closely connected with this fact.
The mass loss by feed uptake of the pests is less important than quality losses by contamination caused by secretion of insects (for instance by Tribolium, Tenebrio, Trogoderma any Oryzaephilus), by sensorial and chemical parameters and last not least by containing living pests (mainly mites) and subsequent fungus infestation including the mycotoxin content in forage (Vogel, 1973; Braude et al., 1980; Smith et al., 1971).
For the control of populations of pests in empty store rooms Pirimiphosmethyl or Phoxim are the most effective compounds, since they offer log-term protection against pest immigration due to their higher persistence..
Basic material showing heavy infestation has to be fumigated by insecticidal gases preferably phosphine with an concentration of 6 to 15 g/t or Methylbromide with 32 to 120 g/m^3. It must be pointed out here, that by fumigation the pests are only killed but not removed from the product. The cleaning effect of aeration is low because separation of internal infestation in

coarse-grained and of freely living stages in fine grained and powdery products is nearly impossible so that a decrease in quality can hardly be eliminated.
To maintain all quality parameters of raw material during storage the only way - according to our investigation results - is additional cooling. The basic feedstuffs in stores are bad caloric conductors and thus keep a low temperature once reached over a longer period, mobile cooling apparatus for silos or flat store buildings can be used instead of costly stationary cooling units: thereby investment costs are reduced (Barth, 1984).
From the viewpoint of integrated store protection it is very important that favourable storage temperatures and the thermic threshold for mass propagation of pests are close to each other. At temperatures of 12 to 15 °C the lowest limit of gradation is reached for the most important store pests.
The secondly important step is the processing of raw materials to finished feedstuffs. Here it can be stated that the mechanical procedures have a strong control effect to infested parts.
In our investigations we found that the crushing process by means of hammer mills destroys all stages of insects. Mite infestation is less successfully controlled by this technology, the eggs survive the processing to a high degree without any damage. After some weeks of storage heavy infestation occur again, as seen in table II.

Table II: The influence of the milling process on surviving of different store pests

product	sample no.	infested with	infestation de density	
			After processing	After 4 weeks of storage at 26 °C
extracted soybean meal	I. a) milled	Acarus siro L.	no living pests	heavy
	I. b) milled	Acarus siro L.	no living pests	heavy
	I. c) not milled	Acarus siro L.	very heavy	very heavy
rape oil meal	II. a) milled	Acarus siro L.	no living pests	heavy
	II. b) milled	Acarus siro L.	no living pests	heavy
	II. c) not milled	Acarus siro L.	very heavy	very heavy
maize	III. a) milled	Sitophilus zeamais L.	no living pests	no living pests
	III. b) milled	Sitophilus zeamais L.	no living pests	no living pests
	III. c) not milled	Sitophilus zeamais L.	heavy	very heavy
maize	IV. a) milled	Tribolium confusum Duv.	no living pests	no living pests
	IV. b) milled	Tribolium confusum Duv.	no living pests	no living pests
	IV. c) not milled	Tribolium confusum Duv.	heavy	very heavy
maize	V. a) milled	Trogoderma granarium Ev.	no living pests	no living pests
	V. b) milled	Trogoderma granarium Ev.	no living pests	no living pests
	V. c) not milled	Trogoderma granarium Ev.	heavy	very heavy

The high killing quotient for insects is also confirmed by other authors. According to Podany (1976), more than 90 % of the insect population in raw materials are destroyed. The effectiveness of hammer mills in case of Rhizopertha dominica Fab. amounted to 98,5 %, according to Bahr (1980).
If pellets are produced as final product the efficiency is further increasing and insects and mites are killed in all developing stages. In this way we get a product absolutely free of pests without application of any chemical compound.
In tropical and subtropical countries however the danger of reinfestation in case of attractive products is very high as flying activity of beetles and moths suddenly increases at 25 °C.
For the third phase - the storage of mixed feed up to the moment of use - it is important to know whether they are an attractive nutrition source for store pests or not and hence in danger or not.
Since there are only few information about pest incidence in the subject we investigated the development of the Lesser grain borer (Rhizopertha dominica Fab.) as an very polyphagous pest in different raw material components and the adequate milled and pelletized mixed feed as final product.
The results of egg deposition indicated in table III show that both kinds of the final product are preferred substrates which are only surpassed by fodder meal.

Table III: Egg laying rate per week (eggs/100 adults) in different nutritive substrates (incubation at 26 °C, 65...75 % R.H. and permanent dark).

Nutritive substrate	Period of investigation (weeks)							Total number of eggs
	1	2	3	4	5	6	7	
mixed feed	225	650	980	850	750	630	440	4525
pellets	90	625	840	820	960	820	780	4935
rye	95	350	230	140	45	80	100	1040
maize	150	50	980	650	480	570	690	3570
barley	30	20	175	25	50	50	50	450
fodder meal	175	860	850	1000	840	870	810	5405
wheat fodder	25	210	100	25	25	30	30	445
yeast	110	40	25	0	0	0	0	175

The rate of larvae hatching is only little influenced by the substrate. An retarding effect was found only for extracted soybean meal and dry green pellets.
In contradistinction to this fact, the postembryonic development (from the 1st instar larva up to the adult) is very strongly affected by the nutritive subtrate. The significantly increased number of adults in the milled mixed feed is of

special importance in comparison to all other products, causing however a high danger of the final product (figure 1).

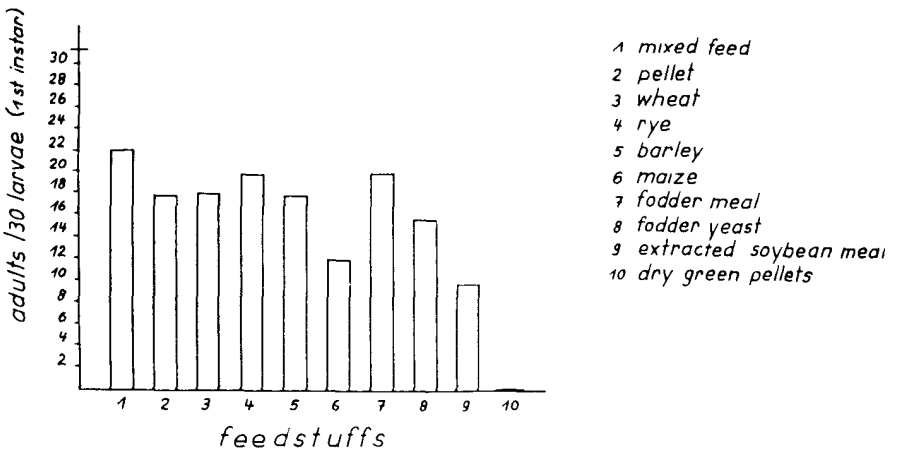

Figure 1 : The influence of different feedstuffs on the postembryonic development of Rhizopertha dominica Fab. (incubation period 4 weeks at 26 °C).

In figure 2 the population density after 10 weeks of storage at 26 °C is indicated. This test-complex represents the proper problem under practical storage conditions which consists in the fact that adults migrate from outside into the store-rooms and propagate.

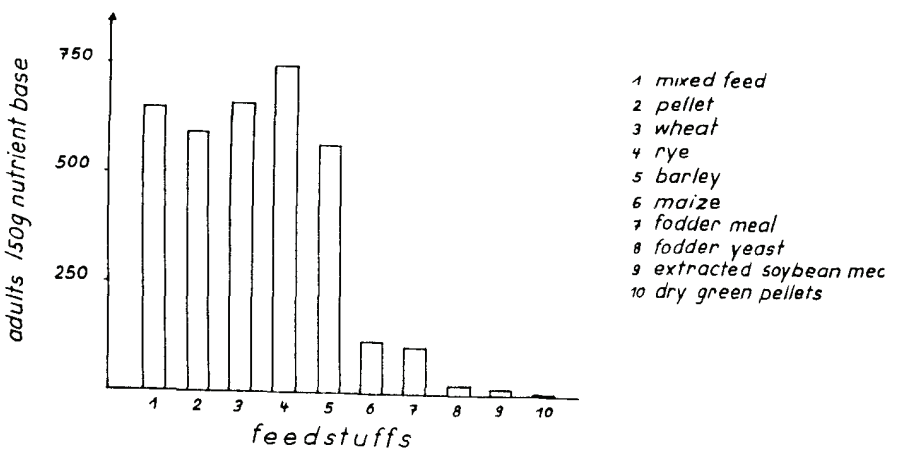

Figure 2 : Population density of Rhizopertha dominica Fab. after 10 weeks of incubation at 26 °C.

It is evident that the developing conditions for the Lesser grain borer in both kinds of mixed feed (milled product and pellet) are similar to those in the preferred cereals wheat and barley. From this a high infestation danger of the final product also can be derived (Richter et al., 1988). On the other hand however in fodder yeast and extracted soybean meal a low propagation rate was determined and in dry green pellets no development was found. The applied adults survive in the substrate up to a maximum of 5 weeks without laying eggs. Fish meal as a component of animal origin showed an insecticidal effect, the pests survived only a few days.
These retarding and toxic effects are of specific interest as the respective components are included in the final product but the retarding effects are not efficacious.

Conclusions
Summarizing we can state:
An important factor in increasing animal production is the application of industrially produced mixed feed. This technological process guarantees
- promt introduction of new scientific knowledge in animal nutrition into the practice
- the rational use of raw material for animal feeding and
- a high degree of mechanization and automation of the feeding process.
For this reason the use of mixed feed in tropical and subtropical countries is increasing permanently.
From this viewpoint of store protection the technological process includes some problems which have to be solved with regard to animal health and the quality of final products.
Analysing the entire technology we found out that the elaboration of an integrated method for store pest control is possible. The following components have to be taken into consideration:
A) the favourable ecological conditions formass propagation require to minimize the population density of pests during storage. The best measure for maintaining all quality parameters is cooling of bulk grain. Temperatures between 10 °C and 15 °C are the limit for insect development. Furthermore the mortality increases and fungal growth is inhibited by simultaneous water removal.
B) By using hammer milling or pellet power presses process the most pests (except mites) or all pests are killed (Share 98,5 to 99.9 %).
C) This advantage of processing has to be used, hence pelleting is prefered.
D) According to our investigation results the final pestfree product is an attractive nutritive substrate for store pests.
Mixed feeds should therefore be stored so brief as possible and in pestproof store-rooms. In this way by a minimized application of postharvest chemicals an optimal reduction of losses during storage, transport and processing can be reached.

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LUTTE INTEGREE CONTRE LES RAVAGEURS DANS LA PRODUCTION D'ALIMENTS COMPOSES POUR LES ANIMAUX ET SON APPLICATION DANS LES PAYS TROPICAUX

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Résumé

Le développement important de la production animale passe par l'utilisation d'aliments composés de fabrication industrielle. Pour cette raison, l'utilisation de produits alimentaires destinés spécialement à la fabrication de ces mélanges augmente en permanence dans les pays tropicaux et sub-tropicaux. Au point de vue de la protection des stocks, plusieurs problèmes sont à résoudre. Après l'analyse du processus complet de transformation agro-alimentaire, nous avons pensé que l'élaboration d'une méthode intégrée de lutte contre les ravageurs des produits stockés est possible. Les paramètres suivants doivent être pris en considération :

a) Les conditions écologiquement favorables à la propagation des ravageurs, en masse, nécessite la réduction de la densité de la population des déprédateurs au cours du stockage. Le meilleur moyen de maintenir une qualité uniforme est le refroidissement des produits stockés en vrac. Les limites de températures au dessous desquelles les insectes arrêtent leur croissance se situent entre 10 et 15° C.

b) En utilisant des moulins à marteaux et des presses extrudeuses, la plupart des ravageurs (sauf les acariens dans le premier appareil et tous les ravageurs dans le second) sont tués (98,5 à 99,5 %).

c) Le produit final sans ravageur est aussi un substrat nutritif très attractif pour les insectes.

d) Les aliments composés préparés devraient donc être stockés le moins longtemps possible et dans des salles étanches aux ravageurs.

Par ces moyens, on devrait pouvoir atteindre une réduction optimale des pertes en réduisant également l'utilisation des produits chimiques après récolte.