Christoph Otto Reichmuth, born 1945. Director and Prof., Inst. for Stored Product Protection, Federal Biological Research Centre for Agriculture and Forestry (BBA), Berlin, Germany. Dipl.-Ing. (1970) and Ph.D. in Physical Chemistry (1974), both at the Technical U. (TU), Berlin. 1975, appointed scientific staff member at BBA, Inst. for Stored Product Protection. 1975, Sabbatical at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Div. of Entomology, Stored Grain Research Laboratory (SGRL), Canberra, Australia, research on radiolabelled phosphine and inert atmospheres to control stored-product pest insects. Since 1980, lecturer at TU, Berlin, and since 1988, at the Humboldt-U., Berlin, on Grain Technology and Stored-Product Protection. 1992–, Director and Prof., Inst. for Stored Product Protection, BBA. Consultant for: the World Health Organization (WHO); Methyl Bromide Technical Options Committee (MBTOC) of the United Nations Emission Protocol (UNEP); European Plant Protection Organization (EPPO); as well as of several developmental agencies on fumigants in stored-product protection. Several patents and author and co-author of three books and about 150 publications on the latter subject.

Trends in Stored-Product Protection – The German Perspective

The area of research called "stored-product protection" is still growing worldwide. This is evident from the change of the title of the most important International Working Conference on Stored-Product Protection which had started as a "Conference on Stored-Product Entomology". The term stored-product protection comprised for many years solutions for problems created by insects occurring in stored agricultural products of plant origin, mainly in grain. Other products affected were coffee beans, cocoa beans, legumes, herbs and spices, almonds, nuts and those with a relatively low water content and a fairly long storability under normal warehouse conditions. Mites, rodents and birds followed insects closely as potential pest organisms. Dried fruits, dried fish and meat were also counted as stored products in this context. In addition, the occurrence of insect pest species determined to some extent the range of possible products being included under stored-product protection. These products have in common being attacked by organisms belonging to a small number of species. Out of millions of insect species, only some

100 pest species are of significance in this field, species which have specialized to survive with very small amounts of free water and under unfavorable conditions; some can even survive feeding on tobacco with its high nicotine content, which is lethal to most other animals. Their high rate of multiplication may also be the reason why some species of arthropods and a few vertebrates have exploited the provision of man during his evolution towards organized society. One of the interesting questions that have been posed, is: What did these animals do before man appeared? From their occurrences under barks of trees, within bird nests, in all sorts of seeds and elsewhere in zones without human cultivation, it may be deduced that those insects which are at present typical 'domesticated' associates, have already lived in niches in natural habitats millions of years ago.

These pest species still carry the genetic capability to survive under extreme climatic conditions or on various diets. On the other hand, man is still changing his storage technique, *e.g.* from bag storage to intense bulk storage with columns of more than 10 - m height for grain. This leads in zones of cold or moderate climate to [micro-] habitats which now offer a permanent warmer climate in these grain stores. The spread of the rice weevil, *Sitophilus oryzae,* from southeast Europe to Germany traced by Bahr *et al.* (1) supports this theory.

Since the Fourth International Working Conference on SPP (see Table 1), the forum has been broadened to include microbiological problems. Storage fungi and mycotoxins are currently of wide interest and presumably have led to a further increase of the number of conference participants. It is debatable whether this proliferation has been very helpful, because it led to excessive growth of the scope of the conference, preventing the participants from joining all sessions, which now run parallel. Microbiology and entomology have only some common scientifically overlapping fields. From the grain storage point of view, the cure for microbiological problems after harvest sounds fairly simple: keep moisture within the stored products below a_w=0.65 and you are on the safe side as far as mold growth in the store is concerned. This demand is hard enough to fulfill and requires close cooperation with engineers. The production of mold- and mycotoxin-free grain in the field is quite another story. The pleading of Bruce Champ (2) of Australia in his closing speech at the IWCSPP in Canberra (1994) still rings in my ears: "The basic knowledge of the biology of the insect and arthropod pests is still rather incomplete and requires more thorough dedication and research to approach appropriate methods and procedures of stored-product protection." These pests are the cause of roughly 80% of the problem worldwide.

In Germany there is a clear distinction made between insects which appear as pests in the food and feed chain when the products have already been sold in the market, and those which are pests before sale. The latter are covered by the Plant Protection Act and the former by the Food or the Feed Act. The Plant Protection Act is not concerned with quality, but only with pests and diseases and their control. Thus, the storage of apples under controlled atmospheres to prevent early ripening is not a procedure of stored-product protection, although the technical details of the method and its parameters are similar. When meat is stored or prepared in restaurants and kitchens, cockroaches can be severe pests, but this is not a typical case for stored-product pest control; similarly, flies are not typical objects of stored-product protection. Throughout the literature food of animal origin such as dried meat, dried fish, meat powder, egg powder and others are also being considered as stored products, which may have to be treated like those of plant origin. So-called household pests may be described as stored-product pests in the future. Many

TABLE 1. Overview of the seven International Conferences on Stored-Product Protection and the growing interest in them. The proceedings of this series contain a very good collection of subjects, descriptions and scientific papers which represent the history of the past 20 years and the developments in this important field of keeping the food and feed supply safe between harvest and consumption

Number, location and date of the InternationalWorking Conferences*	Number of countries repre-sented	Number of partici-pants
1: Stored-Product Entomology (Savannah, Georgia, USA) Oct. 7-11, 1974	27	214
2: Stored-Product Entomology (Ibadan, Nigeria) Sept. 10-16, 1978	>20	69
3: Stored-Product Entomology, (Manhattan, Kansas, USA) Oct. 23-28, 1983	25	171
4: Stored-Product Protection (Tel Aviv, Israel) Sept. 21-26, 1986	28	165
5: Stored-Product Protection (Bordeaux, France) Sept. 9-14, 1990	50	401
6: Stored-Product Protection (Canberra, ACT, Australia) April 17-23, 1994	33	>400
7: Stored-Product Protection (Beijing, China) October 14-19, 1998	34	384

*Copies of the proceedings are available from Dr. Jim Throne, 2950 West 12th Ave., Manhattan, KS 66502, USA.

of the control procedures are similar, especially as regards physical methods, trapping and early detection. It is noteworthy that controlled atmospheres were introduced much later into the field of control of pests in museums than in grain storage. In Germany, the use of residual insecticides is much greater in the control of hygienic pests than in stored-product protection, a field in which *e.g.* no registration exists for pyrethroids. This may presumably be ascribed to the different fields and situations of application in individual households, kitchens, hospitals and hotels, compared with warehouses and granaries.

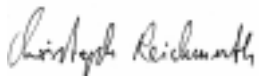
It is at least interesting to note how developments and trends in one field of pest control influence the others, as in the control of hygienic or stored-product pests.

Apart from the specialization in research, thinking in terms of integrated pest management (IPM) methods leads to implementation of methods from other fields. A good example in this respect is the use and re-introduction of natural insecticides, mostly substances which are produced naturally by plants or even by insects themselves. Neem and other oils have been thoroughly investigated and are presently developed as one keystone in IPM systems. This applies to SPP as well as to pest control of wood-boring insects and of hygienic pests. The recent registration of diatomaceous earths belongs to this category, which Friedrich Zacher in Germany proposed in the early thirties of this century (6,7). Of course, thousands of years ago, in ancient human cultures, ashes and sand were used to prevent insect infestation of stored seed and grain.

Instead of simply combining chemical, physical and biological methods, the trend in pest control and particularly in stored-product protection leads clearly in the direction of

highly sophisticated combinations of several chemical, physical or biological methods with associated procedures such as: the application of heated phosphine with carbon dioxide or heated carbon dioxide under pressure of 20 bar; or heated and distinctly humidified air; or air which has been taken from the environment, cooled or heated and de-humidified and pumped into the stored bulk to create a climate within the product which prevents both mold growth and rapid development of arthropod pests. Biological methods comprising the use of predators (5) represent an attempt to combine biological and chemical control when searching for chemical agents which are lethal to the pest but not to the predator. As confirmed during the session on 'Biological Control of Storage Pests' at the recent 7th International Working Conference on Stored-Product Protection at Beijing, biological methods in particular, but also other new approaches, require a very detailed study of the individual pest species which are to be controlled, including all important factors determining the situation where the pest occurs or is likely to do so in the future. Longstaff (4) has presented a review on all the 'tools' which will play important roles in future pest management in grain storage, where computers and artificial intelligence (expert systems) will support decision making. However, the best system will give proper answers only after sound data have been provided and introduced.

Also in Beijing it became quite obvious that engineering, storage technology and economics in SPP should be subjects for thorough investigation in the future. It was noticeable that African, Latin American and Asian developing countries are quite up-to-date as far as their SPP problems and solutions are considered, compared with industrial countries. Especially the People's Republic of China is quite aware of all recent developments in the field of SPP. As Champ (2) said, there is a long way to go before we can lean back and simply press the button to obtain a proposal for a solution. The computer will not replace the thorough and competent scientist being expert in his field and delivering concepts for safe pest control on the basis of broad and possibly computer-supported knowledge.



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