TROPICAL STORAGE ENTOMOLOGY BY THE END OF THE TWENTIETH CENTURY

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INTRODUCTION: The twentieth century in the tropical regions of the world has largely been characterised principally by a rapid explosion in human population and a decline in the quantity and quality of food available for consumption. In the developing countries, in particular, there is now a widening gap between total calorie and protein requirements of human and animal populations and some scientists have even gone as far as predicting a catastrophic shortage in human food by the end of the century. Comparison of food consumption patterns of developed and underdeveloped countries show great disparities not only in per capita calories consumption but also in the ratios of carbohydrates, fats and proteins and the sources and quality of proteins. These characteristics manifest themselves in terms of hunger, malnutrition and what Ruthenberg (1) refers to as 'harmonious undernourishment.' Poverty and malnutrition are therefore still largely characteristic of tropical countries where even the 0.2% excess rate of growth of food production over population increase recorded in the 60's have not been sustained in the 70's and the optimism of food production and the green revolution seem now to be even more elusive. A more complex picture evolves when we realise that in the period 1850 to 1950 the world population doubled and that the figure of about 3,500 million in 1970 indicates that it would take perhaps only 35 years for the next doubling to occur. But in fact the population doubling in the developing countries is likely to take about 24 years because of the rate of population growth of 2-3% in contrast to 0.5-1% in the developed and industrialized countries of the world. With about 7,000 more people every hour and over 160,000 everyday, in all probability there will be 6,000-7,000 million in the world by 2,000 A.D.

The state of food and nutrition in relation to this phenomenal and reasonably certain world increase in population is often considered in terms of increases in agricultural production to be achieved through the extension of cultivated areas, the improvement of genetic potential of crop plants for increased productivity, and increases in yields per unit area of cultivation (2). These three well-publicised cornerstones of the 'Green Revolution,' however, fail to take into cognizance the urgent and pressing need for the conservation and preservation of the harvested crop. It is obviously erroneous to assume that all the increase in food production would reach the consumer when we are fully aware that storage losses ranging from as little as 2-5% in

some developed countries to over 30% in many developing countries occur. It is therefore faulty strategy to attempt to increase yields by a factor of 5-10% through massive scientific and technological inputs in crop production only to lose 20% of the crop during handling and storage. Estimated annual world losses in maize, a major cereal staple in most countries of the tropical world, provide a good example of the extent of the severity of losses due to insects and other agents (Table I).

TABLE I. Estimated annual world losses in maize (millions of tons).*

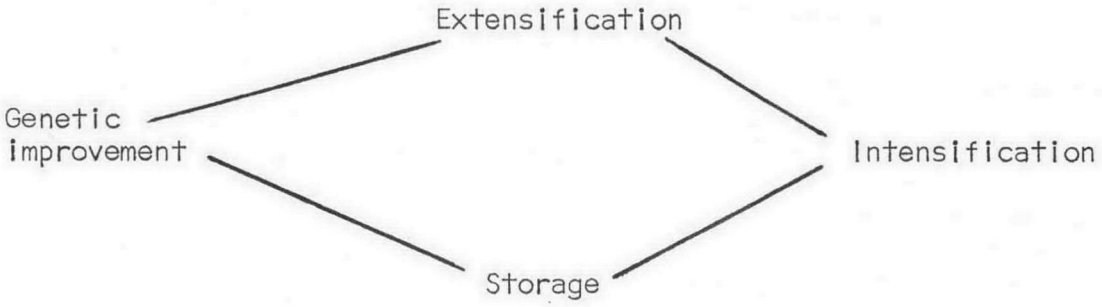
Region	Production		Losses		Total
	Actual	Potential	Insects	Diseases	
North and Central America	102.9	144.7	16.9	13.6	30.5
South America**	19.1	31.8	6.3	3.2	9.5
Europe	28.3	32.9	6.3	3.2	9.5
Africa**	14.9	47.5	9.5	6.5	16.0
Asia**	16.5	26.2	2.6	3.1	5.7
Oceania	0.2	0.2	0.01	0.01	0.02
USSR and China	36.5	56.1	7.0	5.2	12.2
World Totals	218.4	339.4	44.0	32.6	76.6

* Source: H. H. Cramer (1967): Defensa Vegetaly Cosecha Mundial Bayer. Pflanzenschutz Leverkusen p. 179.

** Developing countries.

Losses due to insects in monetary terms range from about 5% in Europe to about 20% in Africa and South America and although some of these losses are field losses a substantial part of these are storage losses which according to Wheatley (3) range from 3.6 per cent to 23 per cent and amount to about 2 M ton/year. Such losses or even more severe losses are recorded in the whole range of agricultural produce, including other cereals, yams, cassava, grain legumes, pulses and other major commodities produced in tropical countries. It is, therefore, clear that the solution to the food and nutrition problem of the developing countries lies

not in the triangle of 'Green Revolution' but in a diamond in which storage forms a fourth important and crucial cornerstone.



STORAGE PRACTICES AND THEIR EVOLUTION: Attempts to store and preserve agricultural produce are nearly as old as agriculture, although major strides were only made in the last few decades. It is now a far cry from the era when the infestation and consequent deterioration of agricultural produce was regarded as inevitable, and commodities were thought to 'generate life.' Storage entomology has not only shown that the most important agents of deterioration during storage are insects, mites, fungi, bacteria, rodents and other vertebrate pests but has emphasized that deterioration and losses may set in the produce which appear uninfested at harvest but often have undetectable pre-harvest infestation which serve as the nucleus of post-harvest and storage losses. The conditions of the produce at harvest and the environmental conditions of post-harvest handling and storage have also been shown to have a major impact on losses due to microorganisms and vertebrate pests. Storage practices have therefore evolved to create conditions for the disinfestation of produce, the prevention of deterioration and reinfestation and the preservation of the quality of produce during periods of storage which may vary from a few months to a number of years depending on the purpose of storage and the nature of the commodity.

Storage under tropical conditions is hazardous because of the climatic conditions, the physical characteristics of commodities and facilities available for adequate disinfestation and preservation. The high ambient temperatures (25°-35°C) and humidity (70% or more) accelerate the growth and multiplication of the various agents of deterioration and often contribute to the inefficiency of traditional methods of storage that have been evolved. The physical characteristics of the commodities often make them susceptible to biodeterioration by a range of organisms; for example, high moisture content (20-30%) which is often encountered in tropical maize after harvest leads to deterioration by fungi and attack by *Sitophilus* and other insects. Adequate drying therefore has to form an integral part of post-harvest handling and storage in all storage practices in the tropics. Facilities available for adequate disinfestation and preservation often depend on the value of the crop, the accessibility of the

farmer to the necessary capital for improved structures and other inputs and the availability of such imputs. All these are in contrast to conditions in some temperate and semitemperate countries where as indicated by Watters (4) few grain storage problems are experienced because of the cold winters and well-developed bulk handling systems.

In the main, storage practices in the tropics have evolved through traditional methods which depend largely on physical factors such as natural drying, storage and preservation in simple structures with little or ineffective provision for the prevention of reinfestation and the preservation of quality, and little or no use of pesticides. Hence in many parts of the developing world, storage practices involve traditional structures such as simple wooden platforms, storage baskets, timber tripods, vertical or horizontal poles or racks, varieties of cribs made from wooden or grass materials, 'rhumbus,' pots or other earthen containers, gourds and other types of granaries. These structures and practices are largely ineffective in the prevention of deterioration of stored agricultural produce. Under such conditions, Taylor (5) indicated that losses due to insect infestation, biodeterioration by microorganisms and rodent damage are considerable. Until recently, very limited inputs of pesticides for safe disinfestation of produce were used but recent developments which combined improvements in the designs of cribs and storage bins with the wise use of pesticides such as lindane, malathion, pirimiphos-methyl and synthetic pyrethrins show great promise for the future. In particular, successes that have been achieved in incorporating these grain disinfestation and protection methods into traditional storage practices in Nigeria, Kenya, Zambia, India and many other countries in tropical Africa are now beginning to have major impact on the reduction of losses at the farm level and therefore on the economy and nutrition of the small farmer. Surveys in some developed countries, for example, in England and Scotland (6), in the last decade also showed increases in the use of malathion and fenitrothion for the protection of stored grain and old and new rodenticides for the control of harmful vertebrate pests; this trend is likely to continue and be strengthened in the rest of the century. These developments indicate that future strategies should focus attention on the application of storage and protection technologies at the farm level, since most of the losses occur at this level, at the level of the handling and distributing agents and, as medium and large scale production develop, at the major bulk storage centres where highly efficient and sophisticated systems of drying, disinfestation by fumigation, and storage can be employed. Such applications at these various levels of storage, handling and distribution are destined to make considerable impact on the quantity and quality of available food and other agricultural produce in the last two decades of this century.

AGRICULTURAL PRODUCTION AND MODERN STORAGE TECHNOLOGY IN THE NEXT TWO DECADES: The present trends in agricultural production patterns and systems and the displacement of populations from the rural to urban areas seem to indicate that in the remaining two decades of this century decreasing percentages of human populations are likely to be directly involved in farming, small farms are likely to give way to medium scale and large scale farms, and the storage of agricultural produce is likely to evolve along the lines of greater coordination and cooperation in the use of modern techniques of disinfestation and storage. Already in many developing countries, the percentages of agricultural workers are going down from 60-70% of the total working force to 40-50% and greater efforts are going into the organisation of coordinated and centralised storage systems which would receive surplus agricultural produce and utilize modern techniques of storage to ensure their preservation and release into the marketing channels as and when necessary. Although this trend is likely to continue and be strengthened in the immediate future, it must be realised that it would depend on a fundamental understanding of the role of the farmer, small or large scale, in the first stage handling and disinfestation necessary to ensure that produce delivered to medium and long-term storage depots do not constitute foci of infestation and deterioration of the bulk of stored items. In other words, clear guidelines which now form the basis of on-farm disinfestation and handling of agricultural produce should be retained and strengthened and the inputs necessary for their observance ensured at the farm level.

Considerable progress appears to have been made in the organisation of such network services, for example, in Kenya and Zambia, where maize represents a major staple in the diet of the people. The result is that when adequate precautions are taken in accordance with the established practices of farmer, depot and warehouse handling and disinfestation, the quality of the stored maize even after many months of storage remained high and losses are kept to the minimum. The success of the system can be seen to depend largely on the efficiency of the delivery systems of necessary inputs such as insecticides, jute bags, etc., effective communication and rapid delivery and handling and the use of modern techniques of drying, fumigation and bag treatment, and storage in well-designed warehouses and silos. In Kenya, these are guaranteed through a network of District and Central Depots with facilities for grading, drying, fumigation and storage in warehouses and bins. Even here, the farmer's role is considered crucial because of the need to halt pre-harvest infestation by treatment with malathion or lindane before delivery to the depots. Fumigation with methyl bromide or phosphine, or bag treatment with insecticides combined with store hygiene maintain the quality of the produce whilst in the district or central depots.

A modification of such a coordinated and centralised system is operated by the NAMBoard in Zambia. The focus of grain

collection in this case are the Rural Depots and the Rail Line Depots to which produce are delivered by farmers as soon as possible after harvest. The depots serve dual functions of receiving grain and supplying inputs for stimulating production, including fertilizers, pesticides, herbicides, jute bags, etc. Here also efficient transportation and communication is important to ensure early evacuation of produce to larger central depots where fumigation and storage take place in silos or on hardstandings under sheets. Provisions are made in all cases for fumigation or grain treatment at rural depots in order to avoid further deterioration in grain which on inspection show a potentially dangerous level of infestation. In Nigeria, where a programme for the handling and storage of 600,000 tons of grain as operational and reserve stocks is currently being implemented, a similar network is envisaged. The Agro-Service Centres which are being located within 20 km of individual farmers will serve as the depots not only for the supply of inputs, including pesticides, fertilizers, improved seed and technical advice, but also for the receipt and purchase of grains from small farmers. They will also serve to receive surplus grains from large-scale farms in the future. In this context and in other parts of the tropics, one of the major problems at such depots is likely to be the moisture content of grain at delivery, especially in the humid and sub-humid zones. It may, therefore, be necessary, as is the case in some parts of Kenya, to provide some rapid drying and handling facilities at some of the larger depots to ensure that the moisture content of the grain can be brought down to a safe 12% or less before storage in bags in warehouses or in silos. Details of some of these proposals for Nigeria and how they are expected to function in a changing agricultural economy are discussed by Taylor (7, 8). Such a network if efficiently operated in Nigeria is likely to improve the quality of agricultural produce and reduce storage losses to 5% or less. In addition, it will provide an avenue for the build up of reserve stocks that can be used during periods of drought, crop failure or other natural disasters and may even generate the beginnings of an external trade in grains and stored agricultural produce. These components in themselves have a major role to play in the world food problems of the rest of this century.

THE FUTURE: The last two decades of this century will be crucial in the efforts of man to expand and improve agricultural production and protection in order to feed itself at a level compatible with modern and acceptable concepts of social and economic welfare. The intensification of agricultural production must be matched with the pursuit and application of modern storage technologies if the gains to be realised by such intensification are to be maintained so that they could reach the consumer. Tropical storage entomology has many of the answers in terms of developed technology, organisation and relevant research. It is my view

that we may yet avert a possible food crisis before the end of this century and indeed close the food and nutrition gap and strengthen the economies of the developing countries of the tropical world.

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